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Welcome to the 11th AIIA Conference in Bari, Italy!

I am very pleased to welcome all the participants of the 11th AIIA 2017 Conference, jointly organized by the Italian Society of Agricultural Engineering (AIIA) and the University of Bari Aldo Moro.

The AIIA2017 Conference "Biosystems engineering addressing the human challenges of the 21st century" has a multidisciplinary approach, framed in 10 thematic areas concerning the aspects currently shared by the Agricultural and Biosystems Engineering:

1. *Cultural heritage preservation and rural landscape protection, planning and management*
2. *ICT, precision systems and new technologies for land, farm and forestry management*
3. *Energy, waste and by-products smart use*
4. *Challenges in water and soil conservation and management*
5. *Hydrology, debris flow, sediment-large wood connectivity in a changing environment:processes, control and consequences*
6. *Post harvest, logistics and food chain equipments and structures*
7. *Organic farming, sustainable plant and livestock production processes and technologies*
8. *Safety, health, ergonomics, management and standardization for agriculture and forestry machines, equipment and structures*
9. *Natural resources and environmental systems monitoring and assessment*
10. *Biosystems engineering at urban and suburban scale*

We received approximately 230 papers from 10 different countries. The Conference consists of three days of scientific paper presentations, including 3 invited lecturers, 135 oral presentations and 92 e-posters.

I am confident that all the papers that will be presented during the oral and poster sessions, along with the relative discussions, will contribute to increase the development and dissemination of Agricultural and Biosystems Engineering. I believe that AIIA2017 will highlight new routes for the cooperation among different research teams.

On behalf of the Organizing Committee, I wish you a fruitful and interesting Conference and a pleasant stay in Bari.

Prof. Giacomo Scarascia-Mugnozza
Convenor Department of Agricultural and Environmental Science
University of Bari "Aldo Moro", Italy

TOPIC 1

CULTURAL HERITAGE PRESERVATION AND RURAL LANDSCAPE PROTECTION, PLANNING AND MANAGEMENT

Assessing volumetric and geomorphologic changes of terraces in Amalfi Coast using photogrammetric technique

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Keywords: Photogrammetry, Soil loss, Terraces, Terrain Morphology

Summary
Terraced landscapes are largely widespread in Mediterranean area from Neolithic, since their construction has been essential to make mountain or steep slope areas habitable and arable. Among these areas, Amalfi Coast is the most famous zone thanks the uniqueness of its landscape. Over the years, these areas have been subjected to quick geomorphologic and volumetric changes, causing serious problems of hydrogeological instability. Hence, in this work, the volumetric and geo-morphology changes of terraced landscapes in Minori, a small municipality of Amalfi Coast, over forty – years period, have been performed by applying the changes detection analysis to historical series of photogrammetric aerial photos. Indeed, two panchromatic series of images (1956-1996) has been processed, separately, in order to generate a high resolution orthophoto (0.03 m) and a fine Digital Elevation Model (DEM) (1 m) for each period. Subsequently, DEM of difference (DoD) has been created. DoD shows significant changes in all the study area, due to terraces abandonment or new human construction. The combination of photogrammetry and DoD shows promising results for detecting the geomorphologic and volumetric changes by historical series.

1. Introduction

Terraced landscapes are the most distinctive sign of human influence on territory modelling, since their construction reduce the slope gradient and increase soil permeability (Sofia et al., 2016). Among these areas, Amalfi Coast is one of the most famous. Unfortunately, terraces presented on its territory, have been recently subjected to a rapid abandonment process due to their inadequate and insufficient competitiveness in terms of agricultural production (Tarolli et al., 2014). This trend is causing several volumetric and geomorphologic changes which are responsible of hydrogeological instability. Therefore, both UE and Italian agricultural and environmental policies promote their protection (UE Soil Thematic Strategy, on 13 February 2012; Draft law n. 2383 of 13/05/2016). In order to safeguard these areas, assessing their volumetric and geomorphologic changes over the time is essential. Previous studies have shown that several methods are suitable for spatial patterns of change analysis, comparing historical maps. Only the technique based on Digital Elevation Model of Difference (DoD) is able to quantify, cell-by-cell, volumetric and geomorphologic changes (James et al., 2012).
Assessing the volumetric and geo-morphology changes of terraced landscapes in the municipality of Minori by analysing a DoD, based on historical photogrammetric aerial photos, is the aim of this study.

2. Materials and Methods

2.1 Study area

Amalfi coast is part of coastline of Salerno Province in Campania Region (Southern Italy). It extends to over a 11.223 ha, comprised between the Gulf of Naples and the Gulf of Salerno, involving thirteen municipalities. Its climate is Mediterranean and its economy is essentially based on tourism, attracted from the great beauty of its landscape and biodiversity (Pindozzi et al., 2016). Among its municipalities, Minori is considered the most ancient since it has been founded in 1th century AD. Its territory covers about 256 ha and it borders with Maiori and Ravello (Fig. 2.1).

Figure 2.1: Study area

2.2 Data source: historical series and field data collection

In order to analyse the volumetric and geomorphologic changes over forty - years period, two panchromatic historical series of 1:26000 and 1:39000, respectively, have been taken into account: the former, taken 13 April 1956 at height of 3900 m, involves 3 images (197-V-1811; 197-V-1812; 197-V-1813); the latter, acquired 3 June 1996 at the altitude of 5456 m, consists of 3 frames (197-110-5055; 197-110-5056; 197-110-5057). The images format is 23 x 23 cm for both series. Photos have been scanned with a photogrammetric scanner at the resolution of 2500 dpi by the Italian Military Geographical Institute (IGM).

Three different field surveys campaigns were performed in order to acquire 159 Ground Control Points (GCPs) useful to georeference and orthorectify the aerial photos. The GCPs have been acquired using a Differential Global Position System (DGPS) Sokkia GRX1 in ETRF 2000 Epoch 2008 .

2.3 DEM generation

The metric reconstruction of the study area has been performed importing, separately, the aerial photos in Agisoft Photoscan Professional. As preliminary steps, images block orientation and georeferencing have been carried out. Therefore, frames alignment and tie points extraction have been achieved and in order to improve the final result. The 159 GCPs, acquired during the survey activities, have been inserted in the processing phase (Triggs et al., 2000; Gruen and Beyer, 2001). Thus, a polygonal model (mesh) has been generated and, subsequently, processed in order to obtain a geometrically corrected imaging (orthophoto), accurate surface texture and DEM (Capolupo et al., 2014; Capolupo et al., 2015).

The two generated DEMs have been consequently pre-processed in order to remove their small imperfections, commonly called "pits", because they could create discontinuities and affect the final result (Infascelli et al., 2013). Pits filling has been realized using ArcGIS hydrology tool.

2.4 Volumetric and geomorphologic changes analysis

Several techiniques have been applied to investigate volumetric and geomorphologic changes over the years, even if, the most common method considers the DoD computation (Martínez-Casasnovas et al., 2004; Wheaton et al., 2009; James et., 2012). Also in this paper, the volumetric and geomorphologic changes of the study area over the time, have been performed creating a DoD. The DoD allows to detect and quantify changes in elevation grid and in spatial patterns of the surface model (Brasington et al., 2003 ; Rumsby et al., 2008). The DoD was generated by subtracting the earlier DEM from the later DEM:

$$\Delta E_{ij} = Z_{2ij} - Z_{1ij} \tag{2.1}$$

where ΔE_{ij} is the difference value between the two considered DEMs for each cell, Z_{2ij} is related to the DEM generated by the historical series of 1996, while the Z_{1ij} is the DEM reconstructed by the aerial photos of 1956. The resulting DoD can assume positive or negative values according to the increase or the reduction in elevation, determining the several cause of this change, such as erosion, collapse, deposition, anthropogenic modification (James et., 2012).

3. Results and Discussion

For each aerial photograph series, a high resolution orthophoto and a pretty fine DEM have been generated (Fig. 3.1). The resolution of the generated DEM is equal to 1 m, while the resolution of the generated orthophoto is of 0.03 m. Even if the sorted out DEM resolution is comparable, the quality of reconstruction is essentially different. Comparing the orthophoto (Fig. 3.1), it is possible to appreciate that image generated by the historical serie of 1956 is less limpid than the other one and it shows some blurry spots. This can be ascribed to the quality of the original photos. Indeed, the altitude, the sky light and the technology adopted to acquire them have affected their traits and, consequently, the outcome.
DoD evaluation was possible thanks to DEMs comparable resolution. It quantifies the volumetric and geormophologic changes between the analized periods cell by cell, showing positive and negative values (Fig. 3.1). The negative values are linked to collapse of some areas, erosion process or the anthropogenic influence, on the contrary the positive values are due generally to new human buildings.

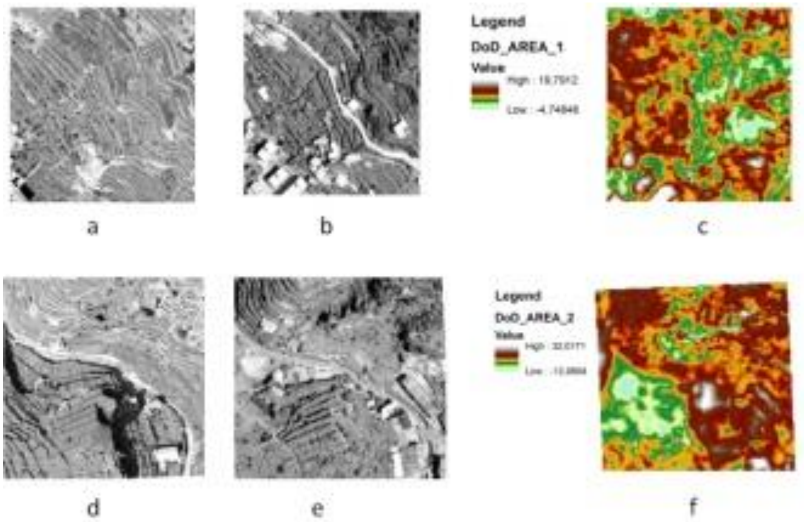

Figure 3.1: Details of different areas of Minori: a) orthophoto 1956 area 1; b) orthophoto 1996 area 1; c) DoD area 1; d) orthophoto 1956 area 2; e) orthophoto 1996 area 2; f) DoD area 2;

4. Conclusion

Results show that the combination of historical series photogrammetry and DoD is a promising technology for quantification of volumetric and geomorphologic changes for terraced landscape. Moreover, it is also appropriate to analize the spatial allocation of the changes. Definitely, the DEM and orthophoto resolution obtained from historical series is suitable to achieve the aim of this work. DoD is able to define the volumetric changes cell by cell, giving a first indication about the causes. It is worthy to remark that for a good results, it is of fundamental importance the quality of the dataset.

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Could the environmental issues in agricultural areas be an effective driver to set up a participatory and sustainable management? The experience of the Rural Observatory in the Municipality of Corinaldo (Province of Ancona, Italy)

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Keywords: Landscape degradation, Participatory GIS, Rural observatories.

Summary
Soil erosion and landslides affect considerable portions of agricultural land of the undulating rural landscape in center Italy. Such an issue interests a wide poll of actors, among which: farmers, administrative bodies, public services, citizens, etc. The Municipality of Corinaldo and the Landscape Research Center (CIRP) of Polytechnic University of Marche have recently implemented a permanent "Observatory on Rural Landscape". The main aim is to monitor the local processes of landscape degradation by mapping agricultural areas and improving their sustainable management at a very detailed scale.

Introduction

Agriculture plays a fundamental role in shaping the rural landscapes. Its impact on management of natural resources is also noteworthy (Baudry et al, 2000; Burel et al., 2013; van der Sluis et al., 2016; Vesterager J.P. et al. 2016). Among all finite resources, water and soil need to be managed in the best possible way because they provide vital supporting services to the environmental system (Giordano and Marchisio, 1991; Schwilch G. et al., 2012; Tyler et al., 2016). Soil erosion and landslides are today a crucial issue in many inner rural areas of most European countries (Panagos et al., 2015). These events are sprawled within micro-basins, in such a way that the challenge of a sustainable soil survey by farmers represents a crucial goal. A major and direct issue due to an underrated soil survey is the impact of landslides on rural infrastructures such as roads network. The maintenance and recovering costs lies on the municipalities who are in charge to keep the functionality of communication ways in good condition.

Facing similar problems, the Municipality of Corinaldo committed with the Landscape Research Center (CIRP) of Polytechnic University of Marche to implement a permanent Observatory on Rural Landscape, which will act as a local center for observation and monitoring of the surrounding countryside.

The main goal of this initiative is to provide local players (mainly farmers and public administrators) with a monitoring and analyzing tool dedicated to the maintenance of the rural lands, starting by the active participation of all the stakeholders (Pretty, 1995; Allen et al., 2002; Whitfield and Reed, 2012; Bautista et al., 2017). Indeed, the presence of a dedicated observatory plays a pivotal role firstly by risen a local shared awareness on the hydrogeological stability. The mapping of such a kind of risks and of their intensity, within well-identified agricultural parcels, allows committing administrators, farmers and all the stakeholders to a shared vision on the possible remediation and prevention measures.

2. Materials and Methods

The research was carried out in the Municipality of Corinaldo, located in the inner part of the Marche Region (43,65°N; 13,05°E). This hilly area, of 49,28 Km^2, stretches between the Nevola and Cesano rivers with an elevation ranges from 50 m a.s.l. to 271 m a.s.l.. The municipality counts 5.069 dwellers with a population density of about 103 ab/ Km^2 (ref. Istat 2017). The area represents a typical center Italian rural landscape, scattered by top hill old town centers surrounding the countryside. Several actors have been involved in the project: researchers from the Landscape Research Center of Polytechnic University of Marche, the administrators and the technical staffs of the Municipality of Corinaldo, the local farmers together with the participation of other local endeavours. All the actors were involved following different steps as follow: 1) assessment of the hydrogeological instability with regard to the agricultural areas; 2) build of GIS dedicated GIS to store and process surveyed data; 3) participative involvement of all the stakeholders to share a common vision.

The scientific staff helped farmers and the other local stakeholders to identifying and mapping the ongoing hydrogeological threatens whose delimitation was too detailed for being drawn by the already existent supports made by the regional agriculture extension services. Afterwards, a set of surveys on each of the identified critical sites were performed to assess the state of the situation, and to classify the critical points according to a specific scale of risk. The administrators and the officers of Corinaldo's municipality have supported the activities contributing to draw a guideline aimed among others to describe the state of the local stability the art. In a later stage of the project, the bulk of result and the guideline have been discussed with farmers to set the ground to the definition of a set of shared agricultural practices and of preventing measures which, if adopted, will allow to limit the hydrogeological instability due to agricultural activities.

3. Results and Discussion

Starting from the alerts spontaneously risen by citizens and farmers at the Observatory, the research team collected a sum of 100 in field inspections. This allowed to identifying 109 critical situations, most of which (67%) would have required high priority interventions. In several occurrences (39%), problems were due to an inefficient drainage management of waterers from private agricultural parcels This generates a pervasive superficial landslide interesting the 30% of lands.

In addition, the spatial distribution of critical points reported by users (i.e. citizens and farmers), analysed by GIS functions, shows that in most cases the criticalities fell within the "at risk" areas already mapped by the Hydrogeological Survey Plan prepared by Regional Basin Authority (Fig.1). In other cases, issues were found lying in adjacent areas. This has highlighted the need to continuously monitor ongoing hydrogeological phenomena in order to update the delimitation of risk areas in the plans drawn up by the regional authorities at a detailed scale.

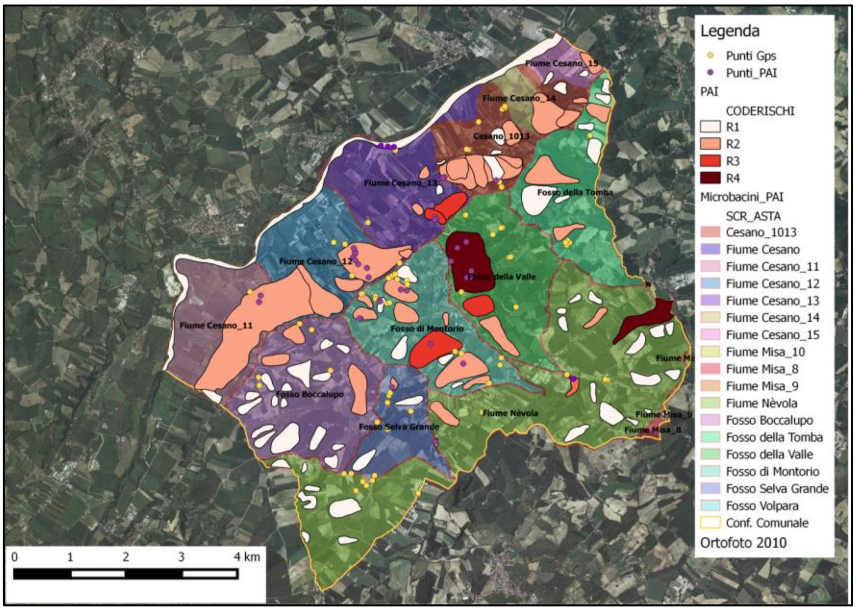

Fig.1 Spatial distribution of critical sites within the sub-basins and PAI areas

4. Conclusion

Thanks the active involvement of farmers, local experts and administrators, a participative approach based on focus groups was applied during the final stages of the overall project. Moreover to shed light on the main soil degradation issues occurred in the reporting area, meetings have allowed to capitalise such a knowledge offering remedies to be locally implemented for a more sustainable land use management. The experience gained will be the base to better define a set of best practices tailor-made on the specific needs of agricultural critical areas. The way to put such a solution in force is uneasy and still far from being concluded, due to the two folded vision of farmers divided between the very willingness of playing fare with nature and the concern of seeing their entrepreneurial activity being limited by an excess of bureaucracy.

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Farm buildings and rural landscape quality: FarmBuiLD as a method to link rural heritage and new constructions. A pilot study in the Emilia-Romagna Region (Italy)

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Keywords: farm building design, rural heritage, building parameters, physiognomic characterization

Summary
The quality of rural building is an integral part of landscape, and one of the essential elements for local and national identity. Many aspects in terms of environmental integration and formal relations with the built context should be considered to improve the quality of rural landscape, the design and evaluation of new rural buildings, as well as building management processes.
In this paper we focus on a phase of the FarmBuiLD (Farm Building Landscape Design) model, a research programme aimed at the analysis of farm buildings and definition of meta-design criteria for the improvement of their landscape quality with reference to a study area of the Emilia-Romagna Region (Italy).
FarmBuiLD has been applied to analyse the peculiar architectonic characters of a place, referred both to historical and contemporary rural buildings, in order to derive quantitative indications about the relationships between the formal features of the built heritage and contemporary design choices. In particular, the joint interpretation of the parametric results about the dimensional aspects (height-width-length), volumetric characteristics, openness/closure of perimeter surfaces, and articulation of volumes, has allowed to identify concordant and discordant elements.

1. Introduction

Land use, rural development and life styles over time have led to "isotropic" and disorienting landscapes, where often new rural buildings have been created through standardized serial design and globalized formal criteria, independently of their surroundings. In those landscapes, underestimated traditional buildings are often degraded and abandoned (Fuentes, 2010). Over the last years, citizens, stakeholders, technicians and administrators have been gaining increasing awareness of the cultural and environmental values of rural landscape as a common good (Jeong et al., 2013). In such a context, the quality of rural buildings is an integral part of the landscape, and one of the essential elements for local and national identity. This new cultural attitude is accompanied by new needs and requirements. On the one hand, those related to regulations and planning, which increasingly call for holistic management tools, considering both outstanding rural buildings and farms in compromised environmental and cultural conditions, thus going beyond constraint-related approaches (Torreggiani et al., 2014). On the other hand, stakeholders see the quality of the rural settlement and of the surrounding landscape as an essential element for rural productivity in a multifunctional perspective (Tassinari et al., 2013).
Many aspects in terms of environmental integration and formal relations with the built context should be considered (Maino et al., 2016) to improve the quality of rural landscape, the design and evaluation of new rural buildings, as well as building management processes (maintenance, restoration, extension, change in use, etc.). In addition to building surface components, such as colour, form, lines, texture, scale, and spatial character, the perception of formal features, such as the dimensional proportions, and the articulation of forms, hollow and solid volumes, play a crucial role in landscape consistency, in terms of visual and aesthetic quality.

In this study we focus on a phase of FarmBuiLD (Farm Building Landscape Design), a research programme aimed at the analysis of farm buildings and definition of meta-design criteria for the improvement of their landscape quality (Tassinari et al., 2011).
FarmBuiLD has been applied to analyse the peculiar architectonic characters of a representative super-municipal study area, referred both to historical and contemporary rural buildings, in order to derive quantitative indications about the relationships between the formal features of the built heritage and contemporary design choices. In particular, the joint interpretation of the parametric results about the dimensional aspects (height-width-length), volumetric characteristics, openness/closure of perimeter surfaces, and articulation of volumes, has allowed to identify concordant and discordant elements.

2. Materials and Methods

The FarmBuiLD model provides analytical tools consisting in a set of parameters (Torreggiani et al., 2014) for the physiognomic characterization of both historical and contemporary rural buildings. FarmBuiLD is developed through interconnected subsequent stages, specifically: *physiognomical characterization of rural buildings (P module)*; *functional characterization of rural buildings (F module)*; *analysis of the rural buildings of a case study (CS module)*. The interpretation of results of the application of analytical tools allows to characterize the features of the rural built heritage, and outline critical aspects (typological discontinuity, critical or inadequate elements), such as the opportunities and potentials (typological continuity, functionality) aimed at planning and designing an high-quality rural landscape.
Therefore the tools to investigate and analyze both historical and contemporary rural constructions are defined in modules *Physiognomical characterization (P)* and *Functional characterization (F)*. In particular, the *P* module allows to formulate the following analytical-design parameters:

- *Height to Width ratio* (HW=H/W) and - *Height to Length Ratio* (HL=H/L), referring to quantitative dimensional aspects of building height (H), width (W) and length (L), where the height is measured from the floor up to the outer portion of the eaves of the building, being width the shortest side of the building, length the longest one (Benni et al., 2012);
- *Enclosed Volumes to open ratio* (EV=E/V) based on the relationship between closed volumes (E) and open volumes (V) and *Enclosing walls ratio* (EW=ΣW/ΣF) considering peripheral surfaces closed (W) and open (F);
- *Building front openings ratio* (BFO=SO/SW), expressing the relationship between the open surfaces (O) on the façades and the overall outer peripheral surface (W)

CS module was developed through analyses of the rural built environment performed over a representative study area in the Emilia-Romagna region (Italy), specifically the super-municipal area of Imola District (province of Bologna). We selected a sample of historical rural buildings, on the basis of typological analyses, and a sample of farm buildings currently used for agriculture, selected on the basis of the representativeness of farms in terms of production features and location.
In particular, the databases about the formal and functional aspects of historic buildings, were collected focusing on the municipality of Imola, where a high concentration of historic rural buildings can be found, largely still used for agricultural activities, albeit within farmsteads that have undergone several transformations and expansions. The basic archives used in this study derive from accurate censuses performed in collaboration with the municipal government. The buildings were classified through a process based on their spatial diversification in the various geographic areas whose influence had produced different typological imprints. This process led to the definition of a database of 634 buildings, among which we selected a representative sample of 56 buildings through the stratified random sampling technique (Snedecor and Cochran, 1980). The stratification was based on the combined use of two variables, one of architectural and one of geographic nature. The first one is represented by the typology class each building belongs to. These classes were defined as an aggregation of the rural architectonic typologies on the basis of the corresponding original functions. The following classes were

obtained: (A) rural houses; (B) farm buildings; (C) buildings with combined residential and farming functions. The second variable adopted for stratification purpose is the altimetry class, which allowed to identify areas with comparable morphological characteristics. In particular, we subdivided the study area into altitude classes adopting the thresholds of 50 m and 300 m above sea level.
The study of the contemporary rural buildings started from the analysis of productive characters of farms in the study area. It was carried out through the definition of their prevailing farming arrangements, according to ad-hoc categories identified in relation to their potential of landscape connotation. Contemporary farm buildings were subdivided into functional classes based on their use, corresponding to the typological classes considered for historic buildings: rural houses (A), production buildings (B), buildings with mixed functions (C). A sample of 57 representative contemporary rural buildings has thus been selected.

3. Results and Discussion

Results arising from the application of the parameters to the sample of historic buildings were used as a benchmark. Parametric results, besides being read individually, have been interpreted together in order to obtain complementary information. A detailed quantitative survey of the historic rural buildings sampled in the study area allowed us to calculate suitable geometrical variables and experiment the above-presented parameters. A remarkable outcome concerning historic buildings is that HW and HL have a clustered distribution for typology classes A, B, C. In fact these buildings were generally built to pursue the central goals of functionality and efficacy, thus resulting in typical architectonic forms with common geometric features.
A physiognomic clustering analysis was performed for the contemporary buildings sample and it led to define the correspondences between physiognomic characteristics and specific functional requirements.
The characteristics of compactness and articulation of shapes starting from the functional classes show that for functional class A (rural house) historical buildings have a compact volume, while for the contemporary ones more articulated forms were found, designed to host balconies and canopies of primary and secondary accesses. At the same time for class B, both for historic and contemporary buildings, compact forms were found. On the contrary, the formal characteristics are diversified as for verticality/horizontality, arrangement of open or closed volumes, opening/closing of the boundary surfaces. This variety comes from the use of materials and construction techniques that reflect those adopted for industrial buildings in urban areas, specifically the prefabricated building systems
On the whole the results, besides contributing to the validation of the FarmBuiLD model and its parametric and analytical tools. allowed to perform an original interpretation of the homogeneous features of the buildings analyzed to provide a basis for monitoring and outlining the characteristics of the contemporary rural architecture.

4. Conclusion

This study showed how the applicability of the analytical tools allowed an increase in knowledge of contemporary and traditional farm buildings. A further development of the research presented is currently ongoing, with the aim to investigate the consistency level between the objective findings derived from the FarmBuiLD model and a survey of the subjective interpretation of the rural built landscape by defined target categories.
By sharing the knowledge gained from application of FarmBuiLD in the conception of new buildings or in renovation and recovery of existing buildings, it will be possible to refer to the physiognomic parametric classes derived from typological analyses. These parameters can inform local governments in project evaluation and planning. During the project evaluation phase, the parameters can be used to interpret how and to what extent new interventions are in line with local conditions, possibly reducing the current demand for "green mitigation" actions as a necessary condition for positive assessment. During the planning phase, the parameters can support the definition of guidelines on the basis of homogeneous classes derived from analysis of the local context.

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Valorization of key buildings of the rural traditional landscape in central Italy: the case of the "Casa Colonica"

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Keywords: vernacular building, traditional farmhouse, life cycle assessment, life cycle costing, dynamic thermal simulation, retrofitting solutions

Summary

Traditional farmhouses are landscape resources of great value as elements of identity that can "narrate" different space-time modality of land management and social organization.
A meaningful objective is to merge the need of preservation of these historic buildings and the need to increase their energy efficiency. This paper is part of a broader research with this aim.
The paper concerns the developing of a model showing the optimal solutions to insulate the roof of a typical vernacular building of central Italy called "Casa Colonica". The model developed an energy simulation model integrated with a life-cycle costing approach and a life-cycle assessment approach. Furthermore, the first outputs of the model are combined using a multicriteria analysis aimed to rank the sustainability of the insulating materials.
Ten insulating materials were tested and the resulting best materials are polyurethane, polystyrene foam, rock wool, glass wool, hemp and kenaf fibres thanks to their good energy and thermal performances and a good LCA performance. The worst materials is mineralized wood. In fact, while presenting a good LCC performance, this material has high costs in terms of human health, ecosystem quality, resources consumed, and a low efficiency as insulating materials, which is reflected in a high number of hour of discomfort and low CO2 avoided.

1. Introduction

In the last decade, the attention of the scientific community to energy efficiency and thermal comfort in historic buildings has hugely increased as evidenced by the many reviewed researches on this issue. Krarti (2015) analyses the energy performance of historic buildings in Kuwait; Ma et al. (2012) develop a systematic approach for sustainable retrofitting of buildings; Martinez-Molina et al. (2016) order different methods to achieve retrofitting on buildings; Fabbri et al. (2012) wonder about merging the need of preservation of historic buildings and the need of energy saving; Yung and Chan (2012) analyse the factors that contribute to the goal of sustainable development in the conservation of built heritage. Many of these researches were carried out in Italy (Martinez-Molina et al., 2016). These studies show how the goal of merging energy efficiency and indoor thermal comfort solutions with the need to maintain and to enhance cultural and historic significance of the buildings demands a multidisciplinary approach.
Inasmuch as the high landscape values of traditional buildings and the legislation about their preservation that hamper external alterations (Mazzarella, 2015), in these buildings, the most viable solutions are to intervene on their enclosures, increasing their thermal inertia with insulating materials and to optimize the operation of mechanical installations such as the ventilation with heat recovery. When the aim of the retrofitting solution is to minimize the energy consumption, prior to design mechanical installations, it is important to insulate the building envelope. The most influential component for comfort is the roof insulation.
This paper evaluates different materials for the roof's insulation of a typical farmhouse in central Italy called "Casa colonica" (Desplanques, 1969). The legislation about the preservation of Italian traditional farmhouse hamper external alterations (Mazzarella, 2015), accordingly to

harmonize the needs of proper preservation with those of energy saving, the insulating material has added internally.

2. Materials and Methods

The objectives of the paper are to define the optimal materials to retrofit the roof of a typical farmhouse in central Italy and to develop a model usable to do an overall sustainability evaluation of insulating materials used in buildings retrofitting.
To achieve these goals the developed model combines an energy simulation engine with a life-cycle costing approach and with a life-cycle assessment approach. The criteria resulting from the simulation engine and the life cycle approach are shown inside the balloons in Figure 2.1. Furthermore, the outputs of the model were combined with a multiple-criteria approach aimed to rank the insulating materials.

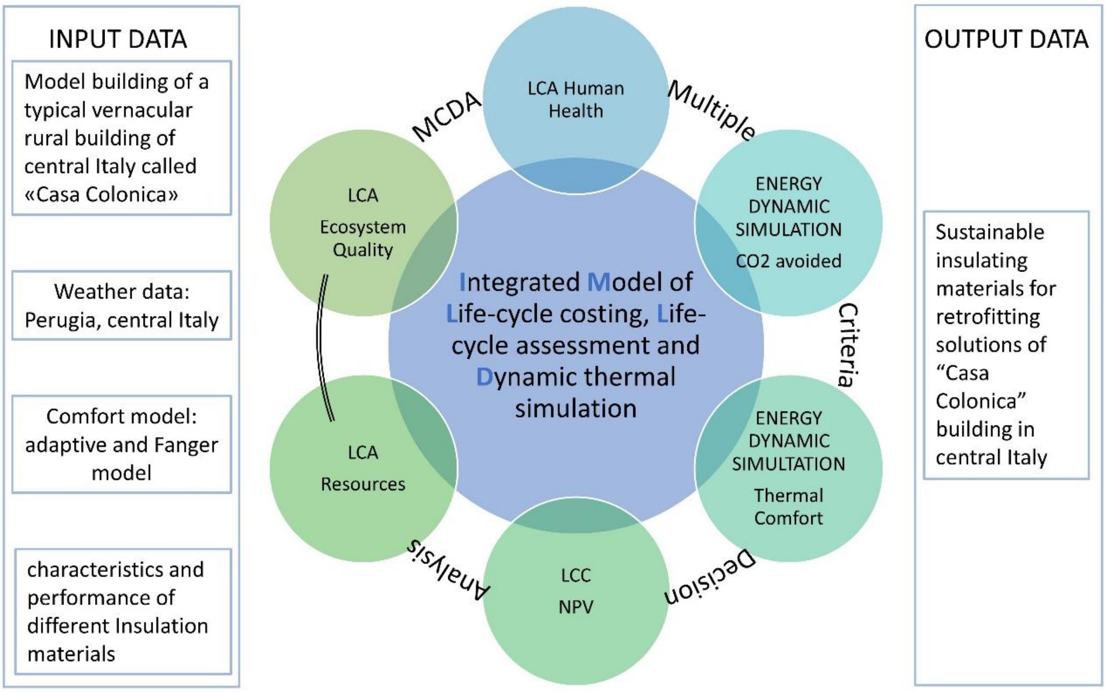

Figure 2.1: Flow chart of the methodology

The Model Building used in this paper is representative of the farmhouses of central Italy (Figure 2.2). The model was developed analysing 860 farmhouses surveyed by the census of the scattered rural buildings of the Municipality of Perugia (Umbria region) (Municipality of Perugia, 2016).

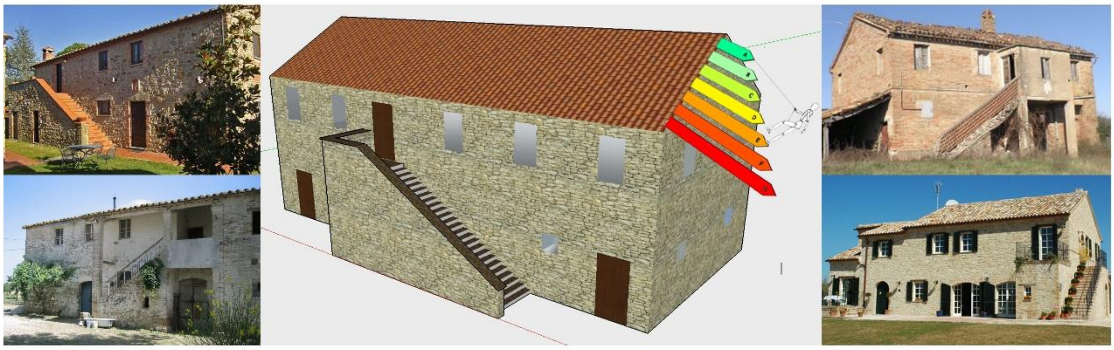

Figure 2.2: Model Building of "Casa Colonica"

To perform the dynamic thermal simulation during one year (8760 hours), it was used the Perugia weather file, available on the U.S. Department of Energy website and there were considered 5 people living in the building.
According with Lou et al. (2015), the model building adopts a hybrid strategy for space conditioning that uses natural ventilation through the opening of the windows and then switches over to air conditioning mode whenever natural ventilation is insufficient to provide acceptable comfort. During the heating season, the model uses the ideal Heating, Ventilating and Air Conditioning system of EnergyPlus. In this paper, ten insulating materials were tested: polyurethane, rock wool, glass wool, polystyrene foam, kenaf fibres, fibreboard hard, hemp fibres, expanded perlite, cork slab and mineralized wood.

3. Results and Discussion

The results of the simulation process is showed in Table 3.1.

Table 3.1: Insulation material characteristics and performance (thickness 15 cm). The coloured cells represents best performance obtained for every criterion.

insulating material (conductivity w/mk – density kg/m3- specific heat j/kgk)	hour of discomfort (hrdis) cost	energy comsupt (gj) cost.	human health (n) cost	ecosystem quality (n) cost	Resources (n) cost	CO_2 avoided (tCO_{2eq}) gain	NPV (€/ m^2) cost
polyurethane (0.025-30-1500)	3357.309	35.480	1.32E-02	5.64E-04	4.33E-02	194.18	330.35
rock wool (0.034-50-840)	3659.441	37.510	1.92E-02	8.25E-04	9.85E-03	188.45	346.14
glass wool (0.036-75-1030)	3681.898	37.900	1.06E-02	1.31E-03	3.34E-02	187.35	316.92
polystyrene foam slab (0.036-10-800)	3750.482	37.980	2.80E-03	2.17E-04	1.65E-02	187.13	322.02
kenaf fibres (0.037-50-2050)	3685.510	38.090	4.76E-03	1.51E-02	3.08E-03	186.82	341.79
fibreboard hard	3657.799	38.630	3.91E-02	1.45E-02	1.36E-01	185.29	243.45
hemp fibres (0.044-50-1700)	3921.449	39.590	2.34E-03	3.08E-03	8.21E-03	182.59	334.10
expanded perlite (0.045-95-837)	3893.646	40.820	6.45E-03	7.59E-04	4.33E-02	179.11	326.26
cork slab (0.052-150-1900)	3974.451	41.040	2.21E-02	1.84E-02	4.07E-02	178.49	282.01
mineralized wood (0.075-400-2100)	4392.808	44.890	4.29E-02	4.55E-03	8.31E-02	167.63	245.45
building model	12940.114	104.300	-	-	-	-	

The results of the simulation process showed that in these buildings, even only with the addition of an insulation material with low conductivity internally to the roof, the perceived discomfort

from residents can be reduced by 74% and the energy consumption related to air conditioning can be reduced by 66%.
For the traditional rural buildings of the central Italy the resulting best materials are polyurethane, polystyrene foam, rock wool and glass wool hemp thanks to their good energy and thermal performances and a good LCA performance.
The worst materials is mineralized wood. In fact, while presenting a good LCC performance, this material has high costs in terms of human health, ecosystem quality, resources consumed, and a low efficiency as insulating materials, which is reflected in a high number of hour of discomfort and low CO2 avoided.

4. Conclusion

This model can be applied to different buildings, to different parts of the envelope and to different geographic places.
The result offer some interesting solutions regarding the optimal insulating materials to be used in the insulation of typical rural buildings in central Italy. These buildings, although of great interest, are still poorly investigated.

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Coping with species' perception of barriers: an assessment of landscape fragmentation

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Keywords: landscape fragmentation, transport and mobility infrastructure, barrier effect, sensitivity

Summary
Landscape fragmentation (LF) is a major consequence of human actions. LF can be caused by transport and mobility infrastructures (TMIs), which have effects on ecosystem continuity, flora, and fauna. TMI-driven LF can be assessed using indices, such as the Infrastructural Fragmentation Index (IFI), which reports on the divisions brought by the road and railway network. By contrast, the IFI does not fully consider other crucial issues, such as the so called 'barrier effect', i.e. the way an animal actually perceive TMIs. Thus, we aim to build and apply the Barrier Fragmentation Index (BFI), a modified IFI-based index, able to quantify the LF as perceived by specific target species. We test the BFI for Sardinia choosing the hedgehog (Erinaceus europaeus L.). Outcomes show that IFI varies with higher absolute values than the BFI. However, BFI and IFI display similar trend lines with a different sensitivity to the changes of their components. Mitigation strategies aimed at defragmenting the landscape could be planned in areas with high BFI values. However, some critical issues need to be dealt with in the next steps of this research in order to measure a more accurate BFI.

1. Introduction

Transport and mobility infrastructures (TMIs) are one of the major causes of landscape fragmentation (LF) (De Montis et al., 2017; Saunders et al., 1991). TMIs have negative effects on flora and fauna (Spellerberg, 1998) and hinder a normal wildlife movement, thus reducing landscape permeability (Bissonette and Adair, 2008). LF is measurable through *ad hoc* indices, but a few of them can be used for measuring LF due to TMIs (Bruschi et al., 2015). The Infrastructural Fragmentation Index (IFI) allows us to measure LF caused by roads and railways (Bruschi et al., 2015; Battisti and Romano, 2007). However, the IFI does not take into account the so called 'barrier effect', which corresponds to the perception of TMIs by wild fauna. In this work, we propose and apply a new IFI-based index, the Barrier Fragmentation Index (BFI) to measure LF in rural areas and take into account the barrier effect. The BFI is a species-specific index, because it measures the barrier effect through unique coefficients for each species. In this study, as target species we have chosen the hedgehog (Erinaceus europaeus L.), a locally-common —and protected by law— species in Sardinia. IFI and BFI have been applied in three landscape units (LUs) set by the Regional Landscape Plan (RLP) of Sardinia.

2. Materials and Methods

LF can be defined as the dynamic process where larger habitat patches, or fragments, become smaller and more isolated than in their original conditions (EEA, 2011). LF is particularly evident in coastal and flat areas, namely the most suitable areas for human activities (Saunders et al., 1991). Roads and railways trigger LF and the IFI allows us to measure it. In this study, we measure LF by using the equation (2.1), which has been used, *inter alia*, by Bruschi et al. (2015) and De Montis et al. (2017):

$$IFI = \frac{\left(\sum_{i=1}^{i=n} L_i \cdot O_i\right) \cdot N \cdot P}{A} \tag{2.1}$$

where: L_i stands for length of TMIs traits, excluding discontinuities (bridges, viaducts, and galleries), O_i for the dimensionless occlusion coefficient, which varies according to the difficulty that wild fauna has in crossing TMIs (Table 2.1), N for number of fragments, P and A respectively for perimeter and area of the LU. While wild fauna perceives TMIs in different ways, depending on the barrier effect (Mata et al., 2008), IFI does not fully consider real fauna perception of TMIs. Thus, we propose the BFI, which considers the probability of barrier effect F(B) instead of the O_i (Table 2.1).

Table 2.1: Oi (according to Bruschi et al., 2015); F(B) (Scolozzi and Geneletti, 2012).

Bruschi et al. (2015)		**Scolozzi and Geneletti (2012)**	
Type of infrastructure	O_i	F(B)	Type of infrastructure
National (four-lane) road and railway	1.00	0.95	Fast-moving (two-lane) national roads and railways
Main and secondary (two-lane) roads	0.50	0.50	Asphalted secondary (one or two-lane) roads with moderate traffic
Local roads	0.30	0.05	Rural and forest paved roads

BFI takes into account F(B) according the equation (2.2):

$$BFI = \frac{\left(\sum_{i=1}^{i=n} L_i \cdot F(B)_i\right) \cdot N \cdot P}{A} \tag{2.2}$$

where the F(B) varies according to target species and linear elements, including waterways and road infrastructure (Scolozzi and Geneletti, 2012). Scolozzi and Geneletti (2012) assess F(B) through a Delphy survey by recording the opinions of scientists, professionals, and experts with specific knowledge background about the target species. In this study, we choose the hedgehog (Erinaceus europaeus L.) as target species, because it is a local-common species and is also protected by a regional law (RAS, 1998). In Table 2.1, we report on how the O_i (Bruschi, 2015) has been linked to F(B) (Scolozzi and Geneletti, 2012). We apply IFI and BFI by using data - regional land cover maps (2003 and 2008) and orthophotos- freely available on-line on the website of the Region Sardinia.

3. Results and Discussion

We apply IFI and BFI in three LUs: Golfo dell'Asinara, Meilogu, and Gennargentu-Mandrolisai (Figure 3.1).

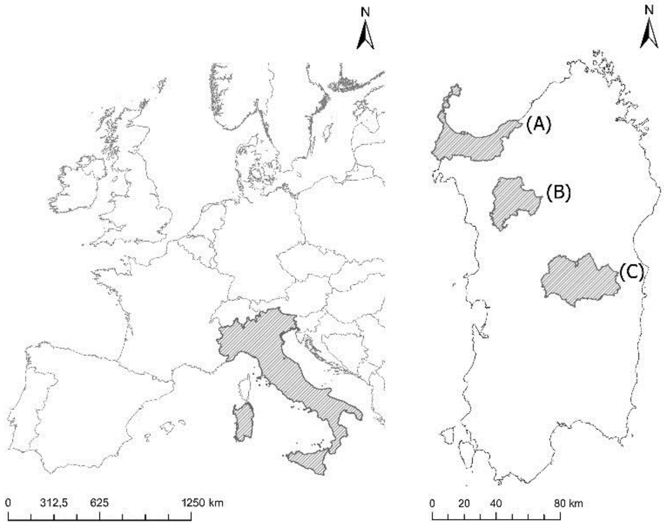

Figure 3.1: Geographical context: Golfo dell'Asinara (A), Meilogu (B), and Gennargentu-Mandrolisai (C).

In Table 3.1, we report on the values of IFI and BFI. Golfo dell'Asinara shows the highest IFI and BFI in both 2003 and 2008, while Gennargentu-Mandrolisai the lowest ones. IFI and BFI for Meilogu remain substantially unchanged over time. Gennargentu-Mandrolisai has the highest variation of IFI and BFI in the time span considered: this is due to a single fragment in addition to the original four ones. BFI and IFI have the same order of magnitude.

Table 3.1: The values of IFI and BFI and their variation.

LUs	IFI			BFI		
	2003	2008	Variation	2003	2008	Variation
Golfo dell'Asinara	21,785	23,273	6.86%	16,198	17,150	5.88%
Meilogu	3015	3012	-0.10 %	2740	2731	-0.30%
Gennargentu-Mandrolisai	186	232	24.73%	135	167	23.70%

Golfo dell'Asinara is the most fragmented LU, due to high urban pressure and a high road density. Meilogu is also fragmented, but its LF mainly depends on railway and four-lane road traits, which divide the LU in two sub-areas. Finally, Gennargentu-Mandrolisai is the lowest fragmented LU, because of low urbanization phenomena and density of the road network, which consists mainly on two-lane roads in mountainous area.

4. Conclusion

Nowadays, it has become increasingly evident that human activities affect rural landscapes, by modifying their features and leading often to habitat loss with relevant ecological impacts on flora and fauna. TMIs are responsible of LF and mortality of wild fauna, which is due to vehicle collisions, which in turn are closely related to the barrier effect. Few indices have been proposed in the literature for quantifying LF due to TMIs, and no one directly considers the barrier effect. Thus, in this study we filled this gap by proposing and applying a new index, the Barrier Fragmentation Index (BFI), able to take into account the barrier effect perceived by the hedgehog. The BFI has been useful for comparatively assessing LF in three landscape units (LUs) in Sardinia. Results showed remarkable difference of LF measured in each LU. The highest level of LF has been measured in Golfo dell'Asinara, a flat coastal area in North-West Sardinia. In this study, LF has increased in two out of three LUs from 2003 to 2008 and may further increase in the next years; thus mitigation strategies aimed at defragmenting the landscape should be planned. Landscape planning tools should include the implementation of strategies, such as, for example, the location of wildlife bridges crossing the main TMIs. This would mitigate the barrier effect and allow habitats reconnection, by enabling wild fauna to cross TMIs in a safer way. However, some critical issues need to be dealt with in the next steps of this research. Firstly, both IFI and BFI vary according to the extension of the reference LU area. Thus, both the indices are partly ineffective when applied to areas of different size. Secondly, traffic flows per season, month, day, and hour should be taken into account for a more realistic assessment of BFI. Thirdly, we considered discontinuities, such as bridges and tunnels, that can reconnect patches, but these (often old) structures are not used, as they are not designed keeping in mind the perception of wild fauna. Finally, statistical data about wildlife-vehicle collision could be used to weight the BFI, but such a data were not available for our case study.

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Rural buildings and landscape fragmentation: measure and interpretation

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Keywords: rural landscapes, rural buildings, landscape fragmentation, fragmentation index

Summary
The European Landscape Convention has opened a new perspective about the study of landscape, acknowledging the importance of natural, rural, peri-urban, and urban landscapes, including degraded and high quality landscapes across the European context. In order to achieve a best quality in protection, management, and planning proposals, all policies should take into account the landscape dimension. Landscape quality is strongly affected by human actions, and the need to fulfill the human needs has had tremendous negative effects on habitats, with a considerable biodiversity loss in the last decades. Negative effects include landscape fragmentation (LF) which is closely related to transformation of natural areas for human use. Urbanization has effects on ecological networks and causes fragmentation processes and soil consumption, which produce qualitative and quantitative effects on habitat, flora, and fauna. LF caused by urban development can be assessed through indices such as the urban fragmentation index (UFI) which has encountered some interest in research. Also suburban and rural sprawl can increase the level of LF and decrease natural and semi-natural habitat area. Suburban and rural sprawl are different from each other: the first one shows a higher housing density than the second one. However, rural sprawl affects much larger areas than suburban sprawl, with wider negative environmental effects. In this study we aim to quantify the LF in rural areas in six landscape units of Sardinia, Italy. In this work, we propose and apply an UFI-based rural buildings fragmentation index (RBFI) taking into account the interplay between rural buildings and their surrounding landscape. In detail, we aim to quantify the level of LF through the RBFI, stress the main critical issues, and propose the next steps of the research.

1. Introduction

In the last years, an increasing request of resources useful to meet the human needs has globally affected the land use, often triggering landscape fragmentation (LF) phenomena. Human actions can be considered as the main cause of LF, a dynamic process where larger landscape fragments, or patches, over time tend to become smaller and more insulated than in the original condition. Transport infrastructure and urban areas contribute in reducing habitats in rural areas. In addition to the urban areas, also suburban and rural sprawl processes have been acknowledged as key factors in increasing landscape fragmentation (Gonzalez-Abraham et al., 2007) and negatively affect biodiversity (Hansen et al., 2005) and habitats. Thus, in this work we focus on LF caused by rural buildings. We aim to propose an index —the rural buildings fragmentation index (RBFI)— for measuring LF due to the built-up dimension. We apply the RBFI in six landscape units (LUs) of Sardinia (Italy).

2. Materials and Methods

LF is mainly due to transport infrastructure and urbanized areas (Battisti and Romano, 2007). LF caused by urbanization induces effects on ecological networks (De Montis et al., 2016), and has negative effects on flora and fauna (Astiaso Garcia et al., 2013). Such a type of LF can be measured through indices, such as the Urban Fragmentation Index (UFI) (Astiaso Garcia et al., 2013). Also suburban and rural sprawl can increase the level of LF. Suburban and rural sprawl are different, as the first one shows a higher housing density (housing units/km^2) than the second one (Radeloff et al., 2005). However, in the context of forest fragmentation, rural sprawl affects "much larger areas than suburban sprawl" (Radeloff et al., 2005), with wider negative environmental effects per house, given that "it occurs in less-altered areas" (Radeloff et al., 2005). Hansen et al. (2005) argue that "many native species have reduced survival and reproduction near homes" in low-density rural home development (6-25 homes/km^2). Theobald et al. (1997) stress that the negative environmental effect of buildings on their surrounding area can be called 'disturbance zone', where the habitat is qualitatively degraded. Furthermore, recent studies (McKenzie, 2011) stress that rural buildings have ecological impact on habitats, and some authors have studied LF and loss of habitat due to rural sprawl (Gonzalez-Abraham et al., 2007; Radeloff et al., 2005). Finally, according to Theobald et al. (1997), quoted by Gonzalez-Abraham et al. (2007), at "a given building density, habitat fragmentation is highest when buildings are dispersed". Some metrics have been used to quantify LF caused by buildings, including "proportion of undisturbed area, decrease in largest patch area, decrease in median patch area, and change in total edge" (Gonzalez-Abraham et al., 2007). In this work, we propose an UFI based-index, which is rooted on the method proposed by De Montis et al. (2017) and Romano and Zullo (2013) for quantifying LF due to urbanized areas (equation 2.1):

$$UFI = \frac{\sum_{i=1}^{i=n} S_i}{A} \cdot \frac{\sum_{i=1}^{i=n} p_i}{2\sqrt{\pi \sum_{i=1}^{i=n} S_i}} \qquad (2.1)$$

where S_i and P_i stand for the extension and perimeter of the i-th urbanized area, and A for the extension of the LU area. In equation 2.1, the first term quantifies the incidence of urbanized areas on landscape surface; the second one is the ratio between the perimeter of the urbanized area and the circumference of the equivalent circle (Romano and Zullo, 2013). Furthermore, Romano and Tamburini (2006) introduced the Urban Dispersion (URD), an index able to measure the distribution of urban nucleus. URD obeys to the very simple equation 2.2:

$$URD = \frac{N}{A} \qquad (2.2)$$

where N stands for the number of urban nucleus centroids and A for the reference area. While UFI measures LF caused by urbanized areas, we now are interested in measures able to assess LF in rural areas displaying a low level of urbanization. In Sardinia, typical rural landscapes are often characterized by isolated buildings or small clusters of rural buildings. Thus, we adopt a modified version of the UFI, by introducing the URD as a weighting factor, according to equation 2.3:

$$RBFI = N^* \cdot \frac{\sum_{i=1}^{i=n} S_i^*}{A^2} \cdot \frac{\sum_{i=1}^{i=n} p_i^*}{2\sqrt{\pi \sum_{i=1}^{i=n} S_i^*}} \qquad (2.3)$$

where RBFI stands for Rural Building Fragmentation Index, N^* for the number of rural buildings, S_i^* and p_i^* for area and perimeter of the surface occupied by rural buildings.

3. Results and Discussion

We have applied the RBFI to study the LF in six LUs, which are set by the Regional Landscape Plan (RLP) of Sardinia. Piana del Riu Mannu di Ozieri and Golfo dell'Asinara, two LUs located in plain areas with several rural buildings, show higher values of RBFI than the other LUs in both 2003 and 2008. Gennargentu and Mandrolisai is the lowest fragmented LU, with very low RBFI values (0.00003 in 2003 and 0.00013 in 2008). Golfo dell'Asinara has the highest increase of LF from 2003 to 2008, while Massiccio del Limbara the lowest one (Table 3.1).

Table 3.1: RBFI values and their variation from 2003 to 2008.

LUs	RBFI (km^{-2})		$\Delta RBFI_{03\text{-}08}$
	2003	2008	
Massiccio del Limbara	0.01169	0.01472	25.87%
Regione delle Giare Basaltiche	0.00214	0.00950	343.61%
Piana del Riu Mannu di Ozieri	0.03289	0.07790	136.82%
Gennargentu and Mandrolisai	0.00003	0.00013	317.47%
Flumendosa - Sarcidano - Araxisi	0.00557	0.01026	84.33%
Golfo dell'Asinara	0.01708	0.08041	370.84%

4. Conclusion

In this work, we proposed an index for quantifying LF due to rural buildings. We have modified the Urban Fragmentation Index (UFI) to take into account the rural landscape context, where built-up areas are often characterized by dispersed and isolated buildings. The resulting new RBFI considers the number of rural buildings in a given area, such as the landscape units (LUs) set by the RLP of Sardinia. We applied the RBFI in six LUs and measured the landscape fragmentation (LF) from 2003 to 2008. Piana del Riu Mannu di Ozieri and Golfo dell'Asinara are more fragmented than the other LUs. The RBFI could be useful for identifying critical areas, which need to be restored and reconnected through mitigation measures. However, this study is still in its infancy and several critical issues need to be dealt with. First, RBFI gives a rough measure of LF, as it does not consider both how rural buildings are dispersed across the territory (completely isolated or in aggregate form), and the reciprocal distances between the buildings. Secondly, the RBFI does not take into account the effect on specific target species, and then it does not give information about the ecological effects that result from the impact of rural buildings on habitats. Thirdly, the RBFI was elaborated without any consideration of the type of land use affected by fragmentation. Furthermore, the RBFI does not take into account whether the rural buildings are inhabited or uninhabited, and hence the possible effects on habitats due to human activities. Finally, the index does not consider the effects of the road network linking rural buildings between them and the main roads, a major cause of LF. Further studies have to be developed in order to solve the above critical issues and calibrate the RBFI with respect to a specific context.

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Stone artifacts of the Sicilian mountain landscape: a cultural heritage to be protected

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Summary
Neviere are stone buildings, likely built between the mid 1600s and early 1700s, found in several rural sites surrounding Mount Lauro. These structures are a testament to the sophistication of ancient construction techniques, and must be protected due to their recognized role in maintaining biodiversity, and their importance both as cultural testimonies and as defining features of this landscape. Today, the neverie are in state of neglect, and are gradually disappearing due to the absence of crops and the conversion of agricultural land into construction areas. This study is among the scoping activities solicited by the European Landscape Convention (ELC). This paper reports the results of a survey carried out in Buccheri, a town situated in the mountain area of Syracuse, characterised by a high concentration of "neviere" of particular architectural merit. This investigation availed itself of historical documents, census files, and field research, all of which pointed to the historical, cultural and panoramic value of these edifices, which urgently calls for adequate public intervention.

1. Introduction

The "neviere" are ancient stone edifices intended for the production of ice which scattered among various european countries at altitudes at which abundant snowfall is expected. While the remaining Sicilian "neviere" are largely in a state of abandon, they are still visible and strongly define the rural landscapes in which they are found. These landscapes certainly fall within the definition of "cultural landscapes", in that they "express the maximum integration between human activity and environmental dynamics" (Farina, 2001). Such landscapes are part of the region's cultural heritage, and must therefore be valued and protected. The European Landscape Convention indicates the need to safeguard and maintain those aspects, deriving from natural or anthropogenic factors, which define the value of a landscape. The ELC further highlights the need to base interventions on research and knowledge, in order to craft the most appropriate response. Consistently with the ELC's solicitations this paper offers a census and survey of the neviere in Buccheri, and aims to highlight the testimonial value of these constructions in order to seek their tutelage and preservation.

2. Materials and Methods

The neviere studied are located within rural designations and forested public land surrounding the City of Buccheri. Their identification is made difficult by their neglected state and because some are completely buried or hidden by dense vegetation.
Therefore, this survey made use of historical documents and census files on the neviere's characteristics in addition to field research. Three specific areas were identified within the municipality of Buccheri, each of which contained constructions with a clearly identifiable structure (17 in total). The survey of the artifacts has been directed to identify the typology, construction techniques and metric proportions of the neviere, and in order to highlight their intrinsic cultural and testimonial value. Furthermore, in order to describe their relationship with their context, some thematic maps, evincing the current state of their surroundings and the potential risks they posed to the structures, were considered.

3. Results and Discussion

The neviere are the last remaining testimonies of the commercial activity of ice gathering, in which naturally formed ice was collected and preserved in the neviere during the winter months, and the sold during the summer (Martignano, 2002). In the past, Buccheri boasted 25 active neviere, however their number decreased drastically during the early 1900s, dropping to just 4 in the 1930s, with their use ceasing entirely after World War Two (Cultrera, 2001). In the 3 km buffer zone from the urban centre of Buccheri, three "zones", containing the 17 surveyed neviere, were identified: 1) a consolidated urban zone, 2) a zone at risk of urbanization, and 3) a consolidated rural zone. The *consolidated urban zone*, characterized by the typical urban development, commencing in the 1970s, of small, historical centres. Despite this, the three neviere surveyed in this area (1, 2 and 3) are found on fallow sloped terrain and are separated from modern construction. These neviere are not subject to the risk of urban expansion, however they are in a grave state of abandon. The *zone at risk of urbanization* is characterised by both urban settlements and rural areas. The six neviere found in this area, may, due to their location in the periphery of Buccheri, either be completely abandoned and left to deteriorate, or be restored and maintained for the purpose of securing the cultural heritage of the area and further enhancing future development (they could, for example be protected as part of a thematic urban park). The *consolidated rural zone* the outermost area of the buffer, contains eight neviere. These structures are likely to be forgotten and left to decay, as they are situated in isolated grazing areas and sometimes hidden by dense vegetation. The Landscape Plan classifies these areas as exceptional and of great value, both at for agricultural purposes and in general (Fig.1).

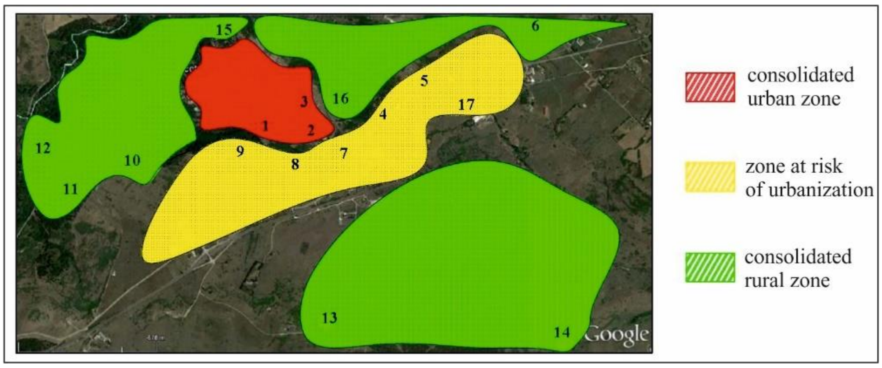

Figure 3.1. "Zones", and surveyed neviere

Analysis of the Neviere

<u>*Typology and Structural Characteristics*</u>

The neviere were generally excavated on northern-facing slopes. On their northern side, there were "withdrawal openings" used to withdraw the ice from the neviere. On the inside of this opening, above its architrave, there were two robust brackets, which supported a pole attached to a pulley system for the withdrawal of snow and ice. The "input opening" is found either on the dome (or vaulted roof), or on the side opposite to the withdrawal door. The slope gave users of the neviera easy access to the dome so that they could unload the snow without excessive exertion. All the surveyed neviere had a drainage canal, ending in an opening facing downhill. A second canal around the perimeter of the neviere disallowed water from entering the structures.

<u>*The typologies of neviere*</u>

- Cave neviera: these are the most ancient, and have inner walls made of limestone, irregular circular bases, and to openings: one on the ceiling and the other on the northern side. Two of these were found in the consolidated urban zone (neviere 1 and 3) and another was found in the zone at risk of urbanization (neviera 17);

- Dome neviera: these have an above-ground portion is in the shape of a half sphere emerging three to seven metres above the ground. Their dome discharges its weight on its underground walls and they may have square or circular bases.The majority of the dome neviere are found in the consolidated rural zone (neviere 10, 11, 12, 13, 14, 15, and 16), while four more are in the zone at risk of urbanization (neviere 5, 7, 8 and 9), while only one was found in the consolidated urban zone (neviera 2);

- Vaulted roof neviera: these have either square or rectangular bases. They have a withdrawal opening at the base of the springer and two or three input openings on the vaulted ceiling. The only one of its type is found in the zone at risk of urbanization (neviera 4);
- Hybrid dome/vaulted roof naviera: has elements of the preceding two types and can be found in the zone at risk of urbanization (neviera 6).

Each naviera is surrounded by a dry wall called "zzàccanu'', which delineates the lot on which the naviera is excavated.

Characteristics of Some Neviere

Neviera N° 1 ''Neviera del Crocefisso''

This is a cave neviera, excavated in volcanic rock and is owned by the municipality of Buccheri. It is barely visible but for the large volcanic rock plates (length 60 cm, width 20 cm and height 50 cm) along its opening which was once sealed by a walnut door. Its circular input door is on the dome and was originally closed with a rock plate. Its inner walls, made of plaster and local sand, are about 2,1 m in height.

Neviera N°2 ''Neviera Della Maddalena''

This is a dome neviera built with volcanic rock quoins and mortar. Its dome has an average width of 1 m. It has a circular base and two openings: a Southern withdrawal door and a Northern input door. This is one of the most elegant, best maintained constructions, despite also being one of the most ancient (dating back to the 1630s) (Fig.2).

Neviera N°4 ''Neviera Balateddi''

This is a vaulted roof naviera. It is almost 10 m wide and 5 m deep. The outer walls are made of volcanic rock plates in various sizes, held together by mortar. Today it is in a state of abandon, as it is covered in infesting vegetation and more than half of its vaulted roof has caved in.

Neviera N°7 ''Neviera di Ribera''

This is a dome naviera with a segmental arch. It has two openings, a Southern withdrawal one and a Northern input one. Its dome and outer wall are are built in volcanic rock quoins which are held together by sand and limestone, while its inner walls are coated with mortar.

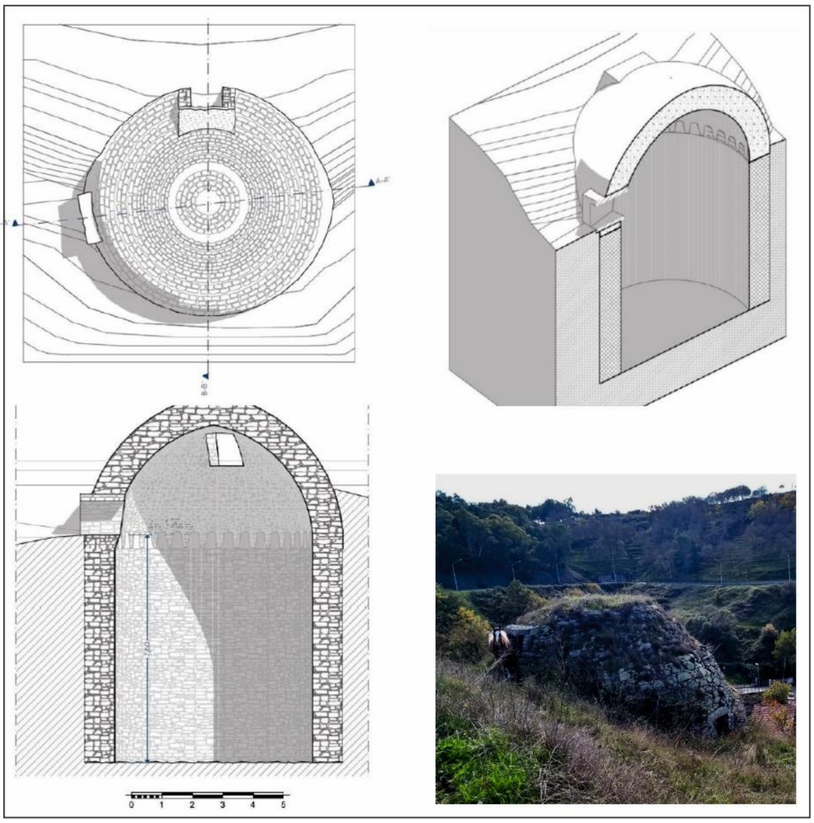

Figure 3.2. Neviera Maddalena

4. Conclusion

This study has laid out the necessary information to tailor tutelage and valorization measures to each individual construction and its surroundings, in order to realize each neviera's full potential.

This paper has further highlighted the following aspects:

- the landscape, typological, and design and construction value of the neviere is clear;
- the abandonment of commercial ice-making activities has led to the neglect and abandonment of remarkable architectural structures. However, today, in the interest of the multifunctionality of rural territory, the neviere can constitute the nodes of a more complex program capable of justifying the costs of recovering and maintaining these structures.

This survey has found a remarkable architectural complexity which can be observed in interesting metric reports and special construction techniques. It has further identified four types of "Neviere" based on their structure and materials. Finally, this study has demonstrated that the cultural, historic and landscape value of these constructions requires adequate and urgent forms of public intervention.

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Integrated geomatic techniques for historical agricultural building surveying

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Keywords: 3D advanced surveying techniques, Integrated Survey, Terrestrial Laser Scanner (TLS), Unmanned Aerial Vehicles (UAV), Structure from Motion, point-clouds, GNSS.

Summary
The research deals with the architectural surveying of historic agricultural buildings, with particular reference to those for food processing. Recently they have gained ever-growing importance as a part of the wider architectural heritage and many still are, or can be, effectively used. Therefore, a thorough knowledge of their current condition is needed as a pre-requisite to implement planning and management actions for their sustainable valorization. It was defined a method based on advanced 3D surveying techniques, that allows to obtain accurate geometric model of buildings and their surrounding. The methodological aspects are presented, with a discussion of procedural steps, tools and materials used. Application to a specific example in Calabria, is shown.

1. Introduction
Historic agrifood buildings often house bulky machinery, plants and furniture once used for food processing and storage. Terrestrial Laser Scanner (TLS) would be a powerful tool for their indoor architectural survey if not for the presence of obstructions generating occlusions and clutter (Barnea and Filin, 2008) of the surfaces in background. Several solutions have been adopted to fill holes in post-processing phase (Dumitru et al., 2013; Pérez et al., 2016; Salamanca and Cerrada, 2012). The method here proposed differs in that it does not offer software integration using algorithms to generate the missing data model, but integrates TLS with the use of Digital Camera (DC) coupled with Structure from Motion (SFM) algorithms to generate the point-cloud. It was applied also to hydraulic powered wheat mills presenting outdoor water-channelling systems and working spaces not easily detectable by TLS, (i.e., steep slopes, dense wild vegetation, etc.). For these reasons, the use of Unmanned Aerial Vehicles (UAV) was proposed.

2. Materials and Methods
The proposed method is based on the integrated use of the following equipment: Unmanned Aerial Vehicles (UAV) for the survey of building surroundings, roofs and outdoor spaces not easily accessible; Terrestrial Laser Scanner (TLS) for outdoor and indoor surveys; Digital Camera (DC) for surveying building components; Global Navigation Satellite System (GNSS) to geo-reference the whole survey. Three methodological steps can be singled out:

- survey project and data-collection;
- pre-processing;
- processing of the data obtained.

The survey project is a key-part of the whole process since it affects the duration of the fieldwork and the accuracy and completeness of the obtained data-sets. Each external TLS scan-station was registered by GNSS in order to combine with UAV scans in the next step. UAV needs to establish Ground Control Points (GCPs) distributed widely across the target area (Bemis et al., 2014); in this case the high reflectivity 6' tilt and turn target of the TLS were used. Internal building components and machineries were detected by use of both TLS and DC in order to avoid clutter and occlusions in the surveyed scene. The pre-processing step basically involves the co-registration of all the surveyed data. In terms of interoperability, all surveyed data are shared as 3D point-clouds. Integration of the surveying systems was ensured by the interoperability between the different software platforms and by the utilization of the open E57 file format. To this end, all surveys and the obtained datasets were georeferenced in a common coordinate reference system (CRS), usually the WGS84/ETRF1989 UTM33N (EPSG 32633).

Figure 2.1: (a) Survey by Terrestrial Laser Scanner; (b)Mesh obtained by point-cloud extracted by photo of Digital Camera using software for Structure from Motion.

Processing is the last step: the whole 3D point-clouds are managed and converted into parametric elements in order to generate the so-called 'as-built' or Historic Building Information Modeling (HBIM). The global 3D point-cloud was imported into Autodesk Recap® to export in RCP file format in order to modeling into Revit®. The parametric model acquires all the geometric information detected and it is possible to generate the required analyses.

3. Results and Discussion

The proposed method allows to obtain a survey of historical agricultural building which is highly accurate and quick if compared to those using conventional tools. The obtained positional accuracy is 2.48 cm of Root-Mean-Square Error (RMSE) (table 3.1).

Table 3.1: Raw data and integrated survey.

RAW DATA from TLS	
N° station points	8
N° target 6'	8
N° target 3'	3
N° points	74.813.809
RAW DATA from UAV	
N° total images	2.842
N° used images	2.790
N° target	3
N° points	11.335.366
RAW DATA TLS+UAV	
Target typology	Tilt & Turn target 6'
N° matched target	3
N° points	47.165.293
RMSE	2.48 cm

The obtained 3D point-clouds coming from the integrated survey (UAV, TLS, DC, GNSS) allow to derive an accurate parametric modeling trough HBIM. Moreover, the obtained model appears as more significant than the simple geometric model, since it is a "smart" 3D model containing a wide range of information usable for various purposes.

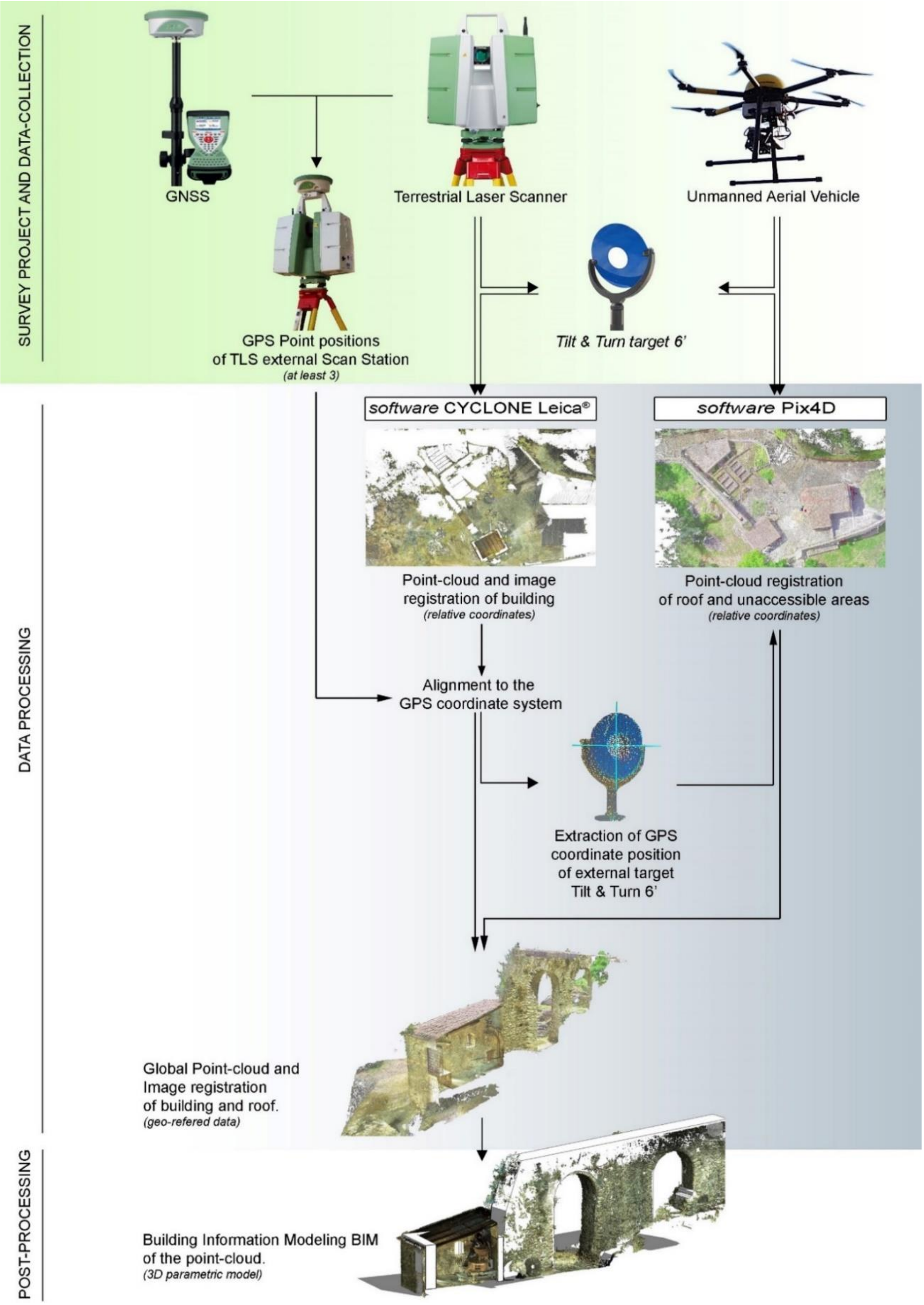

Figure 3.1: Flowchart of proposed methodology of integrated survey.

Figure 3.2: Historic Building Information Modeling (HBIM) built by point-cloud.

4. Conclusion

The surveying method proposed for historic agricultural building, allows to obtain important information otherwise unavailable, i.e. if one considers buildings vernacular in kind for which historic documentation and metric drawings (plans, sections, elevations) often lack. For the redundant buildings, often under risk of disappearance, a complete, accurate and expeditious architectural survey – as proposed in our research with the use of integrated geomatic techniques – allows to preserve better their memory. Moreover, for the whole stock of historic agricultural buildings, it helps addressing properly their management as a part of comprehensive strategies for the protection and creative valorisation of the rural built heritage.

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Characterisation of the historical agricultural terraces of Costa Viola (Calabria – Italy) at landscape and architectural scale

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Keywords: Terraced agricultural landscape, Land Use / Land Cover (LU/LC), Change detection, Dry-stone walls.

Summary

The aim of this research is the characterisation of the historical agricultural terraced landscape of 'Costa Viola' (South Italy), at landscape and architectural scale. The investigation of the built elements and of their distinctive features was related to the functional analysis of the system according to a diachronic approach. Multitemporal analysis of Land use/land cover helped detect landscape change and its main driving forces, clearly showing the extent of landscape abandonment. In sample areas the main features characterising the walling system were singled out and in those functionally redundant the signs of ongoing deterioration were detected. The survey methods are described, showing their potential for the characterisation of a wider category of historic agricultural landscapes and in view of their protection and integrated management.

1. Introduction

In historic agricultural landscapes the study of the changes occurred over time, as a result of the continuous interaction between their natural and cultural components, is of fundamental importance not only for assessing their cultural value but also for defining appropriate management strategies (Antrop, 2005). Among historical agricultural landscapes the terraced ones are widely recognized as of great cultural interest and for them the need to couple protection and functional suitability requires a thorough knowledge of the ongoing change dynamics. The case here analyzed is "Costa Viola", a century old terraced landscape presenting dry-stone retaining walls and located in Calabria (Southern Italy) along a coastal strip about 1÷2 km large and 20 km long, with an area of 24 km^2. Present terraces, mostly used for vineyards, date from the second half of the18th century and develop on very steep slopes (the most representative range is between 30° and 45°) at an altitude varying between 0 and 600 m a.s.l. The main characteristic features of the terraced system were analyzed, also on the basis of previous studies of the Authors (Di Fazio, 2008; Modica et al., 2014).

The cut-and-fill terrace graduation of the slope, with the building of retaining dry-stone walls, proceeded valley to top - the soil removed used as a backfill - so as to have land steps of arable land suitable for agricultural and efficient in water drainage (figure 1.1*a*). At the base of the wall, lying on a slightly inclined layer (angle of 6°-12°), larger foundation stones are sunken 25-cm deep in the soil. Traditionally the top of the walls was 20÷30 cm wide, while the height varied between 50 cm ad 3 m (figure 1.1(b)). Width decreased gradually base to top; in 2 m high walls, typical in the area, it varied between 70 cm and 25 cm. The cultivation of vineyards presents two different historic vine training systems, as shown in figure 1.1(a): A) called *ad alberello*, that is an alberate system with vines supported by individual stakes with about 1.00 m spacing; B) *a pergola*, with grapes growing overhead thanks to canopy support structures. In recent years, many vineyards have been abandoned and, as a consequence, the terraced system has undergone progressive deterioration, thus increasing hydrogeological risk and threatening the coastal settlements below. This phenomenon needs therefore to be studied not only to protect the cultural landscape but also to make the living environment safe for the population.

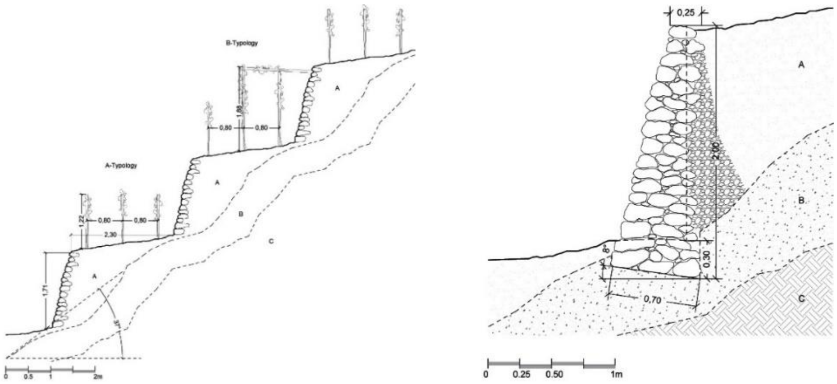

Figure 1.1: (a) Typical section of a terraced vineyard in Costa Viola. Legend: A – Filling layer, B – Soil layer, C – Rock layer. They are also represented the two main traditional vine training systems, *alberello* (a-type) and *pergola*. *(b) Detailed metric section of dry-stone wall.*

2. Materials and Methods

The diachronic analysis of Land Use/Land Cover (LU/LC) has recognised and widely applied as an important method enabling to effectively represent the complexity of change dynamics (Zhou et al., 2008) and help identify the traditional patterns marking the character of historical landscapes (Van Eetvelde and Antrop, 2004). In Costa Viola the evolutionary trends of terraced areas at a landscape scale was carried out comparing multitemporal LU/LC maps for the time interval 1955-2015 (figure 2.1). These were obtained from historical aerial photographs, digitally processed by means of enhanced photogrammetric suite, and orthophotos, by digitalisation in GIS environment (scale 1:1000, minimum unit: 0.20 ha). Post classification comparison (Lu et al., 2004) allowed to build a complete change detection matrix for the period under investigation.

For the characterisation of the terraced system at an architectural scale, the survey of dry stone walls was carried out using Terrestrial Laser Scanner (TLS) in sample areas representing different types of terraces, one of which is shown in figure 2.2(a). In order to survey active terraced terrain, a Leica® C10 TLS (figure 2.2 (b)) was used with a medium resolution and a field of view of 360°. From the seven TLS scan stations it was surveyed a representative portion of whole system in 126.631.864 number of points. The survey helped characterise the walling system (stone geometry and size, stone bedding and organization, coping solutions, integration of other built elements – i.e.: stairs, niches, water channelling and drainage systems, etc.). Their state of maintenance was investigated also by using for this last purpose it was also used Trimble® DPI-8 with B/W target (figure 2.3(b)) and the GPS position was registered by a GNNS. The point-cloud this way generated was analysed also to detecting signs of deterioration, particularly in abandoned terraces, according to the categories shown in figure 3.1. When light conditions did not permit to operate using DPI-8, a Digital Camera (DC) was used and the survey was elaborated by Structure from Motion (SfM) techniques.

3. Results and Discussion

A geo-database of terraced areas, both active and abandoned, a set of change detection matrices and a classification scheme of the main constructional features of dry-stone walls have been produced as main results. The analysis of LU/LC changes highlights two main changing forces: an increase of sealed soil surfaces due to the expansion of settlements and infrastructures; a significant abandonment rate (694.45 ha,) of the agriculture use in the terraced areas. In redundant terraces it was observed loss of maintenance of the dry-stone walls.

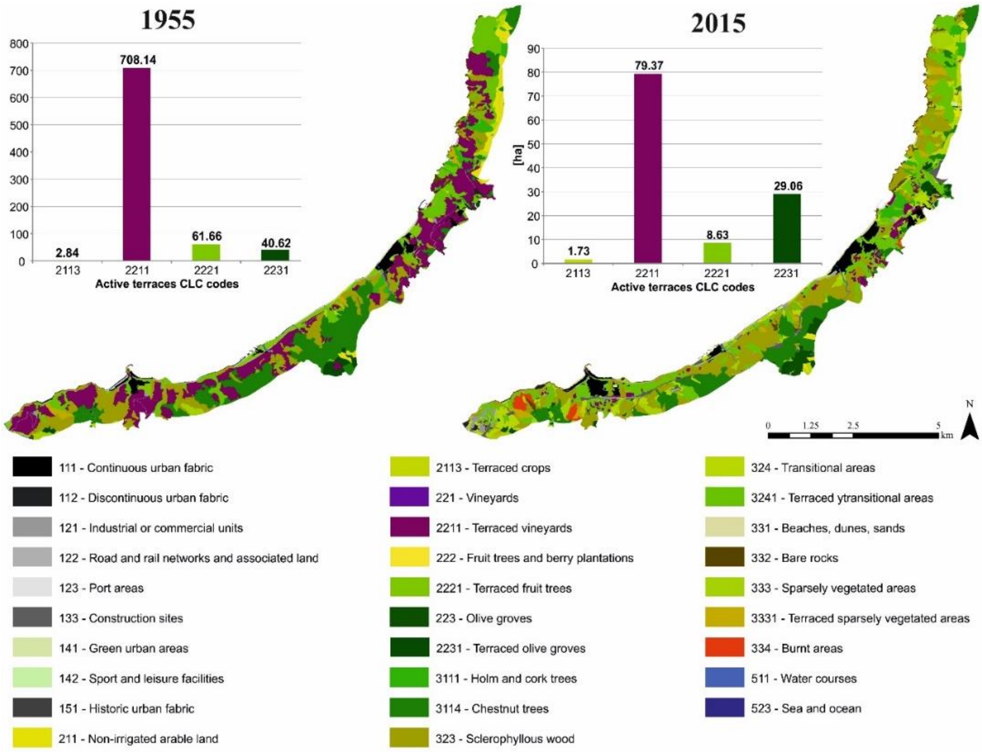

Figure 2.1: Land Use/Land Cover maps for years 1955 and 2015.


Figure 2.2: (a) Agricultural terraces of Costa Viola; (b) The Terrestrial Laser Scanner used.


Figure 2.3: (a) Collapsed dry-stone retaining wall; (b) Use of DPI-8 to detect wall deformation.

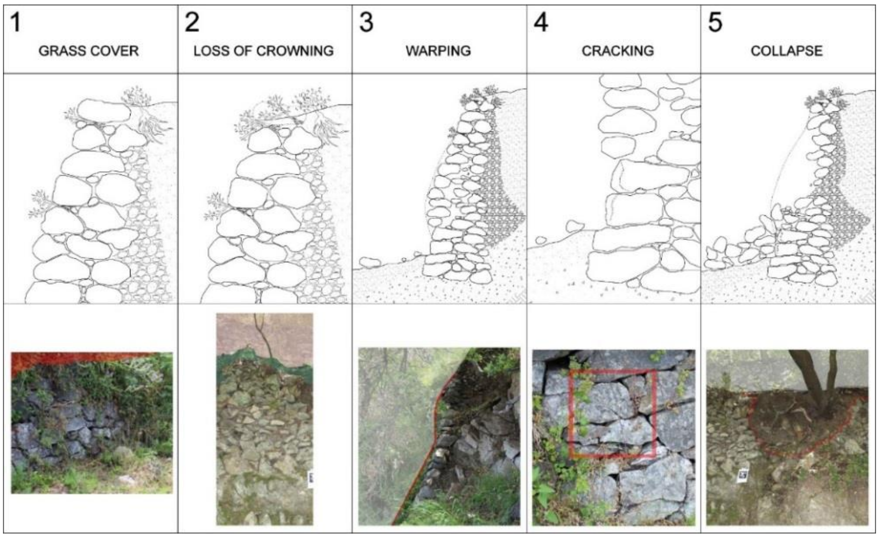

Figure 3.1: Detection of deterioration signs in the dry-stone wall surveyed, according to the main categories classified.

4. Conclusion

The study carried out helps emphasising the need for an integrated approach to the protection and valorisation of the agricultural historic landscapes. In particular, the physical preservation of the terraced landscapes and of their characters strongly depends on the continuity of the agricultural use of the land, which on its turn can grant the maintenance of dry stone retaining walls and of other built elements. Regular monitoring of the landscape terraced system, both at a territorial and an architectural scale, requires expeditious survey methods enabling to feed dedicated geodatabases and helping integrated approaches to landscape management. The methods and tools here proposed are particularly suitable for the survey of terraced areas, as it was shown in the case-study considered, presenting severe deterioration or environmental conditions making physical accessibility and visibility difficult.

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Cultural quality of landscape: an expert-based multicriteria approach to assess functional integrity

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Keywords: landscape quality, functional integrity, landscape cultural services, ecosystem services, cultural functions, spatial multicriteria decision analysis.

Summary
The Potential Cultural Quality of a landscape is its capability to offer cultural functions that, if used, become services providing benefits to different categories of stakeholders. Cultural functions depend on functional integrity of landscape elements that can be both natural and man-made. This research aims at quantifying the functional integrity of a study area in the central Italy characterized by the presence of many punctual elements of value and of a great extension of historical olive yards. To this aim four cultural functions were analysed: educational, recreational, aesthetic, and symbolic. For recreational functions quali-quantitative indicators were used to quantify functional integrity of elements, while for educational, aesthetic, and symbolic functions an expert-based assessment was developed. The scores given to each element were aggregated by a weighted sum to calculate function-specific integrity and then an overall functional integrity. Weights were calculated thanks to the Incomplete Pairwise Comparison Matrices filled by the local experts. Results show that the method is effective for quantifying the cultural potential of a landscape and that it can support landscape policies aimed at the improvement and management of cultural functions.

1. Introduction
Landscape quality is usually associated with visual quality (see e.g. Daniel, 2001; Kuiper, 2000). Nevertheless Vizzari (2011) argued that landscape quality depends on multiple resources, namely physical-naturalistic, historical-cultural, and social-symbolic, that can be potentially found in a given area. In this light, we define the concept of Potential Cultural Quality (PCQ) of a landscape as "landscape's capability to provide cultural functions". This definition is strictly related to the ecosystem services cascade model (Potschin and Haines-Young, 2011) that suggests that landscape functions become services only if they are actually used by people. So, functions can be considered the potential services that could be provided by the landscape.
Ecosystem services are traditionally classified in three main categories: provisioning, regulation and cultural (Millennium Ecosystem Assessment, 2005). The first category includes all the goods and services for human consumption, such as water, food, fiber and fuel. The second category includes mainly the services for risk reduction (e.g. water retention, pollution reduction etc.). Cultural services include all the services provided by a landscape when people interact not only physically but mostly intellectually with it.
Cultural functions – the landscape potential services for which there is no evidence of their use - are provided by the elements of value of the landscape, that can be natural, man-made or both. For this reason, our definition of "cultural functions" - overcome the classical definition of ecosystem functions and includes also the functions provided by all landscape elements including historical-cultural and socio-symbolic ones (e.g.: buildings of high historical value, traditional events, typical productions).

According to our approach, the potential capability of the landscape to offer a defined cultural function can be measured by an index of functional integrity (FI). A synthesis of the FI indices, related to the different cultural functions, can give a clear view on the overall PCQ of a landscape.
In this framework this research aims at the development of a method for the spatial quantification of the PCQ of a landscape. This method was applied on the municipality of Trevi (PG) in central Italy, characterized by the presence of many punctual elements of value and a great extension of historical olive yards.

2. Materials and Methods

The cultural functions to be included in the analysis were identified adapting the Common European Classification of Ecosystem Services (CICES) (Haines-young and Potschin, 2013). Four types of functions were considered:

- **Educational:** capability to supply learning functions (increase of knowledge e.g. about nature, history, arts);
- **Aesthetic:** capability of a landscape feature to increase the landscape visual quality;
- **Recreational:** capability to provide spaces (e.g. gardens, terraces, etc.) and events (e.g. festivals, concerts etc.) for leisure activities;
- **Symbolic**: capability to represent a symbol or an object of worship for a group of people.

A large dataset, including all the recognized landscape features able to provide cultural services, was built processing data provided by the local authorities (Trevi Municipality and Monti Serani and Subasio Mountain Community). An open source web-GIS, accessible from http://maps.agr.unipg.it/, was set up to share intermediate and final results with experts and stakeholders.
A questionnaire was designed to assess the FI of landscape features for each of the four cultural function. It was filled by a panel of experts on the local landscape, and with expertises in different disciplines: ecology, local history and arts, and agronomy. The questionnaire was organized in two parts. In the first one an evaluation of the FI of each single landscape feature was assessed using a 5 points Likert scale ranging from 1 (very low functional integrity) to 5 (very high functional integrity). 0 or "no data" were also possible values for features which do not provide the specific function under investigation or for those elements for which a judgement was not possible. The second part of the questionnaire was aimed at quantifyng the FI of each group of landscape elements. To do this, four pairwise comparison matrices (Saaty, 1977) - one for each function - were filled by the expert panel. To reduce the number of comparisons, and maintain a high reliability of the answers, incomplete pairwise comparison matrices approach (Harker, 1987) was used. The questionnaire response was assisted by a researcher in order to reduce the cognitive burden, and ensure the completeness of the responses, as suggested by (Bowling, 2005).
The FI of each element was spatialized using Kernel Density Estimation tecnique (see e.g. Vizzari, 2011, Vizzari and Sigura, 2015) to calculate spatial indices able to express locally the density of landscape elements thogheter with their FI. Then, the spatialized FIs of all categories of elements were hierarchically aggregated according a multicriteria spatial decision analyis approach (Malczewski, 2006) to compute maps of FI for the four functions under investigation. These were then aggregated to calculate the overall PCQ of Trevi municipality.

3. Results and Discussion

The PCQ map shows of the landscape potential to provide cultural services (Figure 1). Its lowest values are in the agricultural plain on the western part of the municipality, while the highest PCQ values appears in the Trevi town centre and alongside the main river (Clitunno), especially where it flows across high value land uses such as the Canapine Gardens (in the north-west) or within a protected area (in the south). Medium-high PCQ characterizes also the ancient olive yards in the middle part of the municipality.

The PCQ index helps to identify the areas with the lowest cultural potentiality to increase cultural functions eventually. At the same time PCQ index helps to focus on the areas with the highest cultural potentialities, supporting the localization of investments for improving the accessibility to the cultural functions and for the enhancement of their use by residents and by different categories of stakeholders such as tourists, students, etc. In this perspective the PCQ index can support policy makers to develop targeted policies aimed at landscape enhancement and protection.

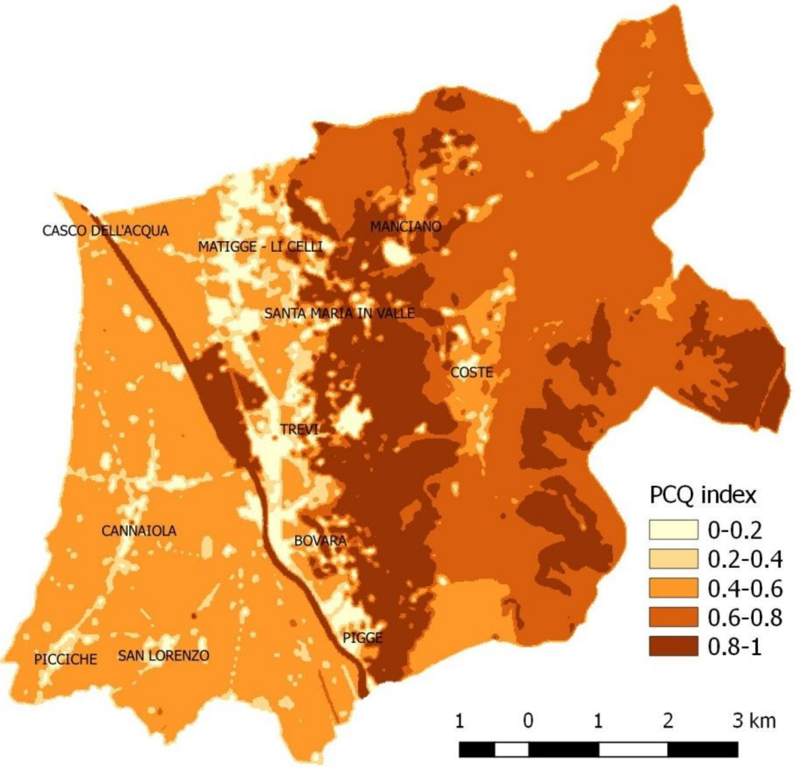

Figure 1: Potential Cultural Quality map of Trevi municipality

4. Conclusion

The suggested methodology allows the provision of a wide PCQ evaluation, that not only considers the aesthetic quality of the landscape, but also other important cultural functions such as educational, recreational, and symbolic. Moreover, the method demonstrated to be flexible since it allows considering the influence of very different landscape features. It can therefore be applied in mixed landscapes where combinations of very varied landscape features can be found. The successful application in the Trevi municipality showed that both the FI values, associated to each landscape element, and the intermediate and final spatial indices can support the landscape policies aimed at the improvement and management of cultural functions. Further studies aimed at the development of methods for the assessment of the Actual Cultural Quality of the landscape – describing the actual use of the various functions – may enrich the landscape cultural quality assessment, giving even finer instrument to policymakers for a more effective management of cultural landscapes.

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The study of green areas in the farm with agritourism

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Keywords: agritourism, green areas, design.

Summary
The agritourism is an activity that has undergone extensive development in many agricultural farms and that, today, requires the presence, in contiguous with the building structures utilized (adequately renovated annexes), of a specific spatial context that characterizes and contributes to the success of the enterprise itself. This area (the farmyard which becomes a courtyard) is generally developed in a design of the green arrangement of the area and its prevalent characteristics tend to be reflected in the development of the surface, in part in relation to the site itself and orography of the terrain where the enterprise is located, and, in part, in relation to the direction and management of the company itself.
In this paper, we will consider the general characteristics of projectual elements of the green areas defined on a theoretical level with a division of the area into sub-areas, which are represented by an entrance area, agricultural area, relax area and a green area.
These studies were conducted also by examining existing or newly renovated rural characteristics of some agrarian activities that are present in the territory of Perugia. From the study conducted, regarding the number of sites taken into consideration, a general picture emerges that, in its entirety is very precise and detailed, and describes the contemporary presence of common elements, in almost all companies, and their own specific characteristics.
All the companies, for example, show in general a scheme of subdivision of the space adjacent to the agritourism structures in use which is distributed in sub-areas as indicated on a theoretical level.
Furthermore, the study shows as during the design phase of the new elements, the businesses followed the PAC/PSR indications and they have also seriously considered the needs and expectations of their guests and users. Thus, as the final result, in most of the cases, is revealed a complete harmony in the connection between the building and the courtyard nevertheless, in some cases, despite the valuable work that was done, the connection between the structures and the courtyard with the territory and landscape is lost. Therefore, in these cases, there is a great expectation about the overall rural development of the territory but, the growth of the purely agricultural activity practiced in the company loses importance.

1. Introduction

This paper deals with the theme of the contiguous areas of the structures (building and annex) used by the farms that practice the activity of agritourism. In particular, the areas that were formerly used by classic farms for the "farmyard", (that is, the space situated adjacent to the farmhouse and used for the threshing and drying of cereals and other products), are to be considered. Today, that area and the spaces connected to the building, in enterprises that practice agritourism activities, after appropriate renovation, have been transformed in such a way as to be an adequate and functional area for the new needs derived from tourism and hospitality activities, and is defined by the term "courtyard" (Photo 1.01, 1.02, 1.03, 1.04).




Photo 1.01, 1.02, 1.03, 1.04 – Agricultural buildings and contiguous and adjacent areas.

Tourism is a growing sector and has seen many changes over the last few years despite the economic crisis that has hit Europe, and Italy in particular. Holidays, and therefore tourism, are not taken simply for rest and leisure, but also as an opportunity for personal growth from a social, cultural, natural and food and wine point of view, all thanks to direct contact with the places one visits. Consequently, agritourism businesses must be equipped to deal with different variables in order to be able to satisfy these needs.

"Rural tourism" represents a segment with interesting development opportunities that stem from a capacity to respond to the trends in tourism demand, as well as an opportunity to diversify the economy and revitalize some of the territories which have been disadvantaged: this is how a business that has ties to the territory in which it operates develops, while keeping in line with the interpretation of the European Union, rather than characterizing itself specifically by the type of activity it engages in.

If, in the tradition of the European Union a territorial approach to rural tourism has been taken, in Italy a conceptual and sectoral approach has been applied to "agritourism" which links tourism to the presence of an agricultural enterprise. In this regard, Italian national legislation has endeavored to regulate and precisely define just what constitutes the agritourism business, distinguishing it from other similar activities carried out in agricultural and rural areas. In fact, talk about farm holidays began in the mid-60s thanks to the Agriturist Association. Agritourism has evolved considerably since then, but only in 1985 was a specific law defined on a national level; and then gradually, individual Regions have either deliberated or adapted the relevant legislation to the territory within their jurisdictions.

Since the aims of an agritourism are numerous, to be able to fully benefit from them, the area adjacent to the building and its restored and utilized annexes to provide accommodations or other services for the farm business take on greater importance today, the characterization of the adjacent and contiguous space (farmyard that becomes a courtyard) also helps to qualify the activity itself (Photo 1.05, 1.06; figure 1.01).

In defining the courtyard, it could also be useful to explain the functions and features assigned to identify sub areas (for example the entrance area, agricultural area, relax area and green area), which, on the whole, may be inspired by "green areas", while pointing out, however, that the agricultural activity and therefore, the areas involved in the cultivation activities (having themselves a predominantly productive function), should not be included in the courtyard.

Additionally, the courtyard's location is very important in that it is an intermediate space, and thus assumes an additional function of separation as it occupies a portion of the surface area covered by two areas represented, in the case in question, by a residential area (an agritourism structure) and a productive area (cultivated agricultural surface). The courtyard, therefore, constitutes a subject of study in relation to the use of the building for tourist activities both in the context of an agritourism, as well as with concepts that can be extended to companies that fall within the field of rural tourism, and especially when they are situated in an extraurban context.



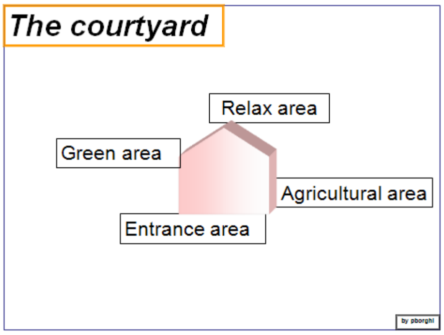

Photo 1.05, 1.06; figure 1.01 – Building/vegetation report and theoretical division of the courtyard.

2. Materials and Method

Having highlighted the importance of the courtyard in the establishment of a farm holiday business, we have analyzed the courtyards of 26 such businesses present and operating in the Province of Perugia to understand their current situations. The importance and definition of this space in particular, which was created both to satisfy the expectations and desires of the future guests of the agritourism, and the will and vision of the business' owners regarding their place in the sector, as well as the territorial features of the site where the business is located. The designation of this area, created to satisfy both the expectations and desires of future guests of the agritourism and the needs and vision of the business' owners regarding their place in the sector, as well as the territorial features of the area where the business is located, is of particular importance. In our analysis, a scheme made up of several parts, each having specific summary objectives, will help provide a more complete picture of the context that was observed. In fact, the division of the courtyard area into several sub-areas (entrance area, agricultural area, relax area and green area) come from the various functions that these can fulfill in addition to the choices made in the project.

In the profile, the first prospectus (type A form) concerns the general description of the territory, the surrounding landscape, the building and the business provided regarding tourism activities and the type of existing vegetation.

The "entrance area" (type B form) is directed at identifying the connecting area between the external and internal areas of the business, and is destined for the reception of tourists, how many enter the agritourism and considers the accessibility of the building, driveway, walkways, cycle paths, rest areas and internal and external fencing of the property (Photo 2.01).

The "agricultural area" (type C form) is intended as that portion of the courtyard that the structure makes available to visitors, and destines it to the cultivation of agricultural crops, and in particular, the horticulture of fruit and flora with the sole scope of being educational and for local consumption (Photo 2.02).

The "relax area" (type D form) is the area to be enjoyed by the visitor who goes there looking for that special, reserved place which is beautiful to see and where he can relax and enjoy the additional sense of well-being that comes from a broader and different outdoor context (Photo 2.03).

The "green area" (type E form) refers to an area where plant elements prevail absolutely, and whose utility is found in the specific functions for which it serves (principally recreation, mitigatory, decor, aesthetical, etc.) (Photo 2.04).

The study ends with the survey phase (type F form) where a schematic diagram is hand-drawn during the inspection of how the area is to be developed in its entirety (courtyard) with respect to the main building.



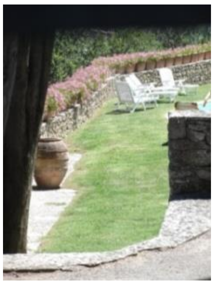


Photo 2.01, 2.02, 2.03, 2.04 –Example of main features of the different areas.

3. Results and Discussion

From the analyses carried out and the experience gained in the field of agritourism, it must be assumed that it is characterized by, and presents several strengths in different aspects of farming and non-farming. Among the first we list the typical agricultural characteristics of the building and its adjacent space represented by the courtyard (formerly farmyard) whose presence today, assumes greater importance and can, therefore, contribute to the success of the agritourism itself. Leaving aside considerations related to the characteristics of an agricultural building (not because they are not important, but because they are not the subject of the present study), all the companies have attributed the importance of the "courtyard" element in distinguishing their agricultural business. This is reflected in the solutions that have been found as all of the businesses we evaluated (No. 20 of No. 26) have created valid solutions with the exception of a single company that has not yet set up the courtyard, but having recognized its importance, is currently planning to do so.

A first consideration that can be made in this regard is expressed by the features that distinguish the courtyard; in fact, within, the four sub-areas are typically found as indicated on a theoretical level and generally characterize the guidlines as described in Figure 1.01. The distinction concerns some aspects. One consideration could regard the range in size of in the companies evaluated in terms of the total surface they occupy (ranging from 2.000 to 22.500 m^2), and consequently, specifically by the individual sub-areas. A second consideration could be made based on the fact that in some cases, the distinction of the different sub-areas is clearly defined; while in other cases, there may be an overlapping of functions (this is particularly true in the case of the relax and the green areas). Moreover, in some cases these different interpretations depend on the orography of the site where the business center of the agritourism is located; in other cases, they depend on the different subjects and relative planning levels that are applied (Figure 3.01; photo 3.01).

The type of project under examination is linked to this aspect: in some cases, the type of project developed is a simple one (7 cases); in other cases, it is complex (4 cases). There are also intermediate cases where a different type of project was applied to the different sub-areas (8 cases). In the first case, this essentially means design and planning that involve open type interventions, with or without the minimum physical barriers, and with or without slight changes to the original profile of the terrain. In the second case, however, interventions involve the delineation of well-defined areas that are clearly marked by physical elements (both vegetable and artificial) that are also connected to the most important modifications carried out on the original profile of the terrain.

A third consideration concerns the agricultural sub-area, to which only a few agritourism businesses attribute importance (4 companies in all). Further reflection refers to the fact that almost all of the companies shared common elements in the courtyard together with specific elements in some companies. We can point to the presence of a swimming-pool in the first case (only 4 companies in all did not have one); and in the second case, there are small agrarian company museums (present only in 3), and different libraries and laboratories (present respectively in 1 and 2 farms).

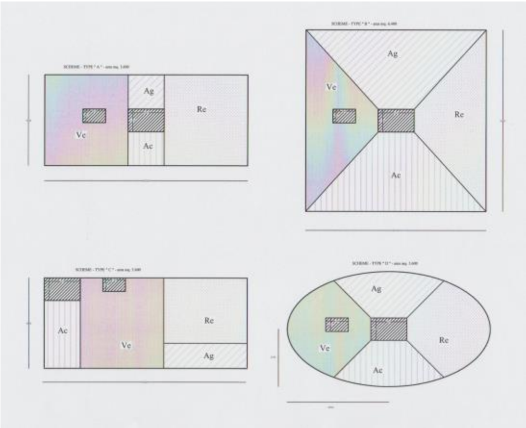


Figure 3.01; Photo 3.01 – A geometric definition of theoretical solutions and a farm example.

On the whole, however, it follows that the building-courtyard relationship is always presented positively with the practical realization of significant interventions in each type of project described above as well as in all the examples that were the subject of this study. What is less perceptible, however, is the building-courtyard relationship with the surrounding territory-landscape relationship in that, based on the type of work planned and carried out, between the two constituent elements is present in reality, a continuity (in 11 companies) or a discontinuity (in 8 companies) is created. This second case is an element to be considered carefully in relation to a vast agricultural area, the maintenance of agricultural characteristics, and in relation to the characteristics of the territory and the landscape.

4. Conclusion

The study of the courtyard dealt with in this survey has made it possible to consolidate the importance of the agritourism sector which, undoubtedly, continues to evolve and represents one of the most promising activities in terms of multifunctionality both for the agricultural company and for the development of the territory. Although the study refers to a limited area and a reduced sampling of companies, it has still provided important useful details. From the examination and survey of the companies analyzed, it is an extremely positive sample on the whole for all the planned solutions, and therefore, for the solutions actually implemented for the "green area" topic (Photo 4.01, 4.02, 4.03, 4.04).




Photo 4.01, 4.02, 4.03, 4.04 – Details of some design contents of the areas.

What should also be highlighted is the attention of the entrepreneur towards the tourist an obvious attention also in the arrangement of the area studied with which it is attempting to organize the time and the well-being of this person by proposing places and activities made specifically for such purposes also taking into consideration the cultural aspect. A classic example is the presence of the swimming-pool, trails, animals (such as horses) in the first case and the presence of small company museums, laboratories or libraries in the second case.

Another important aspect is, even for the purpose of enhancing the territory, that some of the concepts so far exposed in the definition of the functions of the green area are also extended beyond the single farm, by for example creating of pedestrian, cycling, equestrian trails in order to promote the development of activities in the wider agricultural and rural areas, and therefore also in order to exploit the different products conceived in the companies in the territory.

At this point, specific reflections are revealed, for example the the desire to force the division of a single area defined in the same "green area" into more sub-areas arises from the will to emphasize the importance to meet the different needs of tourists but also from other factors such as the site of membership as well as expressing the subjective characters of the farmer. Further reflection comes from examination and contents about the relax area and the green area. For example, in the case of the relaxation area, the purpose can be achieved either by the presence of a swimming-pool (as seen from the data collected in almost all the companies visited the relax area is identified with the reserved area and bounded to it reserved) and both by one open space where it is possible to enjoy a wider area also combined with a panoramic and landscaping point or area. However, the first example may not be considered necessary if there are valid alternatives; in that case its absence may be a factor of distinction from the activities in the territory.
Another important element that can be drawn from the analysis is what agro-tourism activities generally evolve towards to purely touristic farms, a phenomenon that is positive in a view of the overall rural development of the territory. Consequently, a further impression that can be deduced is that in such farms or of rural tourism the importance of purely agricultural activity is reduced compared to the purely tourist one.
Therefore, for the better design of the courtyard, it is necessary carrying out a thorough study of all the positive and negative aspects is considered essential in spatial distribution and in the realization of the areas, always keeping in mind the goal that is to be achieved and that, nevertheless, the same companies, also in order to meet the demands of the users urban consumers, should not lose sight of the simplicity and fundamental characteristics which, in the present time, also contribute to characterizing agricultural activity, its territory and its agrarian and rural landscape (Photo 4.05, 4.06, 4.07, 4.08).



Photo 4.05, 4.06, 4.07, 4.08 – The agritourism, agricultural and rural building, the territory and the landscape.

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The role of DTM/DSM and RGB/CIR digital aerial orthoimages in landscape planning: a case study in Valsesia (Piemonte)

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Keywords: Aerial Orthoimages, DSM, DTM, LiDAR, Landscape planning

Summary
Landscape management relies on accurate and up to date spatial information concerning any recurrent structural configurations having the character of a permanence and needing effective safeguard policies. In this work an integrated approach is presented based on different geographic data sources to support landscape analysis in the aim of improving territory planning by reducing field survey time. New available regional data, such as high resolution digital RGB and CIR aerial orthoimages and Digital Terrain and Surface Models (DTM and DSM), can effectively be used for such task.
The proposed methodology has been applied to a test area in Valsesia (NE Piemonte). It relies on the adoption of the above mentioned data and their processing within GIS environment. In particular CIR (coloured infrared) aerial orthoimages have been used to characterize vegetation and building roof materials. DTM and DSM have been autonomously derived from the available for free regional ALS (Aerial Laser Scanner) acquisition. For each urban or rural aggregate within Valsesia we have mapped through ground survey urban texture, land cover, roof mantle and degradation maps on a cadastral support.

1. Introduction
The Piemonte Landscape Plan (adopted in 2015, not yet in force) recognizes regional landscapes as essential cultural and economic resources and defines both protection and enhancement measures. Our Regional Landscape Plan recognizes 12 macro-areas (i.e. "*macroambiti*") – from the "high altitude Alpine landscape" to the "river and lake landscape" – and 76 landscape areas (i.e."*ambiti di paesaggio*"), namely landscape portions identified through structuring, qualifying and typing characters. For each of such landscape areas the Regional Plan declines focused regulations with respect to landscape quality objectives, strategies and government addresses.
Landscape management relies on accurate and up to date spatial information concerning any recurrent structural configurations having the character of a permanence and needing effective safeguard policies. Such landscape invariants relate to physical and ecological characteristics, lithological typologies, morphological aspects, ecosystem characters, settlement frames and infrastructure facilities, agroforestry systems and cultural heritage. It is widely recognized that obtaining that information through ground surveys is time consuming and much expensive, so high geometric resolution aerial orthoimages and ALS-derived products can be a valid alternative. Administrative bodies have recently promoted onerous survey campaigns and made available for free a huge amount of new geographical datasets, often remaining underused owing to a widespread lack of knowledge within administrators and technicians. Conversely, joint exploitation of the geometric information about landscape topography, buildings and vegetation from DTM/DSM datasets and the semantic one from RGB/CIR digital aerial orthoimages offer a meaningful support to wide-area landscape planning; therefore it is expected that this type of approach is going to represent a real territory framework for the municipal operational planning, in compliance with the UE principles of cooperation and subsidiarity. In particular, these new dataset and related processing skills are becoming central in planning of fringe zones where urban texture, forest and mountain have to be contemporarily

managed. It is worth to remind that these areas are characterized by a high ecological value and, conversely, by a fragile balance between environment and anthropic disturbance.

2. Materials and Methods

While dealing with the planning of transitional landscapes (like the most of mountain villages are) where both antropic and natural factors play a conditioning role in plan redaction, ALS and CIR orthoimages can successfully support the process.

ALS dataset: according to the most accredited scientific references, up to now ALS and remote sensing has been applied in two contexts: the natural/forestry-dominated and the urban/building-dominated ones. ALS is nowadays one of the most used remote sensing technologies for studying and characterizing forests. Specifically, it can be effectively employed for monitoring position and possible movements of ecotones and to characterize forest structure (tree heights in particular). The ALS dataset of the Piemonte Region has been recently released both in a gridded format (DTM and DSM) and point cloud (.las) covering the entire regional territory. The dataset was acquired during the ICE aerial-photogrammetric survey (2009-2011). ALS points were acquired using a LEICA ALS50-II sensor. Nominal density was about 0.5 points/m^2.

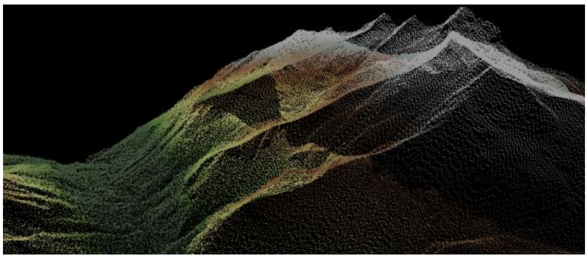

Figure 1. An example of LiDAR point cloud in the study area.

RGB/CIR orthoimages: Piemonte Region has made available for free two datasets of recently acquired orthoimages covering the entire regional territory: the true colour (RGB) and the false colour (CIR) ones. By synthesizing spectral information from both the datasets, a "pseudo" multispectral image (4 bands: blue, Green, red, NIR) – exploring the spectral range 400-900 nm about – can be obtained and used for remote sensing properties. Both the datasets belong to the ICE flight. GSD (ground sample distance) is 0.4 m nominally corresponding to a map scale of 1:5000.

Study area: the study area is located in Valsesia, an alpine valley in the northern province of Vercelli (NE Piemonte). The area is dominated by the Monte Rosa complex on its background and hinged on the homonym river. The Piemonte Landscape Plan includes the Sesia Valley into a specific macro-region, due to the consolidated values of its heterogeneous agro-forestry landscapes and its building heritage, partially dating back to the Walser colonization (13^{th}-14^{th} centuries).

ALS point cloud processing: from the supplied point clouds file (.las) of the area a DTM and DSM have been obtained by filtering, classification ("*ground*" and "*other*") and regularization (LAStools scripts), resulting in a final geometric resolution of 2.5 m. Therefore they have been compared by differencing to obtain the correspondent CHM/OHM (Canopy Height Model/Object Height Model), mapping the height of objects (buildings and trees, basically) above the ground. This information was used to derive, by GIS zonal statistics tools, information about average heights of building and trees. Moreover, DTM was used to generate information concerning the topography of the investigated area, strictly connected, in a planning process, to the evaluation of the role of slope steepness, in respect of hydrologic risk, and of forest surrounding buildings (protection forests?).

Orthoimages processing: CIR/RGB aerial orthoimages have been used to map land cover classes. Since CIR/RGB aerial orthoimages were not intended for specific remote sensing purposes, a rigorous approach to radiometric/spectral calibration is not possible. To minimize effects of this limit during image classification (we adopted a K-mean unsupervised classifier within SAGAGIS) we have preventively computed the following spectral indices useful to map vegetation: I_1*=(NIR-Red)/(NIR+Red);* I_2*=(NIR-Blue)/(NIR+Blue);* I_1*=(Green-*

Red)/(Green+Red). Thence classification has been achieved according to these indices (discriminants). Five land cover classes have been mapped (figure 2): pastures (classes 5 and 3), forest (classes 1 and 2), buildings+bare soil+rocks (class 4).
Finally landscape concerns about buildings, topography and vegetation have then been related to cadastral maps and some synthetic statistics computed (not reported). Ground surveys have also been done in the area and compared with the information derivable from digital geographical data.

3. Results and Discussion

Being a methodological work, results are given in shape of examples with the aim of making reader aware of the planning potentialities hidden in ordinary geographical data which, in most cases, are free for users. Figure 2 portraits some examples of derivable information concerning both vegetation and building characterization and allows some deductions about village exposure to snow avalanches and the role of protection forest (figure 3).

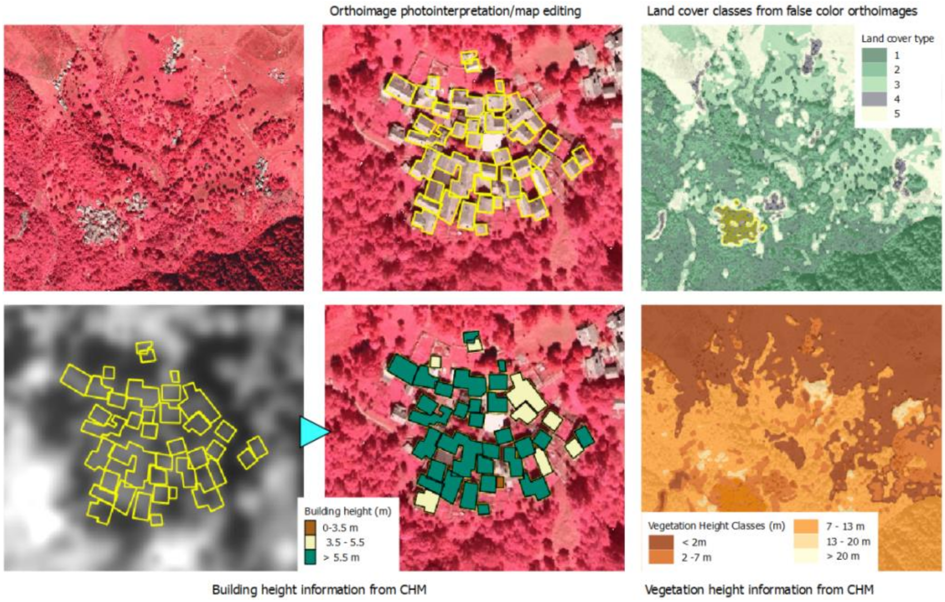

Figure 2. Some examples of information that can be derived from a joint use of ALS data and RGB/ CIR orthoimages. Spectral information from orthoimages can be used to map land cover classes. CHM information can be used to geometrically characterize land cover classes (building included), after vectorizing classification results.

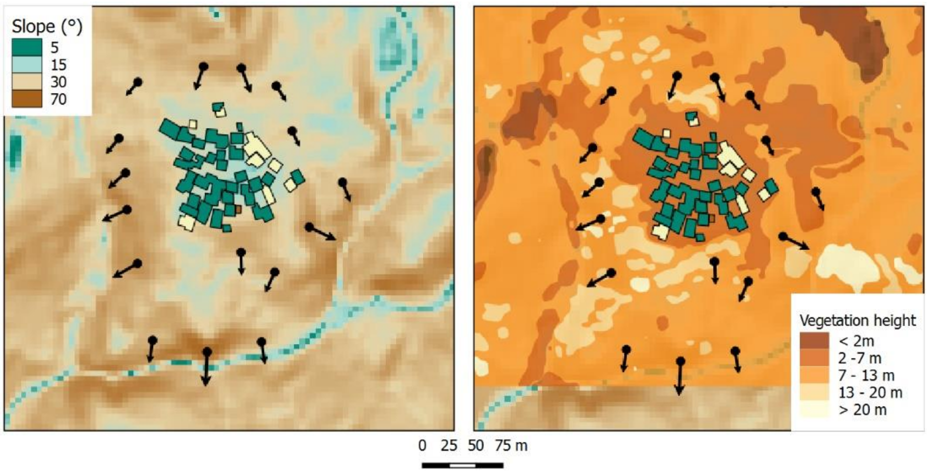

Figure 3. Example of landscape analysis aimed at evaluating exposure of buildings to possible snow avalanches according to slope and direction of movement. (left) Potential snow directions

and slope classes. (right) Potential snow directions coupled with vegetation heights to evaluate building protection by forest.

Ground surveys have permitted to map urban texture, land cover, roof mantle and conservative conditions (figure 4). Information from ground have been transferred onto cadastral maps in order to describe the features of the urban fringe transitional landscape. Among the main outcomes of the conducted analysis, settlement frame is strongly influenced by the steep gradient of the slopes and it is structured with tight clusters being arranged on the slope at different altitudes without any hierarchical connection among them, but connected to a lower, more populated hamlet through trails running perpendicular to the contour lines. In particular, rural settlements are eminently characterized by an uniaxial framework with an arrangement of the traditional buildings being hinged on a generator shaft. In the absence of a primary road axis lowland settlements or those located on a mild slope take a radial structure, especially in the presence of an urban fulcrum point.

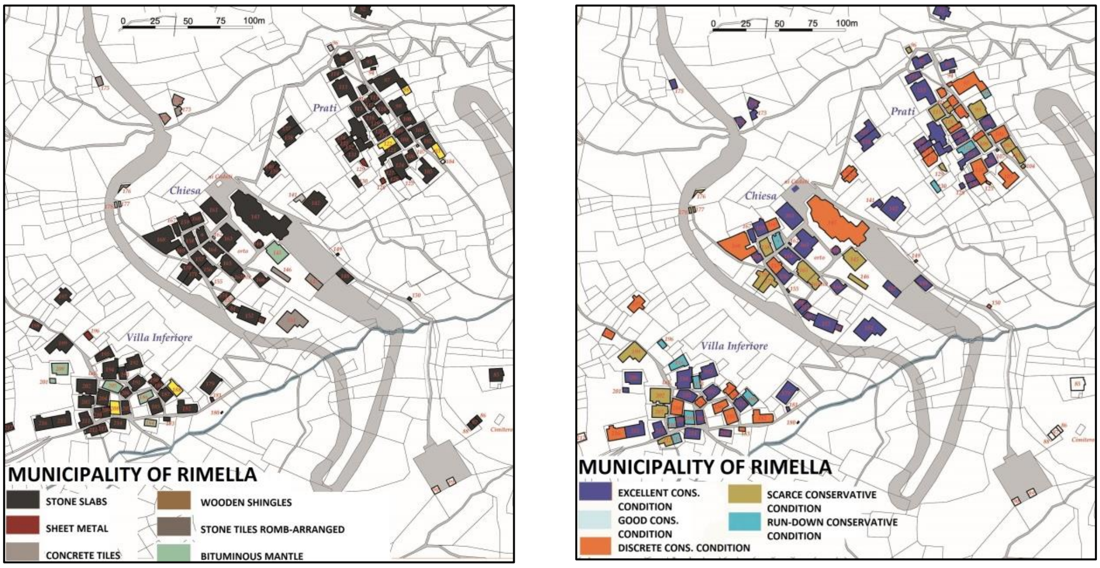

Figure 4. Roof mantle and conservative condition cadastral maps

From such a deep knowledge of landscape, safeguard recommendations within wide-area and municipal planning can just arise, finalized to ensure a sustainable balance between conservation of existing production activities and preservation of both landscape and environment integrity.

4. Conclusion

New digital geographical data have proved to be useful for landscape reading and planning. The underlying technologies seem to finally inaugurate new perspectives for wide-area and sectorial landscape planning, reducing circumscribed, targeted ground surveys, which normally represent town-planning primary costs.

Both semantic (RGB and CIR orthoimages) and geometric (ALS dataset) information from the new free geographical data of Piemonte Region demonstrate to generate a meaningful added value to planning ordinary approach, offering a new type of information both for the characterization of the morphological, vegetation, built and infrastructural components and for the landscape visual analysis (primarily concerning transitional and peri-urban fringe landscapes).

Overall, despite precision limitations, the proposed methodology crossing LiDAR data with digital orthoimages, in the aim of generating "intelligent photos" with automatically quantified variables, demonstrates its effectiveness within landscape planning procedures and policies. In fact engineering and automation of the procedures here adopted allow reducing elaboration times with respect to the more traditional survey techniques and meantime they support the analysis of wide territory portions.

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Tensegrity greenhouses: light structures, technologically advanced and durable.

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Keywords: greenhouse structures, tensegrity, structural design.

Summary
The greenhouse structures represent an important part of the Italian both vegetable and flower production. This paper aims to investigate new types of structures for greenhouses focusing on a new structural typology: the "tensegrity". The tensegrity structures can cover large spans with a low structural weight. One of the more interesting applications is the covering of the Georgia Dome Stadium in Atlanta and these constructions make it possible to change their configuration as needed, or also make themselves folding structures. The objectives of this paper are the analysis and design of this new structural type of greenhouse in order to achieve the reduction of structural elements weight, the reduction of structural shading, adequate resistance to environmental actions and economic feasibility.

1. Introduction

Research focused on new structural systems responds to different needs, such as safety, energy saving, and optimization of both costs and materials used for greenhouse construction. Technological innovation allows us to create more and more special solutions for that category of buildings that we call "smart buildings". The structural typology tensegrity represents an innovative category in many areas: civil engineering, aerospace engineering, robotics and mechanics. In civil engineering, the use of these structures is still limited to important buildings, such as stadiums or important architectural constructions (eg.the covering of the Georgia Dome Stadium in Atlanta and the Centre Commercial in Nantes Epone by Richard Rogers). In simple terms, structural principle of the "tensegrity" is accomplished by employing compression elements included in a network of tensioned cables. This principle, using structural elements of small sections (bars and cables), intuitively allows reducing the structural weight of the entire covering system and consequently allows to cover large span structures. For these characteristics in this paper, we propose to use tensegrity systems in agricultural greenhouses, also because the small thickness of the structural elements allows a slight shading of the inside environment, a key feature for plant growth.

2. Materials and Methods

The basic modular configuration of the tensegrity system, called "T-bar" (fig. 2.1), is made of four cables subjected to tensile stress $t(s_1)$ and two bars subjected to compression stress $f(l_0)$.

In a system of this type, the relation that rules the principle of mass reduction is the following:

$$f(l_0)/l_0^2 < \left(\rho_b^2/E\pi\right)\left(\sigma_s/\rho_s\right)^2 \quad with \quad \hat{t}(s_1) = t(s_1)/f(l_0) \tag{2.1}$$

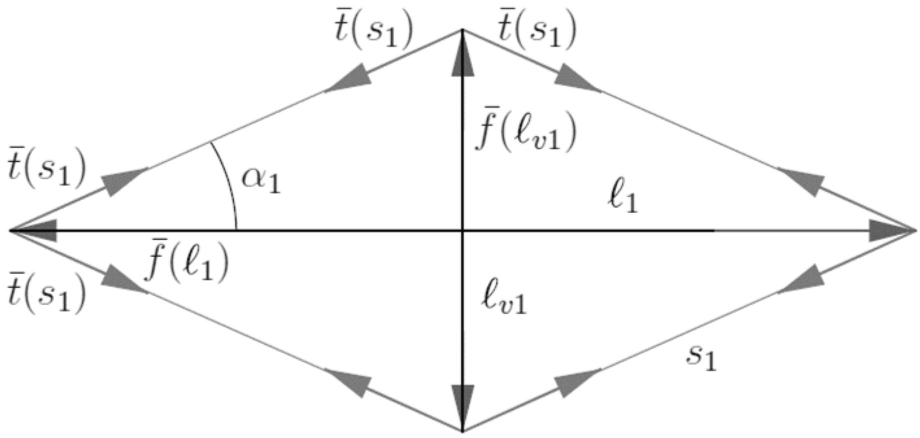

Figure 2.1: T-bar forces

The research was carried out taking into account a tensegrity covering system based on sixteen cables and four bars (fig. 2.2).

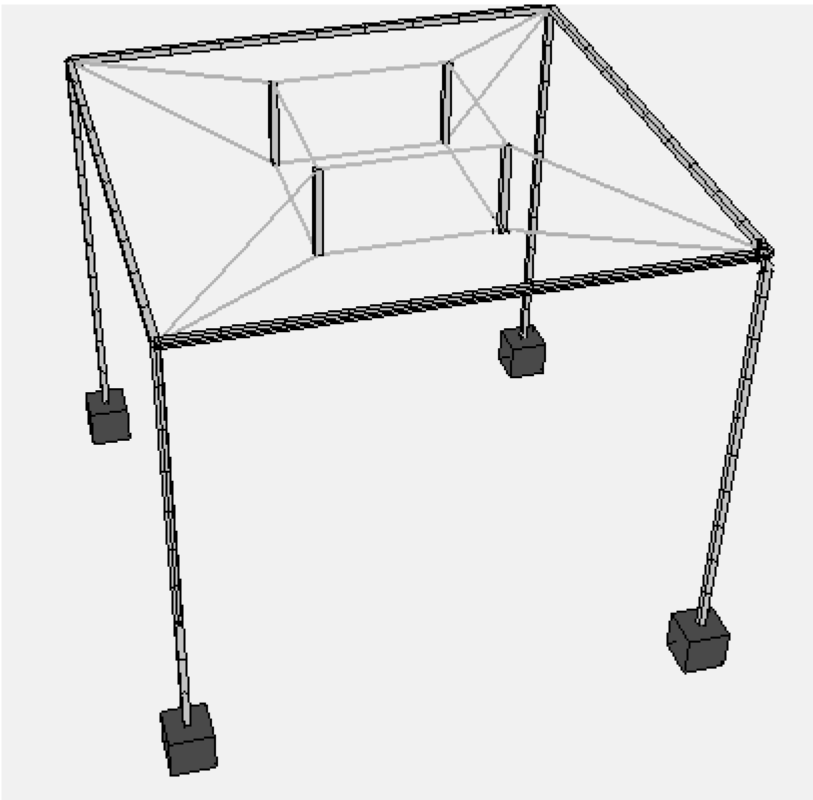

Figure 2.2: Tensegrity structure scheme

According to the UNI EN ISO 13031-1 2004 "Greenhouses: Design and construction. Technical standards for construction" and the Italian law "D.M. January 14, 2008" the structural calculations must consider the following loads on the structure: permanent loads (the weight of the structural elements and the weight of the covering transparent material), equipment loads and variable loads (wind load and snow load). The structural elements are made of steel and the

cables are of spiroid galvanized steel with nineteen wires. A polyethylene membrane has been considered as covering material.
The calculated loads for the structure are as follows:

Table 2.1: Structural weight

Permanent loads	section	Diameter (mm)	weight per meter	Length (m)
Cables	1x19 wires	10	0,50 daN/m	63.00
Bars	circular section	40	9,86 daN/m	4.00

The full analysis of the structural model is under development and will be finalised in a future paper.

3. Results and Discussion
The results of the load analysis comparing the two different structures (traditional structure, considered in steel reticular beams with 12 meters span, and the tensegrity structure) show that the overall structural weight per square meter of the tensegrity is lower than the traditional steel roofs hence, the structure offers less shading and less quantity of steel material used (Tab. 3.1).

Table 3.1: Comparison of the weight per square meter and the percentage of shading

	Weight per square meter [daN/m^2]	Percentage of shading [%]
Tensegrity	1.9	1
Traditional metallic cover*	47.9	15

**Calculated values for a cover in steel reticular beams*

A small amount of steel assumes a lower cost but in reality is necessary take into account the complexity of the technological solutions that are adopted. Another peculiarity of the traditional steel greenhouses is that the structure is completely removable.

4. Conclusion
The tensegrity structures enable to reduce the use of steel used for compressed elements; no bending stress in the covering structural components exclusively subjected to tension or compression; stabilization of the structure to the external actions through the imposition of a state of internal pretension of the cables. The use lightweight roofing materials with high durability, such as plastic films, is compatible with the characteristics of the structure. For these features, this new type of structures have the advantage of being lighter, than the traditional greenhouses structures, and have an higher resistance to exceptional weather conditions, compared to the tunnel greenhouses.

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TOPIC 2

ICT, PRECISION SYSTEMS AND NEW TECHNOLOGIES FOR LAND, FARM AND FORESTRY MANAGEMENT

Thermal imaging and EMI data fusion to delineate homogeneous management zones based on the variability of soil hydraulic properties

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Keywords: soil sensing, geophysical data, thermal imaging, data fusion, homogeneous management zone, crop yield

Summary
Mapping soil electrical conductivity (EC) through geophysical proximal soil sensors is one of the most reliable and commonly used technique to obtain quick and high resolution information about soil spatial variability. Nevertheless, spectral data collected in the visible, near-infrared and thermal infrared regions can be combined with EC data to better characterize the soil variability and to improve the delineation of homogeneous site specific management zones (SSMZs) required in precision agriculture for variable-rate irrigation and fertilization management. The recent scientific literature emphasizes the use of thermal sensors mounted on unmanned aerial vehicles to evaluate the spatial distribution of soil moisture, based on the acquisition of thermal images of bare soils. In particular, the method of soil apparent thermal inertia (ATI) can be applied for this purpose. Objective of this work is the fusion of EC and ATI data to characterize the spatial variability of soil hydraulic properties, and finally to improve SSMZs delineation. The main outcome of this study concerns the elaboration and the comparison of three SSMZs maps, the first derived from EC data, the second from ATI data, and the third from EC and ATI data fusion. The results highlight how geophysical and thermal data may provide complementary information useful to improve the delineation of SSMZs.

1. Introduction

Sensors based on electromagnetic induction (EMI) principle and visible (VIS) and near infrared (NIR) spectroscopy are used in precision agriculture to map soil properties and delineate homogeneous site-specific management zones (SSMZs) for the variable-rate application of water and nutrients. The soil electrical conductivity (EC) measured through EMI sensors depends on soil texture, soil water retention as well as on chemical properties of soils (e.g., pH, organic matter, CSC). NIR reflectance is correlated with many soil properties, including total C, total N, water content and texture (Viscarra Rossel et al, 2006) whereas the vegetation index NDVI, calculated as a combination of VIS and NIR data, is related with soil organic C (Zhang et al., 2012). The fusion of optical data acquired in VIS-NIR regions with EMI data was adopted in different studies to best characterize the soil spatial variability and to improve the delineation of SSMZs (Lopez-Lozano et al. 2010, Scudiero et al. 2013). In the last years, the use of thermal sensors mounted on unmanned aerial vehicles (UAV) has been explored to derive high-resolution maps of soil water content. In particular, the method of the apparent soil thermal inertia (ATI) was proposed (Lu et al., 2009; Minacapilli et al., 2012). Price (1985) retrieved the relationship between soil water content and ATI, calculated from the surface albedo and the maximum soil surface temperature variation calculated on a daily basis.

In this study, the ATI map was used as a proxy of the spatial distribution of soil water retention properties, due to its dependency on soil thermal properties, which in turn are linked to the soil water content. Objectives of this work are the preliminary exploration of EC and ATI maps with respect to yield maps obtained for two fields in the Lodi province (northern Italy), and the successive fusion of EC and ATI data to improve the SSMZs delineation for the two fields.

2. Materials and Methods

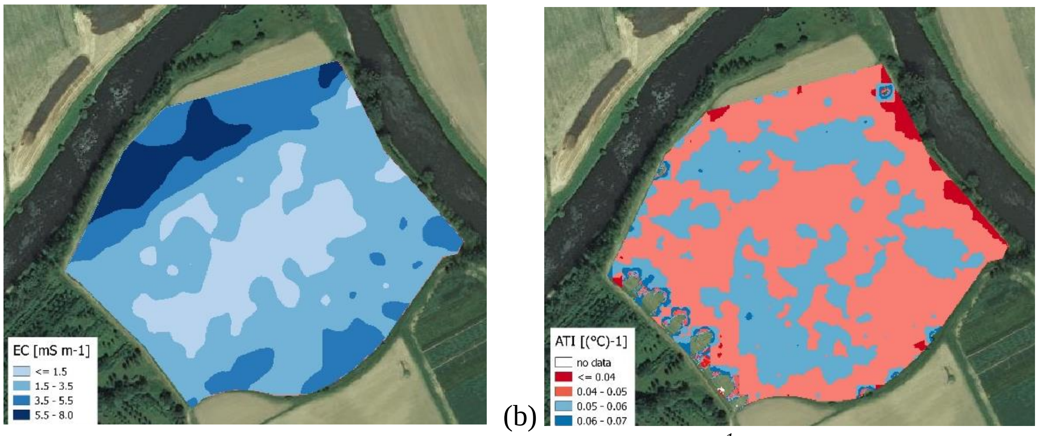
The EC and ATI data were acquired for two fields cropped with wheat and barley (almost 14 ha each) situated nearby Lodi (northern Italy), in bare conditions respectively before the seeding in January, and after the harvesting respectively at the beginning of July and September 2016. Soil texture for the two fields is sandy-loam. EMI and TIR surveys were carried out few days after the last precipitation event of a rainy period lasting for some days, when the bare soil water content was supposed to be close to the field capacity. EC measurements were acquired through the multi-frequency EMI sensor Profiler-EMP400 (Geophysical Survey Systems Inc.). ATI maps were computed on the basis of surface temperature data acquired through the thermal camera PI450 (Optris) during two UAV flights carried out in the same day at 8:00 a.m. and 2:00 p.m.. Albedo values were measured in three points within each field through the ceptometer AccuPAR LP-80 (Decagon Devices). ATI values [$°C^{-1}$] were calculated according to the equation:

$$\mathrm{ATI} = (1 - \alpha)/\Delta\mathrm{T} \tag{2.1}$$

where α [-] is the surface albedo, and ΔT [°C] is the daily maximum variation of soil surface temperature. The surface albedo α was assumed to be uniformly distributed within the fields, with the following average values: 0.15 (±0.01) and 0.16 (±0.03). Temperature values acquired from the UAV were atmospherically corrected to obtain the surface temperature values following Labbé et al. (2012) and Maes and Steppe (2012).
For each field, SSMZ maps were elaborated from EC and ATI maps, through the MZA (Management Zone Analyst) software (Fridgen et al., 2004). Afterwards, principal component analysis (PCA) was carried out to integrate EC and ATI data, in order to derive the soil fusion maps related to the main independent factors governing the soil variability. Finally, for each field, a SSMZ map was delineated from the soil fusion map through the MZA software. For each field, SSMZ maps were compared to a crop yield map obtained by a variable rate harvester.

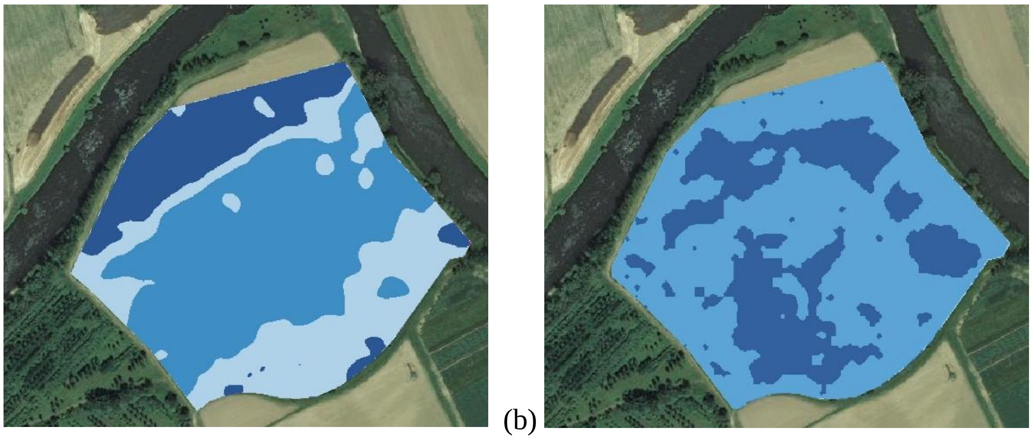
3. Results and Discussion

Due to the limited space available, only the results for the barley field are presented. Anyway, results for the wheat field are well in line with what shown for the barley field.
The Profiler-EMP400 was used with selected frequencies of 15, 10, and 5 kHz, corresponding to increasing depths of exploration. The shallow EC maps, interpolated from data acquired with frequencies 15 and 10 kHz (Figure 2.1a, for frequency 15 kHz) corresponding to depths up to almost 2 m, were considered: they were integrated by applying PCA to obtain SSMZ maps through the MZA software. Three SSMZs were in particular identified for the barley field (Figure 2.2a).
For the barley field, the crop yield map (Figure 2.3a) shows a significant variability across the three SSMZs, suggesting that SSMZ map obtained by the EMI technology may be improved. The ATI map for the barley field (Figure 2.1b) seems to allow a better (even if not complete) explanation of the yield variability (Figure 2.2b). Since EC and ATI data are both involved in the description of different aspects of the soil variability, they were integrated through PCA to obtain soil fusion maps for the two fields. In the case of the barley field, the two PCs were found to describe respectively the 53% and 47% of the total variability of EC and ATI maps, then both the PCs were considered to delineate the final SSMZ map (Figure 2.3b).



(a) (b)

Figure 2.1: Field cropped with barley: (a) EC map (mS m^{-1}) measured through EMP400 (operative frequency 15 kHz), (b) ATI map (°C^{-1}).



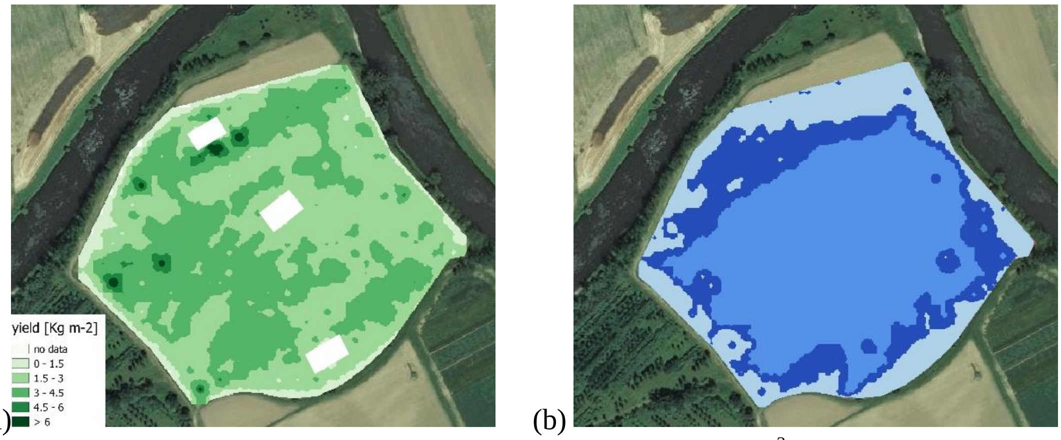
(a) (b)

Figure 2.2: SSMZ map through MZA software (Fridgen et al., 2004), field cropped with barley: (1) from EC map (3 zones), (2) from ATI map (2 zones).

The fusion of EC and ATI data allowed splitting the SSMZs delineated from the EC map in different zones in the north-eastern and south-eastern areas of the field, but not in the central-western area (Figure 2.3b).

4. Conclusion

In the case of the two experimental fields, EC data alone did not provide adequate information to describe the soil variability affecting crop yield. In such cases, ATI data were used to try to improve SSMZ maps, on the basis of their hypothesized correlation with soil properties related to the soil water retention. During the experimental campaigns, at several points within the fields soil sampling was performed for the subsequent laboratory determination of pH, C, N, C/N and AWC (available soil water content). In the following steps to study the two experimental cases, the correlation between crop yield maps, EC maps, ATI maps, and the production factors mentioned above will be further explored.



(a) (b)

Figure 2.3: Field cropped with barley: (1) crop yield map (kg m^{-2}), (2) SSMZs map obtained through MZA software from the two PCs explaining 53% and 47% of the total variability of EC and ATI maps.

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Soft path water management adaptations to climate change: the SO-WATCH project

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Keywords: Water management, Climate Change, Drought, Water scarcity, Hydrological model, Optimization

Summary
The SO-WATCH (SOft path WATer management adaptation to CHanging climate) project (Fondazione Cariplo, grant n° 2015-0220) aims to overcome the limits of traditional hard-path solutions to cope with water scarcity (e.g. large-scale infrastructures) through the development and testing of a novel decision-analytic framework to assist decision-makers in designing and assessing alternative soft-path measures (e.g. better use of information, introduction of efficient coordination mechanisms among water sectors, low-cost and reversible infrastructural interventions, smart economics). The framework is applied to the Como lake river basin, that includes a large regulated lake, an extended upstream area characterized by many hydropower plants, and a vast irrigation-fed cultivated area downstream. The project is structured into four stages: calibration and validation of physical models of the system sub-components; development of agent-based behavioural models to represent human decisions and their effects on the system; construction of hydro-climatic and socio-techno-economic scenarios; design of soft-path adaptation measures to improve the multi-sector water use under the current and projected scenarios. Some preliminary results are: (1) simulation of the main hydrological processes in the upstream catchment contributing to the lake inflows under current and future climate conditions; (2) implementation of a new spatialized agricultural drought index to provide measures of the evolution of this phenomenon to irrigation managers and farmers.

1. Introduction
Climate change and growing population are expected to severely affect freshwater availability across much of Europe by the end of 21st century. In a warmer climate, many river basins, especially in southern Europe, are likely to become more prone to periods of reduced water supply (Feyen & Dankers, 2009). The last-century dominant approach to cope with water scarcity largely relied on a hard-path, by investing in centralized, large-scale infrastructures such as dams and distribution systems, with the purpose of expanding the existing supply capacity. Nowadays, such a hard-path is becoming economically, environmentally, and socially unsustainable (Gleick, 2003), and the attention is moving toward more sustainable soft-path solutions, where the emphasis is on increased use of information, improved predictive capacity, optimal decision making and drought risk management.

2. Materials and Methods
The SO-WATCH framework is being developed for the Lake Como river basin, Italy (Figure 2.1). This basin is a heavily man-overworked water system, that includes the Lake Como, a large regulated lake with an active storage capacity of 254 Mm^3 fed by a 4552 km^2 upstream catchment, many hydropower reservoirs, with an overall capacity of 545 Mm^3, and a large irrigation-fed cultivated area of 1320 km^2, mainly cropped with maize (61% of the area, with a total productivity of 0.8 Mton/yr). Flood protection of both lake and river shores, recreational uses and environmental protection are other primary objectives to be considered in the water basin management.

The SO-WATCH project is structured in the following four stages:

1. Development and calibration of a spatially distributed, physically-based model aimed at describing the hydrological system components, by applying three main sub-models (Figure 2.1): a hydrological model of the Lake Como upstream catchment (TOPKAPI-ETH), a model of lake dynamics and routing of water released from the lake in the Adda River (DISTRILAKE; Giuliani et al. 2016), and an irrigation district model simulating the water balance in the irrigated system downstream of the lake (IDRAGRA, Gandolfi et al. 2014);
2. Coupling of the hydrological model with a detailed representation of the human decision-making behaviour (i.e. dam operations, farmers' practices), by developing multi-agent systems models (Wooldridge, 2009). These models are being developed with the participation of stakeholders (irrigation managers, framers, water institutions) to characterize their purposes and interactions;
3. Construction of hydro-climatic and socio-techno-economic scenarios, through the statistical downscaling of IPCC 5th assessment scenarios (Anghileri et al. 2011), assessment of their effects on water-related activities within the catchment, and identification of the sources of vulnerability (Culley et al. 2016);
4. Identification of soft-path adoption measures to robustly improve the overall productivity (efficiency) of the multi-sector water use system. Candidate actions will be identified in collaboration with stakeholders, and derived from previous studies, to develop and assess a comprehensive set of adaptation measures. These measures must be easily implementable and economically sustainable.

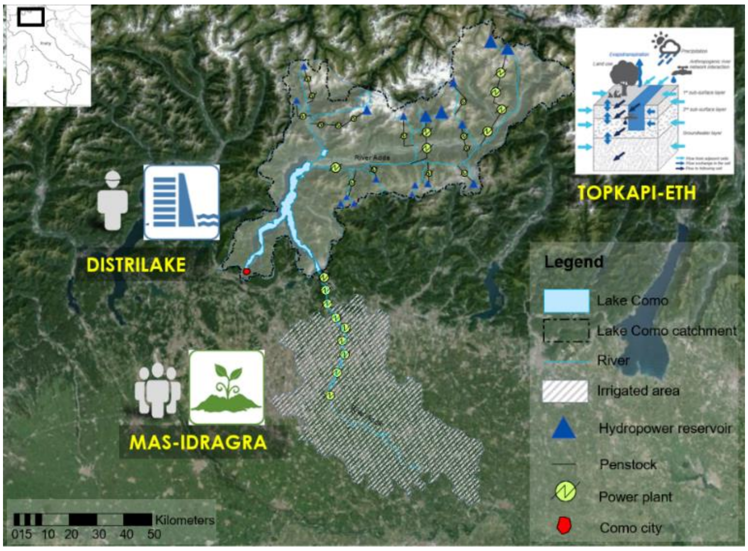

Figure 2.1: Overview of the SoWatch study area and of the model sub-system components

3. Results and Discussion

The preliminary assessment of the climate change scenarios focuses on 28 alternative scenarios, defined as combinations of different Radiative Concentration Pathways, Global, and Regional Circulation Models (Giuliani & Castelletti, 2016). The projected time series of temperature and precipitation are obtained from the application of a cascade of models: the RCPs' scenarios C (IPCC 2014) are used as input to a general circulation model (GCM), which provides the boundary conditions for a regional circulation model (RCM). Since the spatial resolution of the RCMs is too rough to provide representative climatic scenarios at the basin scale, a statistical downscaling method based on quantile mapping is applied to correct RCM outputs. The data used for the downscaling were obtained from the EURO-CORDEX project (www.euro-cordex.net). The downscaled trajectories of precipitation and temperature are then used as inputs to generate the projected Lake Como inflow for the time period 2096-2100. A HBV hydrology model was used to simulate the soil water balance and subsequent runoff produced by rainfall, snowmelt, and evapotranspiration. Successively, the TOPKAPI-ETH model (under construction) will allow to refine the simulation of these hydrological processes. The resulting ensemble of inflow's trajectories is represented in Figure 3.1 as the daily inflow anomalies under the different scenarios with respect to the historical cyclostationary daily mean of the lake inflow over the period 1946-2011. All the scenarios suggest a general reduction of the water available in spring and summer, potentially exhacerbating the conflict between water users in the system.

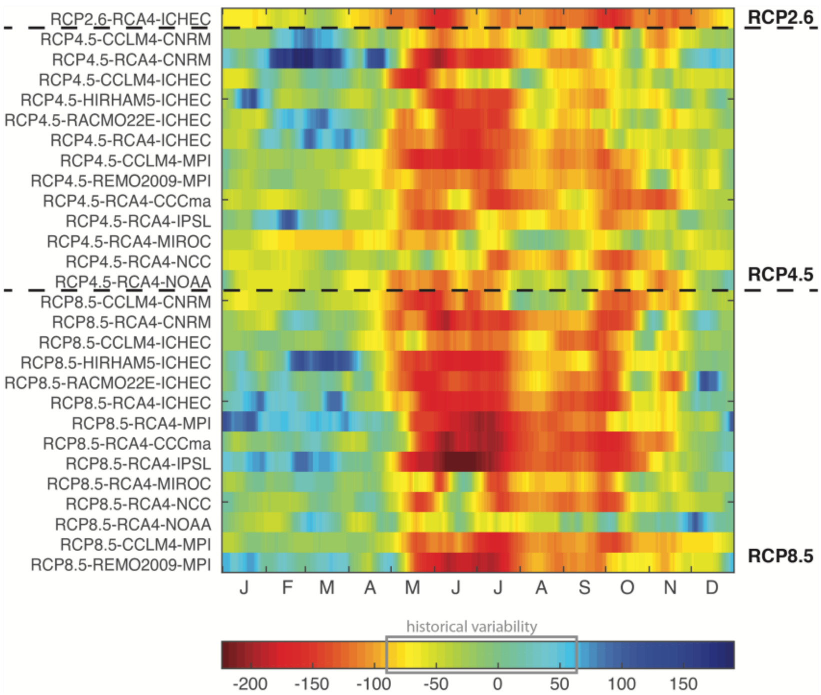

Figure 3.1: Lake Como inflow daily anomalies with respect to historical mean under the different climate scenarios over the period 2096-2100.

The newely developed Transpiration Deficit Index (D-TDI) was applied to a pilot study area to assess agricultural response to meteorological drought in the current scenario (Borghi 2017). The index is based on transforming the interannual distribution of the transpiration deficit (i.e. the difference between potential and actual transpiration) over a time lapse (e.g. 10-day period) to a standard normal distribution; D-TDI is therefore expressed in standard deviations from the long-term mean of the considered time lapse. Results can be used to map (or forecast) drought prone areas, to improve the ability of farmers and irrigation district managers to cope with agricultural droughts and set up adaptation actions. An example of the maps obtained are reported in Figure 3.2.

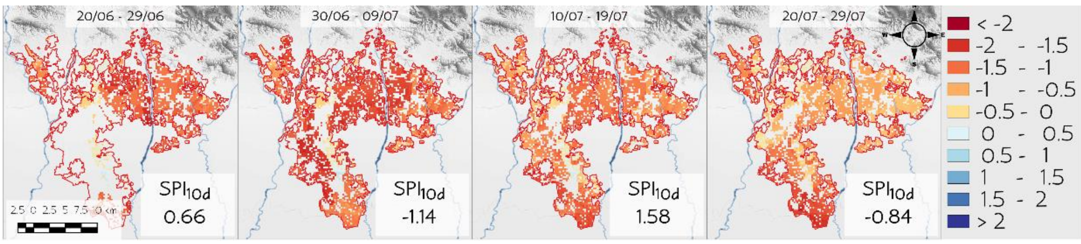

Figure 3.2: 10-days D-TDI maps calculated for the Media Pianura Bergamasca irrigation district (a 210 km^2 area within the study catchment downstream of the Como lake) for the year 2011

4. Conclusion

The SO-WATCH project aims to identify robust adaption strategies for the water management at the river basin scale, in order to cope with climate change. Measures are selected with the direct involvement of stakeholders (i.e. hydropower utilities, lake operator, irrigation district managers, farmers). As a future outcome, the SO-WATCH framework will constitute an example of application of a multilateral and multidisciplinary approach to a real world case study, that could be applied to other areas affected by the co-existence of multiple water uses and potential conflicts.

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Harvesting yield and material other than olives from mechanical harvesting of some Tuscan varieties

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Keywords: mechanical harvesting, olive, harvesting yield, crop purity

Summary
Some olive Tuscan varieties (Frantoio, Moraiolo, Leccio del Corno and Pendolino) have been investigated for the efficiency of the mechanical harvesting (HY) by a hydraulic eccentric-mass trunk shaker. Further, the crop purity in terms of amount of material other than olives (MOO) has been assessed and compared, along with the drupes detachment force (DF) and the correspondent average mass (OM). HY significantly differs between varieties, as well as the DF and OM. The HY seems to be not strictly related the overall DF and/or the OM. A significant linear relationship was recorded between the HY and the ratio between DF and olive mass (Acc). Finally, significant differences have been found in the amount of MOO, which ranges from about 2% of Pendolino to about 9% of Moraiolo.

1. Introduction
In intensive olive groves mechanical harvesting is an essential practice in order to decrease production costs (IOOC, 2015). The most used machines are trunk shakers, which proper working strictly depends on tree and fruit characteristics. Being equal all the other conditions, the genetic factor, i.e. the variety factor, could be crucial to reach the target of a convenient mechanization of the harvesting operation. In the present work some olive Tuscan varieties have been investigated for the efficiency of the mechanical harvesting (HY). Further, the crop purity in terms of amount of material other than olives (MOO) has been assessed and compared.

2. Materials and Methods
Four Tuscan olive varieties, namely Frantoio, Moraiolo, Leccio del Corno and Pendolino, have been investigated. Olive grove (5 x 7 m planting distance, N-S row orientation) was located in a rain fed area of Tuscany, Central Italy (Figure 2.1, left) (https://www.google.it/maps/@43.8397689,11.3862531,231m/data=!3m1!1e3!4m2!7m1!2e1?hl=it). Plants had quite the same average traits, from 20 to 25 cm diameter at the base of the trunk, about 4.5 m high and about 4 m diameter of crown extension, trained to open vase system by a two-years pruning turn, subjected to the conventional cultivation care applied in the area. Three 25-years old trees of each variety were randomly selected from the same olive orchard and treated as plant replicates. Harvesting was performed by means of a hydraulic eccentric-mass trunk shaker (model TORNADO-P75, Berardinucci srl, Italy) by clamping the trunk at 50 cm from ground and applying a vibration time of 20s. For each plant, the following parameters were recorded: harvested olives; non-harvested olives; amount of material other than olives, i.e. leafs and debris, (MOO). Moreover, for each plant 100 olives were manually picked by measuring the detachment force (DF) and the correspondent average mass (OM). The ratio between these latter parameters gives a detachment index (Acc). Harvest yield (HY) was computed as the ratio between the amount of harvested olives and total olives production. MOO was expressed as mass fraction of the harvested olives. Recorded data were analyzed by one-way ANOVA (Tukey's HSD post-hoc-test), Pearson linear correlation and LS linear regression.

Figure 2.1: The olive grove (left) and the trunk shaker (right)

3. Results and Discussion

Harvest yield (HY) significantly differs (by one-way ANOVA and Tukey's HSD test) between varieties, ranging from about 54% of Moraiolo to about 76% of Frantoio. Varieties also showed significant differences in the DF and consistently with the HY result, Moraiolo showed the highest value (about 6.4 N).

*Table 3.1: Effect of olive variety on some harvesting parameters**

	Variety			
Parameter	Frantoio	Leccio del Corno	Moraiolo	Pendolino
HY (%)	76(6)a	67(1)ab	54(7)b	70(3)a
DF (N)	5.37(0.17)b	4.11(0.12)c	6.45(0.39)a	5.67(0.09)b
OM (g)	183.92(3.64)a	150.15(9.31)bc	140.14(7.18)c	160.74(4.7)b
a (ms^{-2})	2921.36(66.74)c	2746.62(139.77)c	4604.58(144.98)a	3528.07(44.05)b
MOO (%)	5.18(0.66)b	4.76(0.36)b	8.68(0.7)a	1.99(1.24)c

*Values are mean of three independent replicates; standard deviations are reported in brackets; within each row, different letters indicate significant difference among varieties according to Tukey HSD post-hoc test ($p<0.05$)

The same holds for the average mass of 100-olive (OM), where Moraiolo showed the lowest value (about 140g) against Frantoio with the highest value (about 180g). Only poor and not significant correlations have been found between the considered parameters when computed on the entire dataset, i.e. regardless the varieties factor, so that the HY seems to be not strictly related to the overall DF and/or the average mass of 100-olive (Tab. 3.1). Nevertheless, a significant linear and inverse relationship was recorded between the HY and the ratio between DF and olive mass (Acc, Table 3.1 and Figure 3.1), that it might be thought as the average acceleration threshold to provide olives detachment. This agrees with findings of other authors, which indicate Acc as the main index that characterizes the olive mechanical harvesting. Also, a theoretical threshold of 2000 ms^{-2} was generally accepted to achieve the maximum harvesting yield by shakers, while this value rises to 2500-2700 ms^{-2} for continuous harvesters. This range of Acc is consistent with the present study, where the maximum HY was achieved in correspondence of Acc between 2800 and 3000 ms^{-2} (HY greater than 82% had not reached).

Table 3.1: Pearson Correlation Matrix on the harvesting parameters

	DF	HY	OM	Acc	MOO
DF	1				
HY	-0.505	1			
OM	-0.101	0.684	1		
Acc	0.862*	-0.756*	-0.587	1	
MOO	0.383	-0.592	-0.407	0.564	1

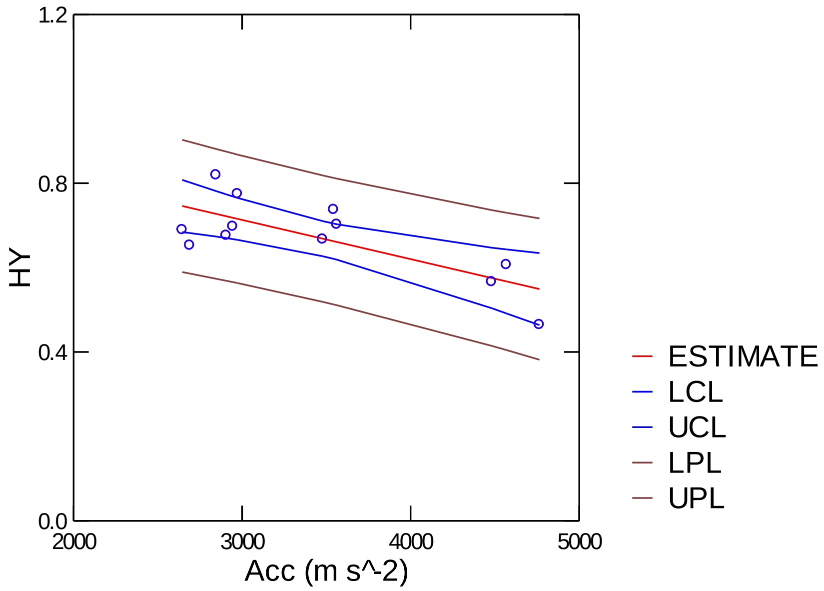

Figure 3.1:Estimated LS linear regression between the detachment index (Acc) and the harvesting yield (HY)

Finally, significant differences have been found in the amount of MOO, which ranges from about 2% of Pendolino to about 9% of Moraiolo.

4. Conclusion

The study showed that harvesting efficiency depends on olive variety. The goodness of the detachment index to relate with harvesting yield has been confirmed. The purity of the crop has been estimated in the range of 2-9%. This parameter seems to be uncorrelated to other harvesting parameters, but rather it depends on olive variety.

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Liner overpressure and teat dimensions: preliminary results of a field study

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Keywords: liner overpressure, teat dimension, mouthpiece chamber depth

Summary

The primary objective of this study was to measure the overpressure (OP) of a liner and assess the relationship between OP and teat dimensions (length and diameter) using a new test device designed to make faster and more accurate OP measurements. The secondary objective was to evaluate the relationship between mouthpiece chamber (MPC) depth and teat-barrel congestion in dairy cows.

OP was measured at 1 min and 3 min after the cluster attachment. Teat length and diameter were measured before milking. Teat-barrel congestion was assessed by observing changes in the color of teat skin within 1 min of milking unit removal.

The OP value at 1 min after the cluster attachment was 9.7 kPa and a significantly decrease of about 2.7 kPa in OP values were recorded at 1 and 3 min from the beginning of the milking. A positive significant correlation was found between teat lengths and OP values and between teat-barrel diameter and OP values measured at 1 min after the milking unit attachment, but not at 3 min of milking. About 80 % of teats were reddened (congested) or tinged with blue (cyanotic).

These results suggest the opportunity to perform OP measurement at a standard time after the cluster attachment to make the measurement values comparable and highlight the importance of a good fit between liner and teat.

1. Introduction

Overpressure (OP) is defined as the pressure difference across the liner at which milk flow just starts or stops. OP has been proposed as a robust and practical method, which uses live teats in near milking conditions, to estimate the relative value of liner compression (LC) across liners (Reinemann, 2012; Mein et al., 2013). Mein et al. (2003) defined LC as the compressive pressure applied by a liner to the teat apex during the late c-, d-, or early a-phases of a pulsation cycle. The LC reaches its maximum value during the d-phase of pulsation cycle and it influences the peak milking speed and the occurrence of teat-end hyperkeratosis, as observed by Zucali et al. (2008) and Bade et al. (2009). The LC depends on: pressure difference applied across the collapsed liner in the d-phase of pulsation; physical dimension, material properties and mounting tension of the liner; teat dimensions and liner teat fit (Reinemann, 2012).

A test methodology for OP measurement was originally developed by Mein et al. (2003). This method provided for removing the short pulse tube from one teat cup and increasing the vacuum in the pulsation chamber, by using a hand vacuum pump, until milk flow was observed. More recently, Gomez (2010) developed a new method for measuring dynamically OP. In this case, the pulsator remained active and the vacuum in the pulsation chamber was increased in steps of 2 kPa until the milk flow was observed. Even if this method was more rapid compared to that one proposed by Mein et al. (2013) it required modification of the milking machine.

The primary objective of the present study was to measure the OP of a liner and assess the relationship between OP and teat dimensions (length and diameter) using a new test device that did not require any modification of the milking machine. The secondary objective was to assess the relationship between mouthpiece chamber (MPC) depth and teat-barrel congestion in dairy cows.

2. Materials and Methods

Tests were performed at a commercial dairy farm of Northern Italy (Lombardy) with 94 lactating cows (lactation: 1 to 5; average days in milk: 224) milked in a 8+8 parallel milking parlour with low-level milk line, with system vacuum level of 42 kPa, 60 pulsations/min rate, and 60 % pulsation ratio.

A commercial nitrile rubber round liner with the following main characteristics was tested: MPC depth, 43 mm; Mouthpiece diameter, 20 mm; Mid-barrel diameter, 22.5 mm; Touch point pressure difference, 11 kPa. Fifteen dairy cows (Holstein-Friesian) were randomly selected from the herd. The 15 cows were distributed across early, mid-, and late lactation (11–311 days in milk) with a parity range of 1–5, and an average milk yield of 15.4 ± 3.9 kg/cow per milking. The OP was measured in increments of 0.1 kPa for one teat on each cow at 1 min and 3 min after the cluster attachment, using an innovative test device, called OP Bucket (OPB), designed and built by Milkline s.r.l. (Podenzano, Italy) in collaboration with the Università degli Studi di Milano. This device, similar to that one used by Leonardi et al. (2015), allowed to measure the pulsation chamber vacuum at which milk flow starts on each individual teats. The OPB consisted of a 30-liters milking bucket equipped with: a digital vacuum sensor; a battery-powered pulsator; a needle valve to gradually increase the vacuum level in the bucket; valves to connect the bucket to the vacuum source and atmospheric air (Figure 2.1).

The measurement of teat length and teat-barrel diameter, and the evaluation of teat-barrel congestion involved the entire herd. Teat length and teat-barrel diameter were measured before milking. Teat-barrel congestion was assessed by observing changes in the color of teat skin (pink, red, and blue) within 1 min of cluster removal. Black teats were excluded from the color-based evaluation.

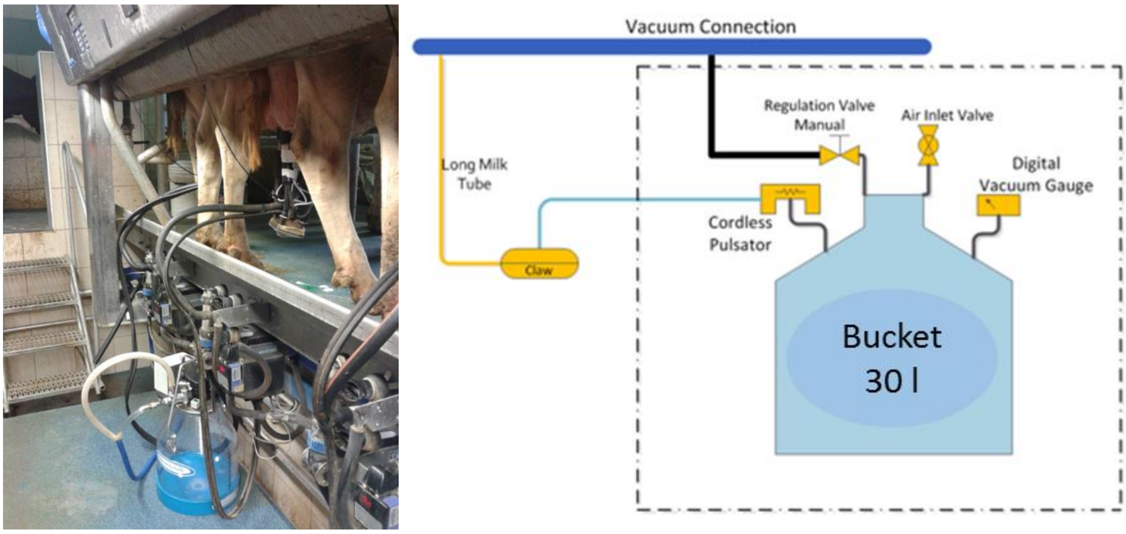

Figure 2.1: On the left, the OP Bucket (OPB) used to measure the liner overpressure during the experimental trial; on the right, layout of the OPB and its connections to the milking machine.

3. Results and Discussion

The 15 cows had pre-milking teat length between 35 and 60 mm and teat base diameter between 14 and 26 mm. The OP value at 1 min after the cluster attachment was 9.7 ± 2.0 kPa. A significantly decrease (*$P < 0.01$*) of about 2.7 kPa in OP values were recorded at 1 and 3 min from the beginning of the milking. Similar OP values decreasing over the time were found by Leonardi et al. (2015). Additionally, a positive significant correlation *($P < 0.05$)* was found between teat lengths and OP values and between teat-barrel diameter and OP values measured at 1 min after the milking unit attachment, but not at 3 min of milking (Figure 3.1). Changes in OP during the progression of a single milking could due to subtle variation in the position of the teat within the liner, small changes in teat sinus pressure, or a slight relaxation of teat end musculature.

As previously observed by Leonardi et al. (2015), these results highlights the importance to perform OP measurements at a consistent time in order to make the measurements values repeatable and comparable. Mein et al. (2003) suggested a standard time of 1 min after the cluster attachment to avoid the effects of the teat penetration into the liner on the OP values and to reduce the variability by OP changing during the peak flow period.

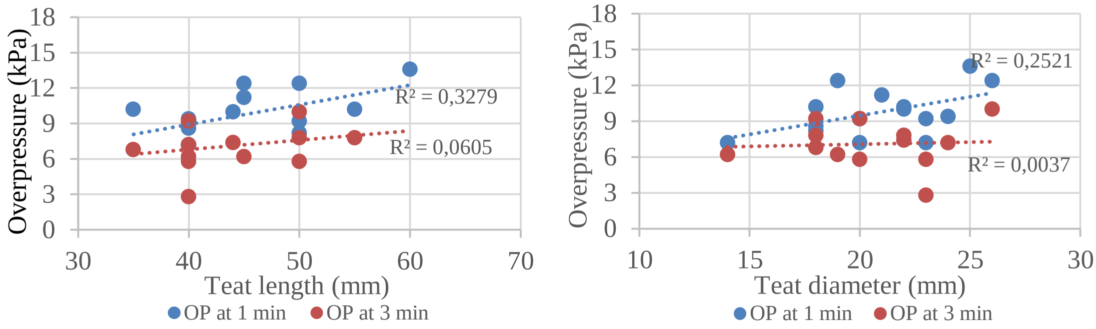

Figure 3.1: Relation between overpressure, recorded at 1 and 3 min from the beginning of the milking, and teat length (on the left) and teat diameter (on the right).

Of the 376 teats of the herd, 60 were excluded from the color-based evaluation because they were black. The remaining 316 teats had an average pre-milking length and diameter respectively of 45 ± 0.7 mm and 21 ± 0.3 mm. About 80 % of teats were reddened (congested) or tinged with blue (cyanotic). Teat-barrel congestion is associated with increased MPC vacuum, which is in turn affected by teat dimensions relative to liner dimensions. Poor fit between the liner wall and teat barrel or around the mouthpiece opening increases MPC vacuum (Gomez et al., 2011; Ronningen and Postma, 2012; Reinemann et al., 2013).

4. Conclusion

A significantly decrease in OP values were recorded at 1 and 3 min after the milking unit attachment and a positive significant correlation was found between teat dimensions (length and diameter) and OP values measured at 1 min from the beginning of the milking, but not at 3 min of milking. This suggests the opportunity to perform OP measurement at a standard time after the cluster attachment to make the measurement values repeatable and comparable.

Teat-barrel congestion occurred on about 80 % of teats suggesting extreme values of MPC vacuum, likely due to a poor fit between liner and teat.

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Performance evaluation of a capacitive mass flow sensor for paddy conveyor transferring

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Keywords: Capacitive sensor, Frequency, Mass flow, Paddy.

Summary
The aim of this study was to investigate the effect of input voltage frequency, mass flow rate and velocity of product on the performance of a developed paddy mass flow capacitive sensor. The paddy variety of Ghaem has been used as dielectric material between the plates of the capacitor. The treatments were mass flow rates (0.8-2.4 kg/s), frequencies (100-700 kHz) and conveyor velocities (0.5-1 m/s). An experimental setup was developed and equipped to measuring system. Results showed that the effect of mass flow rate, input voltage frequency and their interactions had significant effect on the sensor capacity ($p \leq 0.01$). The product velocity had no significant effect on the sensor performance. The input voltage frequency had an inverse effect on the capacity of sensor. By comparing relationship between capacities of mass flow sensor at different levels of frequency, it was observed a relatively high accuracy relationship between paddy mass flow rate and capacity of sensor. The best frequency range to measure the mass flow of paddy was 300 kHz. Results of this research can be effective on the design of an online system to measure the mass flow rate of paddy in harvesting, storing and processing systems.

1. Introduction
The first stage and most advanced process in precision agriculture is the real time yield monitoring by the use of sensors. Various methods have been introduced for the real time measurement of crop yield and some of them have become commercially available. These methods include; auger flow sensor (Wanger and Schrock, 1989), ultrasonic sensors (Klemme et al., 1992), impact force sensors (Borgelt, 1993), x-ray sensors (Arslan et al., 2000). But most of these sensors either have detrimental effects on crop texture, or have no chance of widespread commercial use because of their complexity and high cost (Taghinejad et al., 2012a). So finding a non-destructive, cheap and simple method is necessary.
The purpose of this study was to assess the effect of frequency of sensor inputs voltage and the product transferring velocity on the performance of mass flow sensor. Experiments were conducted using the paddy variety of Ghaem during continuous and real time measurement of mass flow of paddy through capacitive sensor.

2. Materials and Methods
A test rig was developed and equipped with measuring system (Figure 1). Two aluminum plates with a thickness of 2 mm and dimensions of 800×100 mm were used as sensor. For preventing contact with the other parts, two nylon profiles with a length of 250 mm and width and thickness of 20 mm, were placed 300 mm away on the two sides of the conveyor with a length of 2000 mm. To make the conveyer belt move, an electromotor with 0.5 HP and 1200 rpm was used. The velocity was initially reduced down by one quarter with the use of a gear and chain, then using an inverter, the desired rpm was set by changing the frequency.

Figure 1.1: Experimental rig of mass flow rate measuring system

The test material was supplied from Genetics and Agricultural Biotechnology Institute of Tabarestan, Sari, Iran. The variations in the sensor output capacity were measured in the five mass levels of 0.8, 1.2, 1.6, 2 and 2.4 kg/s, four frequencies of 100, 300, 500 and 700 kHz and three levels of linear velocities of 0.5, 0.75 and 1 m s^{-1} in three iterations and then using equation 1, the capacitive sensor output voltage was changed to sensor capacity.

$$C = \frac{1}{2\pi R.f}\frac{V_o}{\sqrt[2]{V_i^2 - V_o^2}} \qquad (1)$$

In this equation, C is the capacitance (F), R is resistance (Ω), f is the input voltage frequency (Hz), V_o is the input voltage (V) and V_i is output voltage (V) (Soltani et al, 2011).

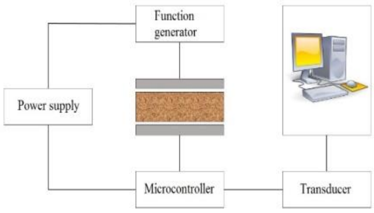

Figure 2.2: Simple schematics of measuring system

3. Results and Discussion

The results of the variance analysis showed that only the effect of mass flow rate, input voltage frequency and their interactions have a significant effect on the sensor capacity at the 1% probability level (Table 1.1).

Table 1.1:Analysis of variance related to the effect of investigated Factors on sensor capacity

Source of variations	df	Mean square	F
Mass flow rate (M)	4	308.786	1430.93^{**}
Frequency (F)	3	1203.576	5577.44^{**}
M × F	12	16.701	77.39^{**}
Velocity (V)	2	0.072	0.33^{ns}
M × V	8	0.044	0.20^{ns}
F× V	6	0.044	0.20^{ns}
M × F× V	24	0.033	0.15^{ns}
Error	120	0.216	
C.V		5.32	

** and ns respectively, are significant at 1% and non-significant

Figure 3.1 shows that although the sensor capacity has a relatively increasing trend with the increase in the flow rate of the mass flow of the paddy, but this increase is not uniform. Similar results have been reported in studies by Kumhala et al. (2009) on potatoes and sugar beet, Taghinezhad et al. (2012a,b) on sugarcane, and banana.

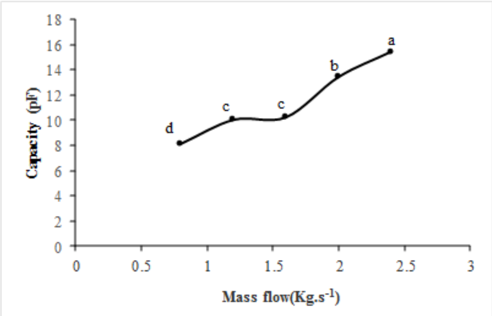

Figure 3.1: The relationship between mass flow and capacity of sensor

The mean comparison results in Figure 3.2 showed that the sensor capacity constant significantly decreases with the increase in frequency of input voltage from 100 kHz to 500 kHz. Increasing the frequency reduces the dielectric polarization and it resulted in capacity decrease. However, with the increase in the frequency to higher levels (500 kHz to 700 kHz), the rate decreases but no significant changes in capacity was observed.

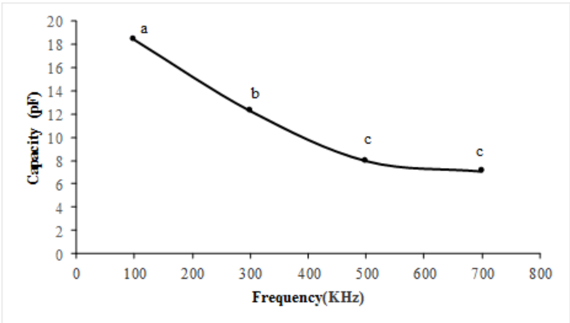

Figure 3.2: The relationship between frequency and capacity of sensor

According to Figure 3.3 and based on the results of mean comparisons in all the frequencies, by increasing in the rate of the passing paddy mass flow, the capacity level increases with an approximately uniform rhythm. However, the rate of the changes varies in different frequencies.

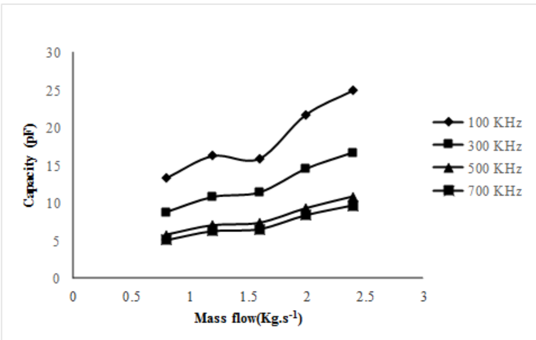

Figure 3.3: The relationship between mass flow and capacity of sensor at different frequencies

Table 3.1 shows the fitting data obtained in this research as a linear relationship between the capacitance with paddy mass flow in different frequencies.

Table 3.1: The summarized relationship between mass flow and capacity of sensor on different frequencies

Frequency(kHz)	Equation	R^2	RMSE
100	C = 7.1832Q + 6.8919	0.883	9.07
300	C = 4.8864Q + 4.5189	0.954	6.18
500	C = 3.1195Q + 2.966	0.944	3.95
700	C = 2.809Q + 2.5787	0.945	3.55

C= Capacity and Q= Mass flow

4. Conclusion

The results of this study showed that the velocity of the product does not have much effect on the sensor performance. But, the frequency of the input voltage had a direct effect on the capacitive sensor of mass flow. Conducting this type of researches can be effective on the design of an online system to measure the mass flow of paddy in the course of harvesting, storing and processing.

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Design and development of a low cost device for the automatic estimation of Body Condition Score (BCS) on dairy cattle

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Keywords: Body Condition Score, Precision Livestock, 3D camera, Microsoft Kinect

Summary
As it is known, the analysis of the Body Condition Score index (BCS) is considered one of the most diffused monitoring system to support farm management in dairy farms. Briefly, the BCS index analysis is a visual methodology - carried out by specialist personnel - to evaluate the metabolisable energy stored in animal in the form of adipose and muscle tissue in different periods of lactation.
With this index, the farmer can suitably modify the feeding of the single animal to optimize, ultimately, its milk production according to the Precision Livestock approach.
The objective of the present work is to design and to develop a device for the automatic evaluation of the BCS based on a low cost 3D camera (Microsoft Kinect) and digital image analysis. The device is implemented in a monitoring system positioned directly in the barn.

1. Introduction
"Precision Livestock Farming" (PLF) can be defined as the application of engineering technologies and methodologies for: monitoring, developing models and managing the production/reproduction, the welfare and the health of the animal (Wathes et al., 2001).
From the methodological point of view, for to reach this goal the logic of "closed loop system" is usually applied. This approach requires the implementation of systems for the automatic management of the process, aimed at fulfilment of one or more specific targets (Bolton, 2011; Aerts et al., 2000; Aerts et al., 2003; Berckmans, 2004).
The electronic monitoring of the herd becomes then a central role in the PLF logic that, borrowing and adapting the classic definition of Precision Farming, can be stated as: *an integrated system that uses modern technologies to collect data from multiple sources in view of their subsequent use under decisions regarding the productive, reproductive and health activities of farms (Wathes et al., 2001; Berckmans, 2004; Lazzari et al., 2011).*
Nowadays, the analysis of the Body Condition Score index (BCS) is considered one of the most diffused monitoring system to support the farm management in dairy farms. Briefly, the BCS index analysis is a visual methodology - carried out by specialist personnel - to evaluate the energy stored in an animal as adipose and muscle tissue in different periods of lactation. For every dairy cow, considering nine specific anatomic parts, a score is calculated according to the Edmonson scale (1989). The score ranges from 1 to 5, where low values indicate an underweight dairy cow, a value of about 3-3.5 corresponds to an healthy animal, whilst values above 4 indicate an overweight cow. In this way, the farmer can suitably modify the feeding of the single animal to optimize, ultimately, its milk production according to the Precision Livestock approach.
The objective of the present work is to design and to develop a device for the automatic evaluation of the BCS based on a low cost 3D camera and digital image analysis. The device is implemented in a monitoring system positioned directly in the barn.

2. Materials and Methods
The sensor used is the Microsoft Kinect, a low cost peripheral device developed for the XBOX 360 home videogame console. This sensor includes a RGB camera (with resolution of

1920x1080 pixels) and an infrared depth camera (resolution of 512x424 pixels). Our idea is to use the Microsoft Kinect as a depth sensor to estimate the BCS index, starting from a 3D image of the dairy cow acquired directly in the barn. The process splits in two steps: i) the image acquisition of the animal through the sensor and the conversion in a depth image, and ii) the identification, on the digital depth image of the animal, of specific points of shape transect (corresponding to the anatomic parts considered by the Edmonson scale) from which automatically extrapolate the BCS index through tracking algorithms especially designed.
The Kinect sensor, similarly to others optical devices, is characterized by a minimum distance of measure which corresponds to the correct focus of the digital image. The determination of such distance (in this specific case the distance between the Kinect sensor and the monitored dairy cow) is necessary to obtain digital images with the correct colour depth in order to elaborate, through the creation of a Disparity Map, the depth image of the cow from which the transects, essential for the BCS evaluation, are subsequently determined.
To do this, at the Image Analysis Lab of Department of Agricultural and Environmental Sciences, a number of tests have been carried out acquiring depth images with the Kinect sensor positioned at increasing distance from an artificial outline, which simulated the cow's body. This in order to identify the minimum eligible distance sensor-dairy cow allowing the correct focus. The elaboration of the digital images acquired, carried out with Matlab software, allowed us to identify this minimum distance, which correspond depth images whit adequate color depth such as to permit the correct reconstruction of the three-dimensional shape of the cow.
This minimum distance was found to be 90 cm. Figure 2.1 shows two digital images (A and B), both referred to the artificial outline simulating a normal value of BCS, and acquired at different focus distance (60 and 90 cm respectively).

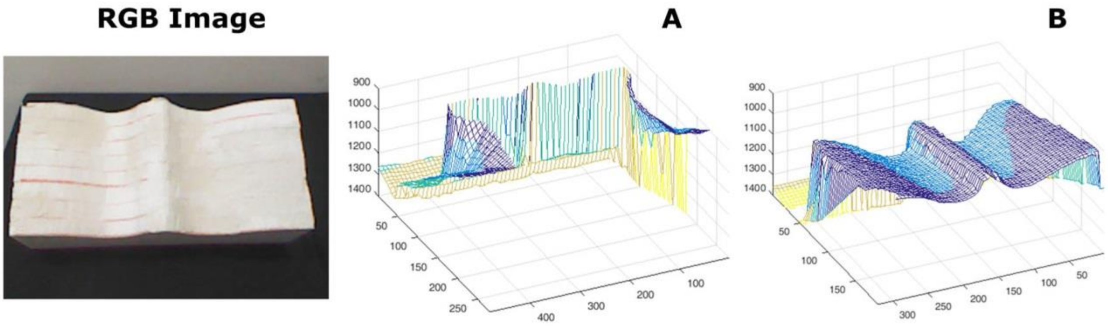

Figure 2.1: Example of digital images acquired with Kinect sensor at distance of 60 and 90 cm respectively.

It is noted that, at distance equal to 60 cm, the sensor tends to saturate the image, whilst at 90 cm, the 3D reconstruction is perfect.
In order to evaluate the proper functioning of Kinect sensors in field conditions, a number of depth image of dairy cows has been acquired. Tests, carried out at the farm of University of Milan, involved 20 lactating cows of different breeds (Fresian and Italian Red Pied) with different body fat reserves (and, therefore, different values of BCS).
For each cow, through Kinect sensor, two depth images has been acquired: one image relating to the rear part (pelvis and insertion of the tail), and the other image relating to the left side of the cow (more significant for the BCS estimation, compared to the right side, because there is not the swelling due to the rumen). Contextually to the images acquisition a BCS estimation, according to the visual methodology proposed by Edmonson et al. (1989), has been carried out by specialist personnel.

3. Results and Discussion

The obtained results are extremely encouraging: the digital images acquired through the Kinect sensor had the adequate colour depth such as to permit the obtaining of very clear transects (and

therefore with very limited blind spots) and, above all, significantly different depending on the shape of the monitored animal. Hereafter, as example, results related to the monitoring of a dairy cow with low value of BCS (2,5) are reported.
Figure 3.1 shows, in order:

1. the RGB image – acquired through Kinect sensor - of the dairy cow;
2. the 3D image elaborated starting from the depth image of the cow's rear part;
3. the depth image;
4. the corresponding transects obtained according to the section planes suggested by the Edmonson et al. (1989) metodology.

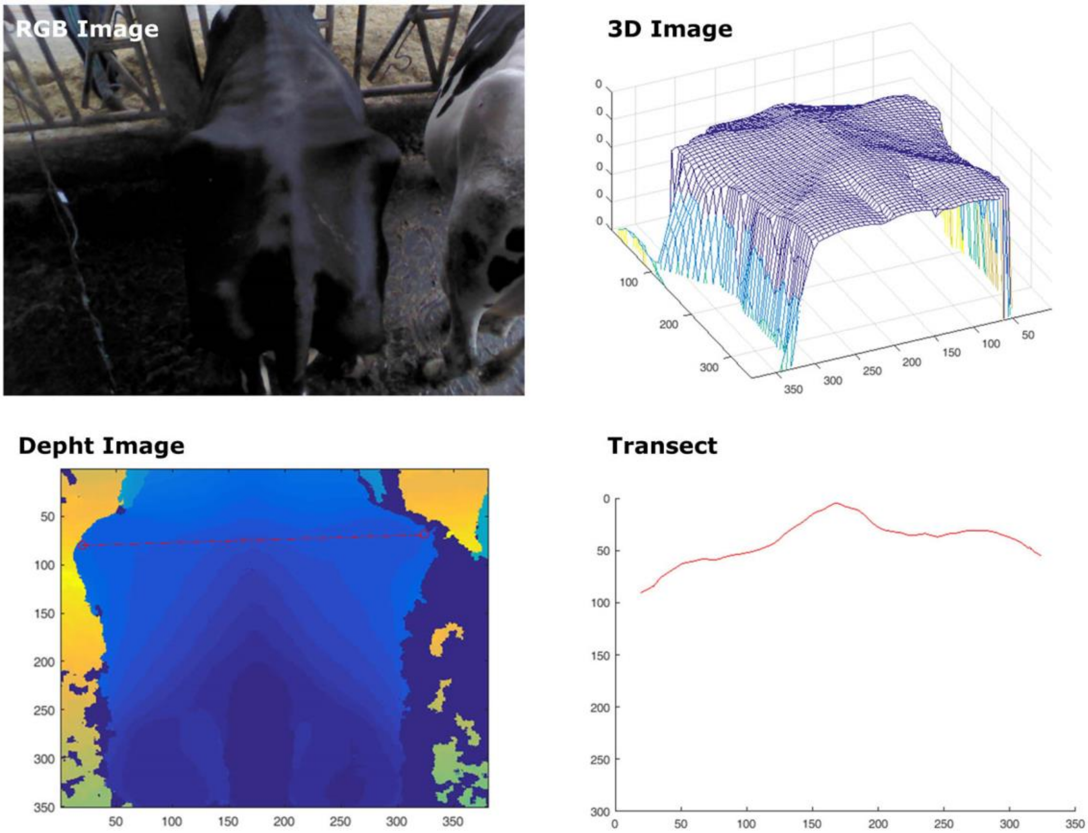

Figure 3.1: Example of digital images acquired through Kinect sensor and subsequent elaborations.

The 3D image is very interesting: the Kinect sensor was able to correctly model the cow's body shape, highlighting quite well the sharpness of the monitored animal.
Figure 3.1 shows also the depth image and the transect obtained according to one of the vertical section plane suggested by Edmonson et al. (1989). The transect was representative of the morphological condition of the monitored cow, and strongly correlated with the BCS value esimated by specialist personnel.

4. Conclusion

Laboratory tests, necessary to characterize the Kinect sensor, and field tests carried out in the barn on a selected number of dairy cattle demonstrated that the low cost sensor and the developed image analysis are capable to correctly reconstruct the cow' shape with high precision. Furthermore, the identification of the specific anatomic parts of the animal, selected according to Edmonson scale, allowed us to correlate every digital section with the corresponding BCS value. In this way, it is possible to monitor the herd during time providing useful and traceable information for the farmer about the energetic metabolism of every single dairy cow.

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Features extraction from vineyard 3D dense point-cloud model for precision viticulture

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Keywords: 3D point cloud, DSM, Precision viticulture

Summary
Precision agriculture relies on a reliable knowledge of the vineyards in terms of identification, quantification and response to the crop intrinsic variability. Objective of the presented work is the further exploitation of UAV imagery information potential, beyond the well-established bi-dimensional mapping, by the vineyard features extraction from 3D dense point-cloud modelling, computed by modern photogrammetry tools. In this work, a 3D point-cloud processing methodology to evaluate a set of relevant vineyard features is presented. More in detail, the detection of points representing vine canopies and the evaluation of vine height have been performed on a sample portion of a 3D dense point-cloud model of a vineyard. The classification process is performed computing a local neighbourhood soil approximation, which allows to define a criterion to discriminate among vine canopy and alien/terrain points, while the vine features extraction is performed projecting the selected points cloud to a plane, obtaining a binary digital image, and implementing ad hoc image-processing algorithm.

1. Introduction
Precision agriculture, the optimization of crop-managing practices, relies on a reliable knowledge of the vineyards in terms of identification, quantification and response to the crop intrinsic variability. In this context, the identification of new methodologies for the features extraction and crops mapping plays a relevant role. With the recent extension of the Unmanned Aerial Vehicle (UAV) employment also in the agriculture field (Turner et al., 2011), a huge amount of high spatial and temporal resolution data provided by fields aerial images, are nowadays available. Objective of the presented work is the further exploitation of UAV imagery information potential, beyond the well-established bi-dimensional mapping, by the vineyard features extraction from 3D dense point-cloud modelling, computed by modern photogrammetry tools (Bendig et al.,2015, Zarco-Tejada et al., 2014).

2. Materials and Methods
In order to properly extract valuable information regarding morphological features, at vineyard up to single plant scale, from a dense 3D point cloud model, several subsequent processing steps must be performed, interpreting and conditioning a complex and huge dataset. The developed methodology can be divided into five main steps: (1) a pre-processing phase to obtain a point cloud defined in a local reference system, starting from a global geographic coordinate system (geographic latitude and longitude); (2) point subset selection by original cloud and section plane intersection procedure; (3) classification of points representing vines canopy within the slice point subset, using a local soil reference detection, (4) a canopy point cloud projection to obtain a binary digital image and, finally, (5) an image processing algorithm to vine features extraction.

2.1 Point cloud pre-processing phase
The original point cloud (PC) model has been obtained by processing a set of aerial images, acquired with a UAV flight over a parcel located in Barolo, Piemonte, by Agisoft PhotoScan software. An in-field set of reference markers has been placed in the vineyard, and has been adopted to georeference the PC in the Latitude, Longitude and Height reference system (LLH).

Since to the LLH anisotropy, using successive conversion to the Earth-Centered Earth-Fixed (ECEF) system and a roto-translation function, the PC has been represented in a local reference metric system, assuming the PC lower point as zero height reference (Figure 2.1).

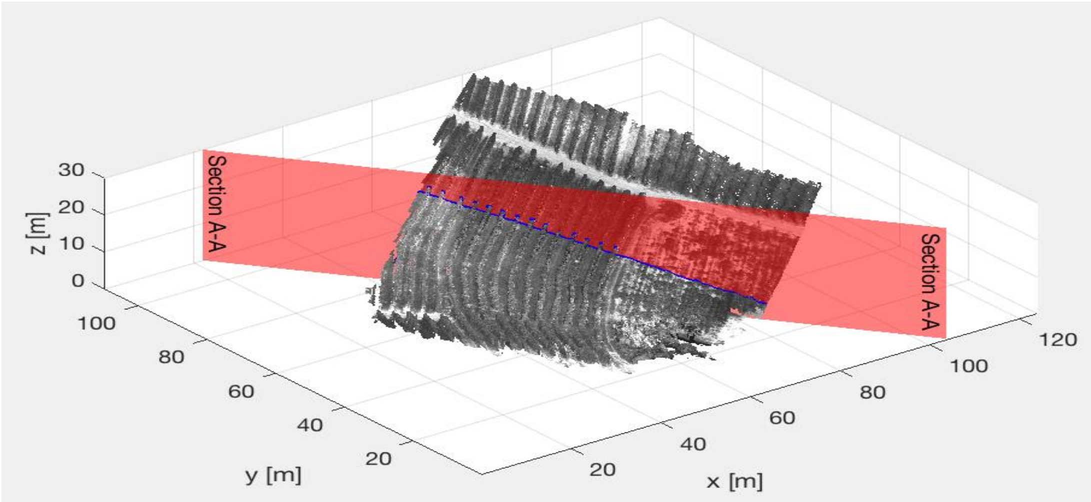

Figure 2.1: Dense 3D point cloud model of a vineyard parcel. The A-A section plane is highlighted in red colour, while selected points subset S, extracted from the 3D cloud, has been coloured in blue

2.2 Point cloud subset selection

Each point p_i of the PC is defined by four numbers, as

$$p_i = [x_i\ y_i\ z_i\ v_i] \quad (2.1)$$

where x_i, y_i and z_i are the three spatial coordinates and v_i is an index inversally proportional to the IR radiation captured by the camera sensor.

A subset S of point has been selected from the entire PC by a proximity criterion, with respetc to a vertival section plane A, defined as

$$AA = \{x, y, z \in \mathbb{R} \mid 1.3x + y - 139.3 = 0\} \quad (2.2)$$

discharging point not complying the relation

$$S = \{p_i \in PC \mid \|p_i - p_{i\perp A}\|_2 < d\} \quad (2.3)$$

where $p_{i\perp A}$ is the projection of p_i on plane AA, along the ortogonal direction, d is a distance threshold. The d value, which depends on the original PC density, has been chosen equal to 0.1 meters. The resulting point selection, projected on the section plane AA, is shown in Figure 2.2.

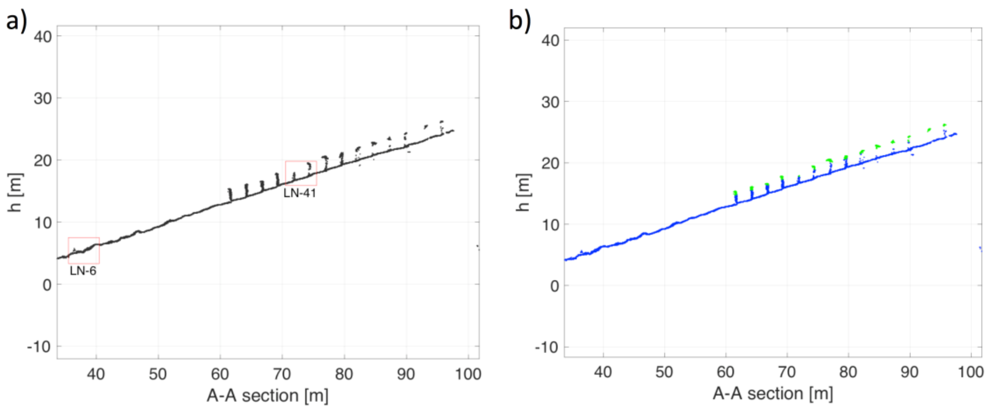

Figure 2.2: a) Planar projection of the points subset S. Two samples of local mobile window, named LN-6 ad LN-41, has been highlighted with red rectangles. b) Final classification of

subset S points, representing the top of the vines canopy (green dots) and others (blue dots).

2.3 Upper canopy detection

In order to properly detect, among the points forming the subset S, the ones representing the upper part of the vines canopy, the local pecular terrain distribution has to be determined. In this work, a local neighbourhood soil approximation has been developed, which uses a moving filtering window to locally evaluate the soil height. Two sample windows, named LN-6 ad LN-41, with a 5 meters length and located at 38 and 73 meters respectively, has been reported in Figure 2.2 by two red rectangles, for explanation purpose. The first one encloses a bare ground area, while the second is located in a vineyard region. Details of the highlighted LN-6 ad LN-41 areas are represented in Figure 2.3 and 2.4 respectively.

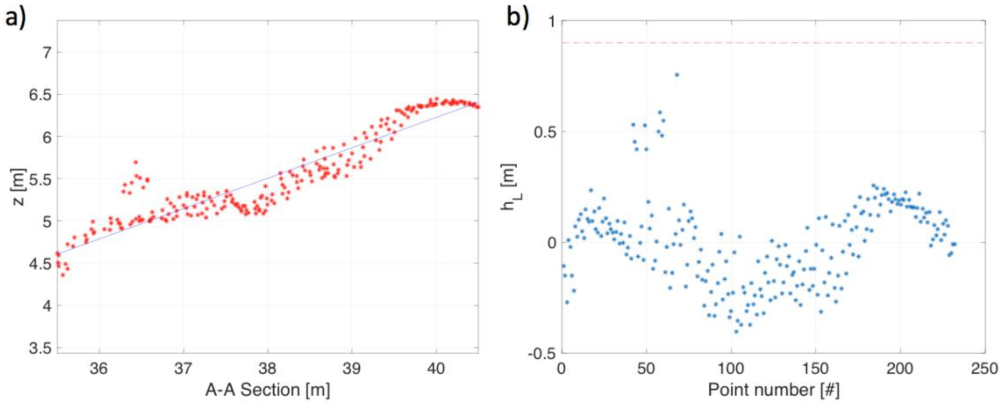

Figure 2.3: a) Detail of the local mobile window LN-6, representing not vineyard area, where cloud points and the local soil approximation are coloured in red and blue respectively. b) Height of each point from the local soil approximation and the threshold value of 0.9 meters. In the reported example, no points overcome the threshold value.

Considering the sole point enclosed by the local window, a reference terrain has been computed by linear regression, finding the best fitting line which minimizes the sum of the squares of the residuals between evaluated terrain and the point location (Figure 2.3.a and 2.4.a). The threshold value δ equal to 0.9 meters has been selected to split the points set into two classes: points with a relative height h_L (Figure 2.3.a and 2.4.a) grater than the threshold δ have been classified has belonging to the upper part of the vines canopy.

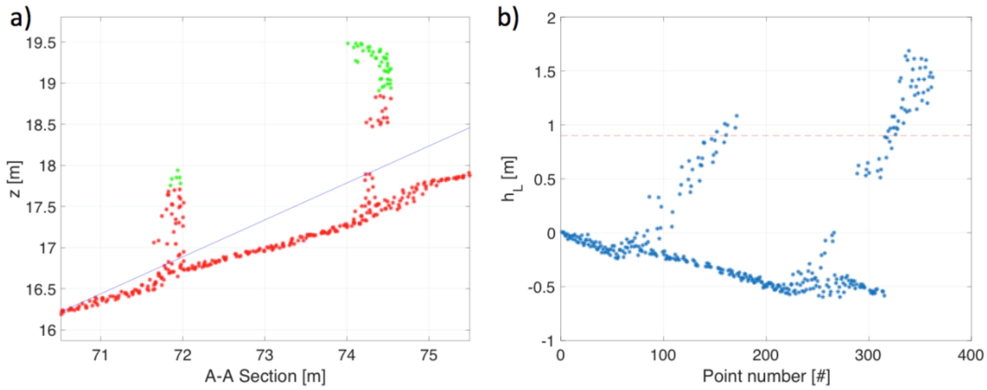

Figure 2.4: a) Detail of the local mobile window LN-41, representing vineyard area, with top canopy cloud points (green dots), other cloud points (red dots) and the local soil approximation (blue solid line). b) Height of each point from the local soil approximation.

2.4 Point cloud projection to image space

Only the points subset representing upper part of the canopy has been thus projected in a raster space, displayable as a digital image, where digital number of pixel hosting one or more points has been set to 1, while to the others, considered background, has been assigned the 0 value.

2.5 Image processing algorithm

To the obtained digital image, a set of morphological operation has been performed, in order to remove noises, allowing the proper detection of a set of cluster of interconnected pixels. Each cluster represents the upper part of a vine canopy, allowing a row counting procedure and the evaluation of some features, such as vines height (Figure 2.5). Of course, results expressed in term of number of pixels have been converted in meters, once computed the pixel spatial resolution which is, in this case, 0.032 meters.

3. Results and Discussion

The proposed methodology has been applied to 50 different subsets S_i, with $i = 1, \ldots, 50$, proving its effectiveness in properly classify point of the cloud, detecting ones representing the upper part of the vines canopies.

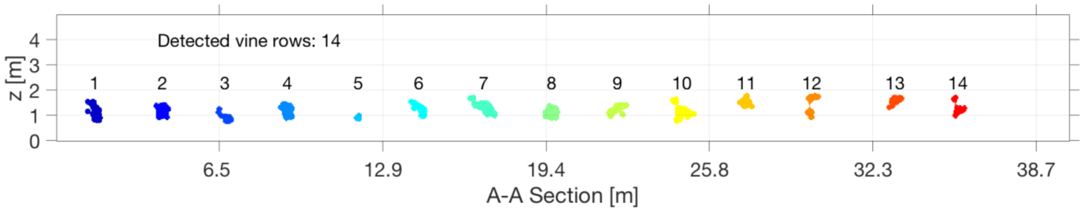

Figure 2.5: Digital image, result of the projection and rasterization of the points cloud. Each cluster of interconnected pixel has been marked with a different colour. Axis are expressed in meters, applying the proper pixel spatial resolution coefficient.

The algorithm successfully provided the number of intercepted vine rows (e.g. 14 in Figure 2.5), and their relative local height with respect to the terrain (Table 2.1).

Table 2.1: Top canopy height of the 14 detected vine rows.

Row number [#]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Height [m]	1,6	1,5	1,4	1,5	1,1	1,6	1,8	1,5	1,5	1,7	1,9	1,9	1,8	1,8

4. Conclusion

A 3D point-cloud model of a vineyard parcels located in Barolo, Piemonte, has been profitably processed by the developed methodology. The point-cloud has been obtained by processing aerial images acquired at in the red, red-edge and NIR wavelength. The developed points-cloud processing methodology, being able to autonomously perform the features extraction, can be profitably embedded in an automatic elaboration algorithm.

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Innovative techniques for the design and the control of operating conditions of rotary harrows: preliminary results on tractor-harrow interactions

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Keywords: rotary harrow, tractor-implement interaction, operative conditions

Summary
A technique and some preliminary results about the evaluation of the interactions between tractor and a rotary harrow are presented in this paper. Forces applied by three-point hitch to the implement and its absorbed torque have been investigated during a set of trials, varying a number of operative conditions. More in detail, different soil state (virgin and tilled soil), different harrow configurations (changing working depth and the rotors angular speed) and two different forward speeds have been considered.
Data processing highlighted a high influence of working depth, soil condition, and forward speed on the torque absorbed by the harrow and the force required to propel the implement in the travel direction.

1. Introduction
Soil tillage is one of the more power-consuming agricultural operations and determines a strong wear, both of tractors and implements connected to them.
Rotary harrow is a widely adopted tool in soil-working operations, in particular to perform secondary tillage (after ploughing or chiseling) or minimum tillage.
The work productivity increment, as well as the crop production costs reduction, which mainly derive from fuel consumption savings, are key factors in modern agriculture. The needs to operate at increasingly higher speeds and to possibly coupling other machines to harrows (e.g. sowing machines), lead to heavier operating conditions with an increment of fuel consumptions and require implements able to withstand high mechanical stresses. These considerations are leading manufactures to search innovative solutions for the design of harrows mechanical components, even if, in most cases, a simple oversizing of all mechanical parts is performed, with a consequent increment in static and dynamics loads on tractors and, thus, in final fuel consumptions.
Research of innovative design solutions requires, as first step, the knowledge of the interactions between tractor and harrow in different operating conditions, in order to identify more stressed mechanical components, the optimal machine setup as well as critical conditions that can determine high wear and/or components breakage.
This topic is one of the goals of PRIN 2015 project, partially financed by the Italian Ministry of University and Research. Aim of the project is the optimisation of different implements, both for tillage and sowing, by the analysis of mission profiles, in order to reduce energy requirements, to develop new design solutions of mechanical components and to equip machines with sensors and control systems able to identify optimal machine setups and critical conditions.

This paper presents preliminary results of the study, with a particular focus on the measurement of physical parameters that define the tractor-harrow interactions as well as the influence of working conditions.

2. Materials and Methods

Trials were carried out using a rotary harrow (Frandent Eternum R19) with a working width of 2,5 m and equipped with a cage roller. During tests, the harrow was fitted to a 4WD tractor (Fiat Agri 88-94, 66 kW engine power) by its three-point hitch. Load sensing pins able to take over the force along two orthogonal axes (*X* and *Y*) were adopted to measure forces due to the interaction between tractor and implement. In order to keep sensor *X*-axis aligned to the longitudinal direction of the tractor, a three-point hitch coupler (similar to ASABE Standards, 2009) was used to connect the implement to the three-point hitch preventing the relative rotation between pins and frame, as proposed in Mattetti et al. (2017). Torque absorbed by the harrow during the working operation was measured replacing the cardan shaft with a torque meter (full scale range 1500 N/m), while Power take-off (PTO) angular speed was measured by an inductive proximity sensor installed the torque meter and coupled with a digital counter implemented with a NI USB-6008 (National Instruments, USA). Forces and torque signals were acquired by a NI USB-6009 with a sample frequency of 500 Hz and stored on a PC, together with PTO angular speed data.

For each acquisition, horizontal and vertical components of the forces measured by the three load sensing pins were respectively added obtaining the horizontal (F_x) and vertical (F_y) components of the total force at three-point hitch.

Field trials were performed on a soil classified as "not plastic soil", according to (ASTM, 2010), with a moisture content of 17.7% (on dry mass basis).

Tests were performed adopting a PTO speed of 1000 rpm varying the following operative parameters:

- two different forward speeds (V_1: 1.7 km h^{-1} - V_2: 2.7 km h^{-1});
- two different roller positions for to different working depth (P1: about 6 cm - P2: about 25 cm);
- two different rotors angular velocity (I_1: 341 rpm e I_2: 411 rpm) obtained replacing directly the gears of the gear unit of the harrow;
- two soil conditions: virgin (V) and tilled (T) soil. In this study for "tilled soil" was considered a ground tilled by the same harrow at the higher working depth (P_2).

In total, 16 different operative conditions were tested; each of these was replicate 3 times.

3. Results and Discussion

Maximum, mean and minimum values of F_x and F_y components of the force at three-point hitch, as well as of the torque absorbed by PTO, were obtained for each condition, considering their average on the three replications. Normalized data (respect to the condition V I1 P1 V1 and expressed as percentage) are reported in Table 3.1, where a colour map was adopted to highlight differences among different operating conditions. Absolute values of each parameter for the reference condition are shown in the top part of the same table. As to be expected, the absolute values of F_x are greater than those recorded for F_y, since the harrow is placed on ground during work whereas F_x is the force required to propel the implement in the direction of travel, defined as draught (ASABE, 2006).

Table 3.1: maximum, mean and minimum values (average of the 3 replications) of Fx, Fy and torque expressed as percentage respect to the values obtained during the trials H I1 P1 V1 (on the top). Greenish colours indicate values lower than 100%, while reddish colours indicate values greater than 100%.

	Fx [kN]			Fy [kN]			Torque PTO [Nm]		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
VS I1 P1 V1	12,03	15,33	19,06	4,01	6,33	8,65	179	241	327

	Fx [%]			Fy [%]			Torque PTO [%]		
Trial	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
VS I1 P1 V1	100	100	100	100	100	100	100	100	100
VS I1 P1 V2	91	98	98	85	92	93	124	120	114
VS I1 P2 V1	124	131	126	101	105	119	165	157	142
VS I1 P2 V2	137	130	128	96	99	101	202	187	170
VS I2 P1 V1	97	102	102	98	104	102	100	106	113
VS I2 P1 V2	93	100	103	82	99	100	135	136	149
VS I2 P2 V1	119	128	124	62	107	109	187	157	179
VS I2 P2 V2	130	129	128	94	104	106	222	211	194
TS I1 P1 V1	95	99	99	123	115	111	69	69	69
TS I1 P1 V2	92	98	100	113	113	112	84	82	83
TS I1 P2 V1	126	120	116	131	120	114	118	103	96
TS I1 P2 V2	124	120	116	126	117	112	145	126	115
TS I2 P1 V1	122	122	115	126	115	109	148	127	128
TS I2 P1 V2	123	122	117	121	115	112	186	153	140
TS I2 P2 V1	104	103	101	119	115	113	94	87	80
TS I2 P2 V2	100	102	102	114	114	111	109	105	97

Mean and maximum torque values in tilled soil (TS) are, respectively, 24% and 28% less than values registered in virgin soil (VS). A very few decrease on draught (F_x) is shown in TS respect to VS (2% on average), while an increase, in particular about mimimum and mean values (35% and 14% respectilely), has been recorded about F_y. This behaviour can be explained with a greater penetration of the front part of the harrow in to the ground in tilled soil (TS) with respect to virgin soil (VS).

A 32% and 16% average increment of absorbed torque and F_x, respectively, is observable increasing the working depth (from P1 to P2). However, an opposite behavior can be noted in tilled soil (TS) at the highest rotors angular velocity (I2), in which F_x and torque are higher during operations at a 6 cm working depth (P1) than at 25 cm depth (P2). The increase in forward speed, from V1 (1.7 km h^{-1}) to V2 (2.7 km h^{-1}), has determined an average growth of the 23% in PTO torque, whereas the draught (F_x) does not appear significantly influenced by this parameter as well as by the rotors angular velocity. Results related to the influence of forward speed are probably owing to the narrow range of velocities achievable with the tractor used during preliminary tests.

Concerning the F_y component of the total force at three-point hitch, it is little influenced by the considered factors, excluding soil conditions as already discussed above.

4. Conclusion

A method and some preliminary results about the evaluation of the interactions between tractor and a rotary harrow, in terms of forces exchanged by means the three-point hitch and torque absorbed by the implement, in different operative conditions are presented in this paper.

Results showed a direct relationship between the torque absorbed by the harrow and working depth, forward speed and soil conditions. Draught (F_x) appears mainly influenced by the working depth respect to the other factors, while significant variations of F_y component of the total force at three-point hitch are only given by soil conditions.

Further trials are needed, considering a wider range of forward speeds as well as different soil textures and moisture content, in order to obtain a broader range of harrow operative conditions. However, obtained results show that the measurement of the considered physical quantities (in particular torque and draught) could be used for automatic control of a rotary harrows in different operating conditions, reducing energy requirements and wear in more critical mechanical components. In addition, maintenance interventions could be properly scheduled archiving data recorded during machine work, with a reduction of downtimes due to sudden breakages of components.

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Precise sowing of row crops for bidirectional mechanical weeding

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Keywords: Precision farming, coordinate controlled sowing, mechanical weeding

Summary
The most commonly applied weed control method in row crops currently is herbicide field spraying. Due to restrictions on admission of active herbicidal agents and for reasons of soil protection, chemical weeding will be not favorable in the future. Mechanical weed control by hoeing is a potential alternative but because of low capacity and the fact that only up to 85% of the soil surface is treated still not a satisfactory method. The space between the plants is not accessible for the weeding tools of conventional hoeing machines. To extend the area of mechanical treatment, other cropping systems are required to support the operation of hoeing machines. By controlling a precision seeder via GPS assisted by additional range sensors the seeds were placed in adjacent rows and in successional traces rectangular, thus cross rows were generated. To comply with an adequate plant population for sugar beets a seed placement of 33 by 33 cm was chosen. This distance between the plants coincidentally is an acceptable clearance for machine traffic. Hoeing was applied 3 times and efficiency of weeding was assessed.

1. Introduction
Sowing is the placement of seeds into the soil aiming at optimal germination, emergence and plant development. Apart from opening the soil to deposit the seeds into the soil covering of seeds is requested. Furthermore sowing includes metering and spacing of seeds. Metering addresses the establishment of an adequate plant population to ensure an optimum of crop plants per area, a second request is the spacing of seeds for an optimal distribution of plants in space. Single seed drills enable sowing of one row per unit and to space seeds in constant distances within the row. The space between the rows can be used as pathway for field traffic. Single seed drills however do not place the seeds in compounds with fixed geometric distances to the plants in neighboring rows. Positioning of seeds means to deposit seeds on predefined positions. The positions are documented as coordinates and can be retrieved for subsequent means of plant stand maintenance.

To establish geometrical compounds an electronic precise steering mechanism was implemented in a seed drill. Each sowing unit was adjustable in spacing. Besides, the theoretical position of the next seed position determined by the angle of the cell wheel and the desired position in dependence on the neighboring row was determined using different sensors including DGPS (Schmittmann et al. 2008). Quadratic compounds of sugar beets (33 x 33 cm) were sown to be suite for mechanical weeding by length- and transverse hoeing. Thus, the area between plants in the rows could be treated using the same hoeing implement as for hoeing between the rows.

A similar approach has been attempted by Griepentrog et al. (2005) and by Norremark et al. (2007). A regular precision seed drill was equipped with a GPS-system recording the seed positions when seeds dropped out of the cell wheels triggered by a light bar. This method retains the coordinates of the seeds but does not actively place the seeds in formation.

2. Materials and Methods
An electronic precise steering mechanism was integrated in a conventional precision seed drill. Each sawing unit was adjustable independently by a stepping motor, actuating the cell wheel by a tooth belt with a transmission ratio of 4:1. An encoder was installed at the belt for

determination of slip, which was compensated by a microcontroller. To comply with the desired plant population density for sugar beets of about 100,000 plants per hectare the desired cross compounds were defined as 33 x 33 cm. For high accuracy of seed positions a sensor system composed of a RTK-DGPS, assisted by an optical speed sensor and an angular rate sensor. The measured values were computed in a Kalman-Filter (Kuhlmann and Siemes, 2007) to calculate the precise coordinates in real-time.

Finally the seed coordinates characterize the position of an individual plant. As the exact position of the crop plant can be retrieved there is no need weed scouting and plant detection by machine vision for later operations like hoeing or precise fertilizing and plant protection applications. The individual plant can be monitored also by sensing tools to determine its health and nutrition status and to explore its potential yield in field scale.

The distances of plant positions were measured by a distance measuring system (AAZ; Heier, 1999). As a reference coordinate the position of the first plant of the first row was defined. Initially the variance inside one row was determined and finally compared with neighboring rows.

Weed plants have been counted before and after the weeding applications. Hoeing was applied three times.

3. Results and Discussion

The precision of coordinate actuated sowing is affected by several items. The accuracy of deposition implicates the actuation respectively the drive of the cell wheel which can be affected by slippage. The quality of cell filling implicates misses and doubles. The quality of seed deposition is influenced by variation of the dropping point and the dropping trajectory. The accuracy of field appearance contains pill rolling effects and after the deposition of the seeds the deviation caused by non-erectophile growth of the plants. Both items are influenced by soil structure. Figure 1 outlines the results on accuracy of plant positions displaying the frequency of the differences between expected and real plant positions.

The accuracy inside one row is higher than for more rows. Regarding multiple rows the results show that it is possible to create cross compounds with the novel sowing technology.

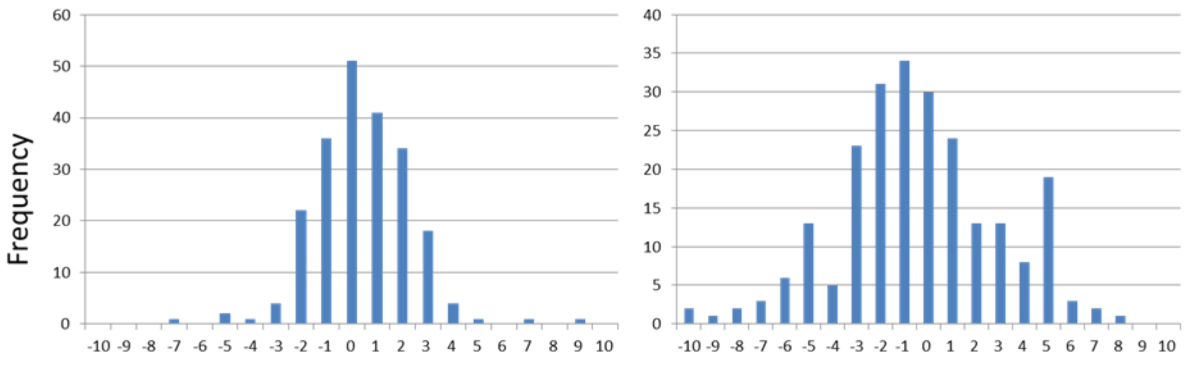

Figure 1: Distribution of differences between expected and real plant position of one (left) and more (right) rows

The effect of mechanical weeding is presented in figure 2. The graphs outline the results of counting weed plants for five different weeding methods including the control plot for two years. Longitudinal and crosswise machine hoeing can be compared with hand hoeing, herbicide application and the reference which represents no weeding at all. As compared to the control plot on average 62% of the weeds were eliminated by conventional longitudinal hoeing. Taking the percentage of weeds eliminated there was an average improvement of 78% through cross hoeing

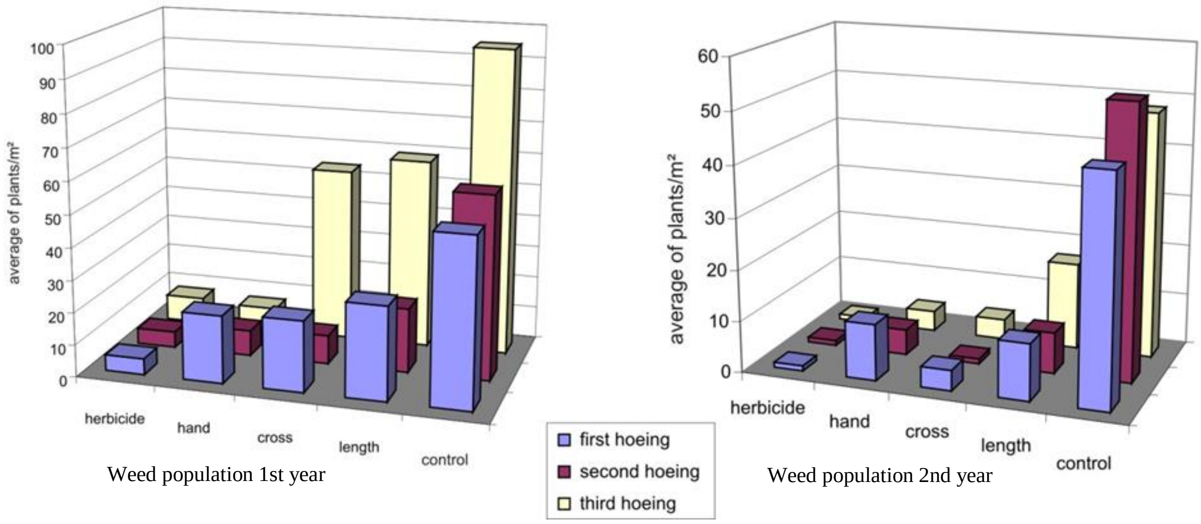

Figure 2: Weed population after different weeding methods (Kam, 2009)

Nevertheless applying herbicides was the most effective method to control weeds, eliminating 94% of the weed plants (Kam et al. 2009). From the results obtained from the control plot it can be seen that the weed population grows continuously during spring time. Therefore, hoeing needs to eliminate not only the weed plants which survived the previous application, but also the newly germinated weeds. In year two the final situation after the third cross hoeing was as successful as hand hoeing. 8.3% weeds were left in the cross hoed plots while in the plots treated with longitudinal hoeing 35.4% survived. Even hoeing the plots by hand left weeds; which were located close to the beet plants.

4. Conclusion

A control and drive system for a seed drill was developed and tested with standardized methods under laboratory conditions and in field trials. The essential evaluation criterion was the precision of seed deposition. The percentage of pills placed +/- 1.5 cm around the target position could be raised from about 91% to 97.5% by the modified sowing unit. Application of the modified seed drill in test fields resulted in longitudinal and transversal rows which were trafficable for crop maintenance e.g. mechanical hoeing applications. Applying hoeing three times conventionally, 62% of the weeds were eliminated. There is an improvement by transverse hoeing which eliminated 78% of the weed plants. Still the most effective weed control is applying herbicides, eliminating 94% of the weed plants.

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Design and preliminary evaluation of a soil resistance sensor for soil compaction sensing in viticulture

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Keywords: soil compaction, precision viticulture, technology choice, dynamometric knife

Introduction

Soil compaction is one of the influential soil characteristics that, if present, may hinder the growth of crop roots and reduce water infiltration into the soil resulting in lower crop yields (Adamchuk and Christenson, 2007). Some practices usually adopted in vineyards management, such us intense tractor traffic along fixed paths and maintenance of permanent grassing of the vineyard for pesticide distribution, were favouring soil compaction. Moreover, the tractor traffic together the soil management has directly effects on runoff and water erosion (Biddoccu, 2017).
In the calendar of agricultural activities for vineyards farm, the crop protection stage constitute the most responsible of soil compaction because the frequent transit of sprayer machine characterized by high specific pressure the ground.
Direct measurement of soil compaction, such as the determination of dry soil bulk density, dry bulk specific volume, void ratio, and porosity are time consuming (Johnson and Bailey, 2002). Soil mechanical resistance, defined as the resistance to the movement of plant roots or tillage tools through the soil, is directly related to soil strength. Therefore, a cone penetrometer used to measure the force required to vertically insert a conical tip into the soil has become the standard practical mean for assessing the degree and variability of soil compaction (ASAE Standard, 2016).
The objective of this study was to develop a new instrument to measure the soil mechanical resistance, called "dynamometric knife", that can measure georeferenced data of soil compaction in a continuous way. Preliminary field tests by using the dynamometric knife were assessed in different vineyard soil conditions.

Materials and methods

The dynamometric knife was composed mainly by a steel pivoted knife connected to a load cell. The measurement principle was based on first-oder lever. This allow achieving the load force (N) necessary to perform a cut at specific deep. Then, this data was related to the contact surface between knife and soil in order to get the specific pressure (MPa). The instrument can be coupled with a standard three-hitch point, and is adjustable for acquiring data at a depth ranging from 0 to 0.4 m. A data acquisition system made of signal sensor processor and a software allows collecting the force required to cut the soil at the pre-established depth, and the relative geographical position in real-time (Fig. 1).
Preliminary field test were assessed to measure the soil mechanical resistance in different soil management vineyards. The dynamometric knife was used in a permanent grassing vineyard and in a tilled one, both in the tractor traffic paths and in the central area among the traffic paths (Fig. 2). Measurements were also taken in a high density vineyard were the soil management consisted in annually sub-soiling tillage in alternate rows (Fig.3). Data collected were modelled in a mixed linear regression model by using the extension package lmerTest (Kuznetsova et al., 2014) of the R statistical software (R Core Team, 2013).

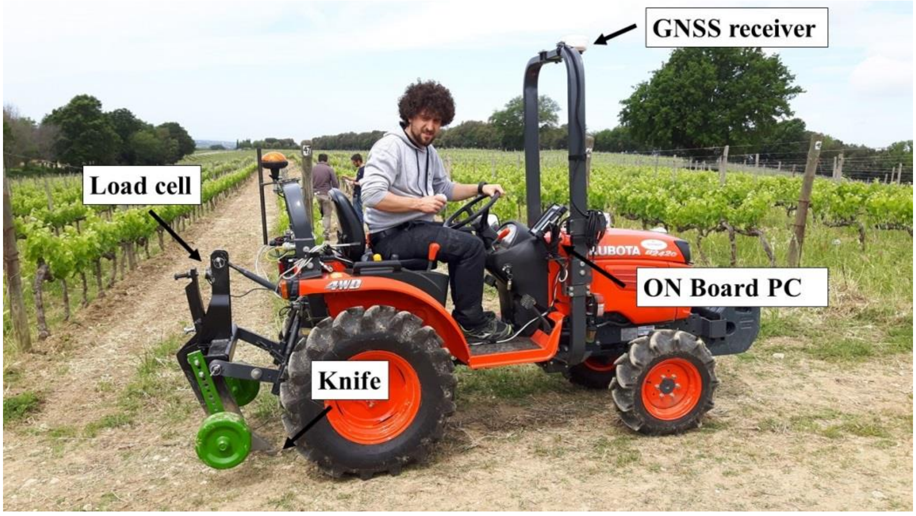

Figure 1 Dynamometric knife mounted on the mobile tractor field laboratory

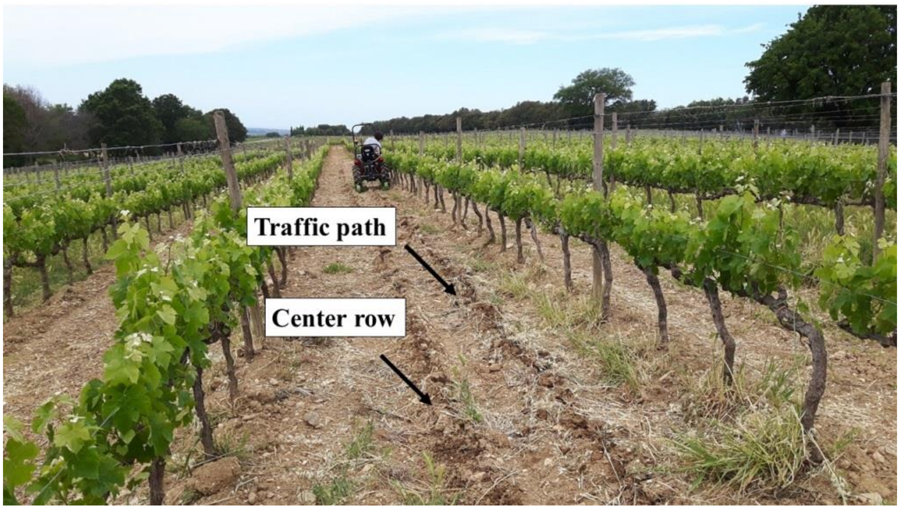

Figure 2 Measurement of soil mechanical resistance in the middle of the row and along the traffic path.

Figure 3 On the go measurements in high-density vineyard.

Results

The preliminary results showed that the dynamometric knife works properly and allows an instantaneous overview of soil mechanical resistance measurements. Nevertheless further improvements are required to enhance its precision and versatility.

Analysis of data showed that the force needed to cut the soil within the tractor traffic paths was always statistically higher compared with the force needed in the central area among the traffic paths, both in permanent grassing that in tilled vineyard. Same results of higher force required were obtained when the no-till soil was compared with the soil tilled the previous year.

Further studies are necessary to investigate the performance of dynamometric knife in relation with the data collected with the cone penetrometer and measures of bulk density, in order to establish a relation between soil compaction data obtained with different instruments.

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AGROMAP – A precision agriculture tool based on satellite ESA images (Sentinel 1 and 2)

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Keywords: Parcels and crops monitoring, Yield limiting factors detection

Summary
Agromap is a commercial WebGis tool that was born within the scope of a University of Évora "Spin Off", the Agroinsider Lda (www.agroinsider.com). The objective underlying the construction of Agromap was to create a remote sensing tool for agricultural parcels using ESA satellites (Copernicus program). With this tool farmers can monitor any parcel, anywhere, in order to optimize agronomic processes and agriculture sustainability.

1. Introduction

Copernicus is a European Union Programme aimed at developing European information services based on satellite Earth Observation and in situ (non-space) data. The Programme is coordinated and managed by the European Commission. It is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Océan.

Vast amounts of global data from satellites and from ground-based, airborne and seaborne measurement systems are being used to provide information to help service providers, public authorities and other international organizations improve the quality of life for the citizens of Europe. The information services provided are freely and openly accessible to its users.

In the domain of agriculture, EU policies aim to foster the development of practices that preserve the environment and sustain productivity. Copernicus helps to assess agricultural land use and trends and their impacts on biodiversity and landscapes. Copernicus can also help assess crop conditions and yield forecasts. Additionally, it can help public authorities and farmers improve irrigation management by monitoring agricultural pressure on water. In the domain of forestry, Copernicus provides solutions to identify forest types, detect changes, map and monitor clear-cuts and assess forest density and health. This can in particular support users in their reporting obligations towards national and international policies (e.g. UN Framework Convention on Climate Change).

2. Materials and Methods

Agromap (Figures 1 and 2) is a Software as a Service (SaaS) tool that provides in time and space interesting radiometric indexes for agricultural management. At the moment, the satellites used in Agromap are optical satellites (Sentinel 2) and radar satellites (Sentinel 1), however more ESA satellites will be incorporated in the Agromap as long as they present value to the agricultural activity. The most used indexes are the indexes of chlorophyll, leaf water content, soil moisture, biomass, etc. The spatial and temporal resolution of these images are respectively 10 m and 6 days.

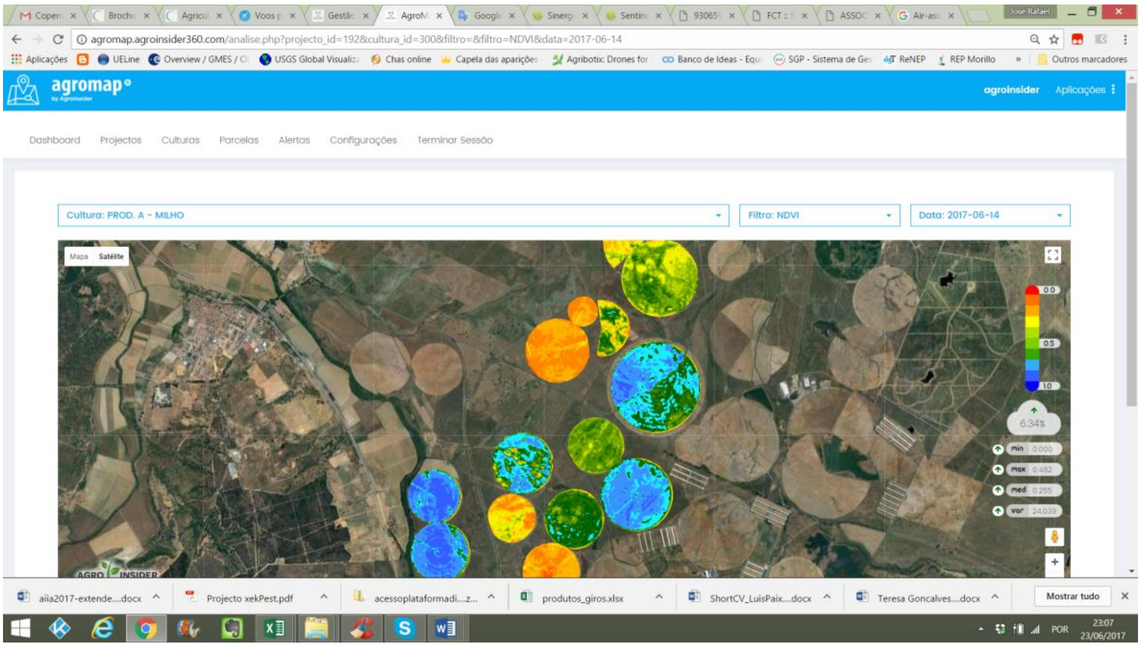

Figure 1 – Agromap showing a NDVI index on 500 ha of corn (Sentinel 2)

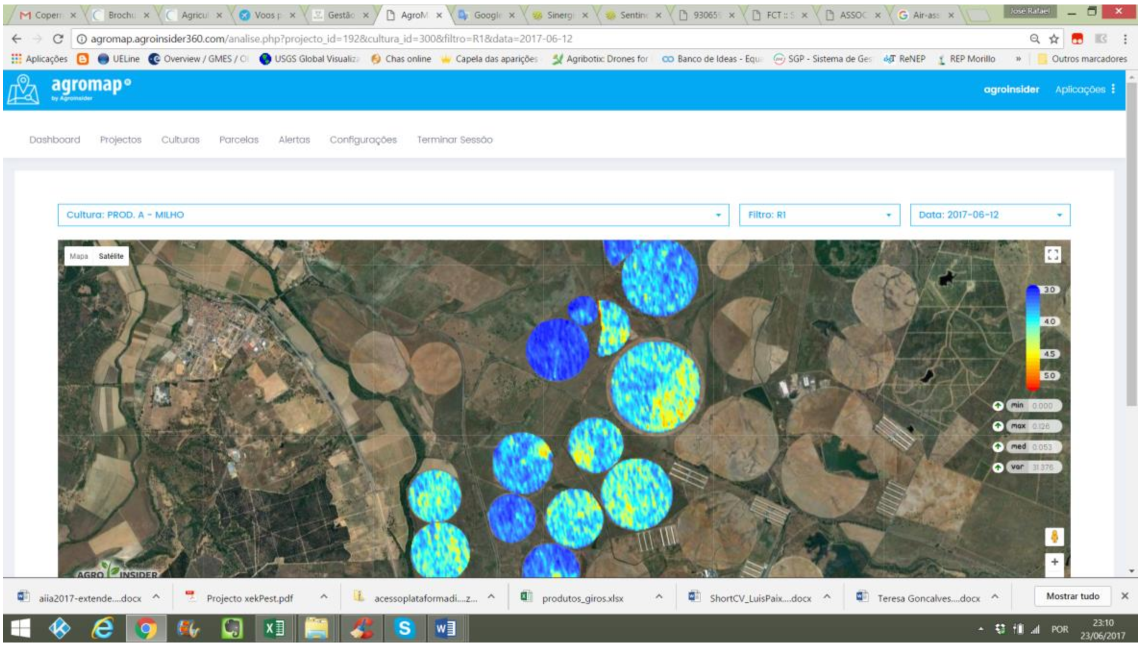

Figure 2 – Agromap showing a Radar index on 500 ha of corn (Sentinel 1)

3. Results and Discussion

AgroInsider using optical and radar European Space Agency (ESA) satellites, as well as proprietary algorithms analysis, is producing an agricultural revolution on parcels remote inspection.

The large agricultural expertise, combined with global monitoring tools, allow AgroInsider to develop specific audits for each plot and quickly identify different types of problems and solutions, which from an economic point of view have a significant impact on agricultural activity.

In the case of the parcels shown on Figure 3 and particularly in the reddish areas, the corn production can vary between 2 to 6 tons/ha less, affecting in this way the parcel sustainability. The impact of these type of problems in the parcel sustainability are more severe when higher input levels are introduced in the fields.

The radar satellite signals, presented on Figure 4, are relatively variable within and between plots, indicating at the same time a highly spatial variability on existing tomato biomass volumes. Areas with more yellowish shades identifies tomato plants with a higher vegetation volume if one compares it with the bluer areas. In tomato crops higher vegetation volumes are normally associated with higher productive plants and thus opens the possibility of managing yield potential and differential management of inputs (nutrients, water, etc.).

With economic margins increasingly small the only way to guarantee success is to control the factors that limit the activity such as the ones shown on Figure 3 and Figure 4.

The AgroInsider consultancy service package, depending on the crop and their respective cost structure, has a very competitive cost value, between 0.5% and 1.0% of annual crop operating costs.

4. Conclusion

For agriculture a spatial resolution of 10 m and a temporal resolution of 6 days are fantastic because most of the agriculture machinery applications have this spatial resolution and 6 days is a high temporal resolution for crops that stand in a parcel for 100 days. These parcels inspections allows a total revolution in agriculture activities because with these images and the respective indexes we can perceive: i) if the plot/crop is below the optimal curve growth, in time and space; ii) the limiting factores that are reducing the plot/crop potential (irrigation systems, soil, nutrients, diseases, etc.); iii) the best plot/crop; iv) in crops such as vines, where vegetative vigor and water stress are important, Agromap can be used to model this vigor by placing it within the higher or lower vigor potential limits, in order to adjust it to the company strategy (productivity vs quality). A good way to start doing smart agriculture is without any doubt, with Agromap (www.agromap.agroinsider360.com).

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http://agroinsider.com/
http://www.esa.int/ESA

Figure 3 – Proprietary vigor index that easily detect problems at parcel level. The reddish areas represent less vigorous corn, limited by water deficit or water excess and normally associated with irrigation systems problems. Other parcels areas, more local, usually represent problems associated with the interaction between water/soil/plant.

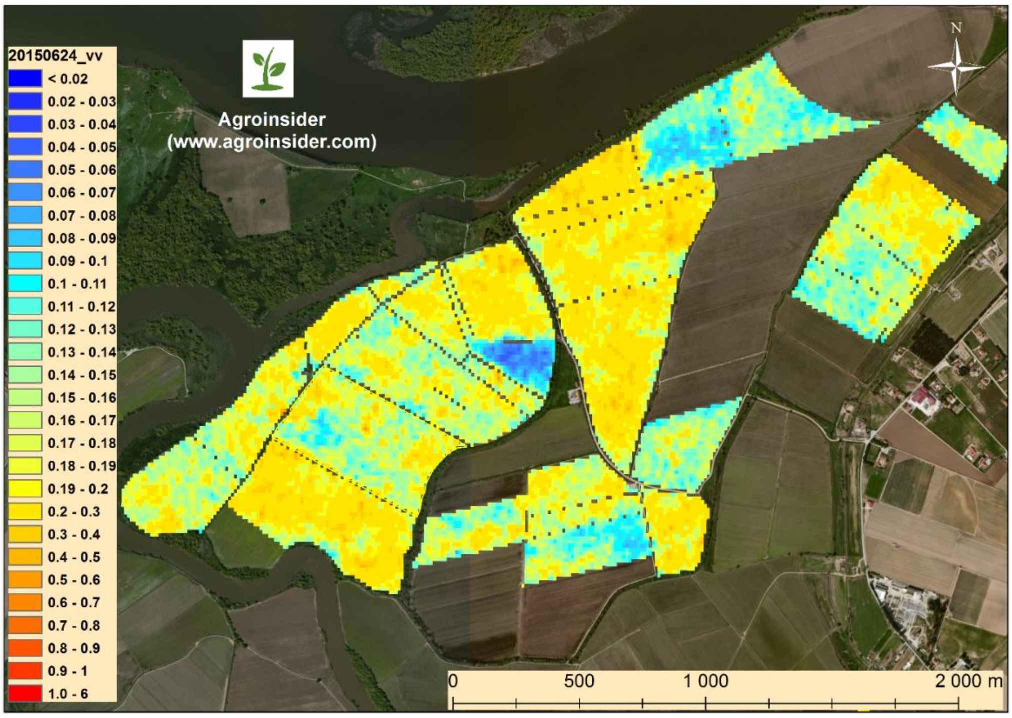

Figure 4 – Radar image from tomato industry plots: VV polarization from SENTINEL 1A satellite.

Big data in dairy farm: acquisition methods and numerical models for integrated real-time information systems

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Keywords: Numerical methods, Precision Livestock Farming (PLF), Environmental parameters

Summary

The adoption of different types of monitoring systems and control devices within livestock barns in last years has remarkably increased the amount of data available for farmers. Automatic Milking Systems (AMS), collar tags, pedometers and environmental sensors have turned also farms into the big data sources currently available. This study aims to define tools and methodologies capable to organize such amount of data into meaningful information and user-friendly indications for farmers and technicians of livestock farms. The output of the research is meant to indicate immediate, precise and simple actions to be carried out for herd management.

Different technologies available for data collection in dairy farms have been analyzed in terms of potentials for data acquisition and mutual integration, with particular reference to data acquired by AMS. An experimental monitoring campaign of environmental conditions and herd management data has been carried out on a dairy farm in Bologna (Italy), adopted as a case study. The analyses have been focusing on a livestock barn equipped with one AMS box, hosting about 70 lactating cows.

Data related to milk production, cow behavior and heat stress have been analyzed according to a wide-perspective research approach. A cluster-graph analysis has been applied to a dataset containing the time series of the parameters (including activity score, parity, and body weight) recorded for each cow in the barn. This analysis proved capable of identifying groups of animals with features affecting their productivity differently. Moreover, climatic data surveyed inside the barn have been analyzed together with cow productivity and outdoor climatic data.

The results proved suitable to enhance the characterization of the herd, lend support to cow monitoring and herd management.

1. Introduction

Nowadays, many new devices are studied in dairy cow farms all over the world. Automatic Milking Systems (AMS), collars, pedometers, cameras are installed by farmers in order to improve the management of the herd and to increase the milk productivity (Sitowska et al., 20156). This scientific and economic trend has generated some important consequences.

First, the modern farms are become big data generators as our houses, web-behaviours or shopping preferences. It is possible monitor each single cow H24, collecting information about her position, rest duration, milking events ….

Second, farmers have to spend more and more time in the office to analyze plot, graphs and tables. It has seen often as a waste of time, work and energy stolen to other activities, so many features of the devices are not used, and many data are not examined with the right attention.

Third, many researches and studies are focusing on this theme. It means that new interesting correlations and links are highlighted and new tools are implemented.

Last but not the least, these devices are not always connected each other: they often come from different companies, maybe also market rivals, with different software and output. It means that there is a very big management potential for the farmer in all these structures, but at the same time, it is very complicated to extrapolate it.

The purpose of this work is to illustrate a simple and easy method to use the big amount of data coming from a barn equipped with AMS and related monitoring systems, in order to help the farmer in dairy cows management in a smart and fast way without losing information and time.

2. Materials and Methods

A dairy farm equipped with AMS, located in the municipality of Budrio, about 20 km north-east of Bologna (Emilia Romagna Region, Italy) has been adopted as case study for the methodology. The barn is a rectangular building 51 m long and 23 m wide and it consists of a storage area, a resting area and a feeding area with an external feed delivery lane. The resting area hosts 78 cubicles with straw beddings, where about 65 lactating and 13 dry Friesian cows are housed. The milk-room is located close to an office and a technical plant room and the ventilation is controlled by three high-volume and low-speed (HVLS) fans with five horizontal blades, which are activated by a temperature-humidity sensor situated in the middle of the barn. Cow milking is performed by means of a Lely "Astronaut A3 Next" robotic milking system, which is placed in the SW side of the barn.

Figure 2.1: Pictures of the barn

Four devices has been considered in this farm:

1) AMS Robot (visible in the left picture of Figure 2.1) - after every milking event, data about milk and cow wellness are downloaded (cow weight, productivity, cow parity, milk temperature …);
2) Temperature and Humidity Sensors - two dataloggers are situated in the central line of cubicles (visible in the right picture of Figure 2.1)at the height of 1 meter from the ground;
3) External Weather Station - it is located beside the barn and it measures temperature, humidity and wind speed;
4) Activity Collars - each cow has a personal collar collecting data about activity every two-hours.

First, all the data coming from these devices have been joined and synchronized for each single cow: the time period from June 21st to September 30th 2015 (i.e. an overall number of 88 cows) has been analyzed.

Then, a k-means cluster analysis (MacQueen, 1967) has been applied to the following parameters (daily based):

1) Number of daily milking per day;
2) Parity;
3) Average daily activity;
4) Milking regularity, in terms of standard deviation of the time intervals between two milking events;
5) Cow body weight.

Five *k* values have been selected a posteriori for each single variable.

Finally, the clusters obtained has been joined in a graph with Gephi, an open source software for the network analysis (Bastian et al, 2009). Here each cow of the herd is defined as a node and two nodes/cows are linked if they are in a same cluster (at least one). The weight of the link between the cow A and cow B is calculated as a sum of the similarity index for each parameter i, defined as follow:

$$S_i = 1 - (|\text{variable}_i\,(A) - \text{variable}_i\,(B)|) / (\text{centroid}_i) \qquad (2.1)$$

Modularity has been used to find subnetworks in the Gephi cluster: it is a measure that allows to minimize the number of edges between two different clusters in the graph. (Newman, 2006)

3. Results and Discussion

Final results of the clustering-graph analysis are shown in Table 3.1. In this specific time period three clusters have been found by the model. Each cluster characterizes a specific group of cows in the barn based on the previous selected parameters.

Table 3.1: Some statistic for the final clusters.

Cluster	Number of Milking Events	Cow Weight (kg)
1	2.0 ± 0.4	674.5 ± 58.0
2	2.3 ± 0.3	587.4 ± 33.0
3	3.0 ± 0.3	646.4 ± 66.8

All these data have to join with environmental ones, both of internal and external. They could be summarized in the THI (Temperature Humidity Index) trend of the analyzed period or also they could be plotted in the expandend version with a single line for temperature, wind speed and relative humidity as shown in Figure 3.1. The combined study of all these data helps the farmer to monitor the herd condition in an easier and faster way without losing information about single animals. In this way, he could also notice some anomalous or undesired trend and change some management aspect.

In particular, the connection between cows data (activity, weight, parity …) and environmental ones is very important. Heat stress is one of the most significant enemy for the farmer in a typical summer in the Meditteranean region. It influences the wellness of cows, as the milk productivity could decreases dramatically (Allen et al., 2015). Numerical models correlating the environmental variables involved have thus been developed, also with forecasting potential. The results have been described in a specific further paper in press.

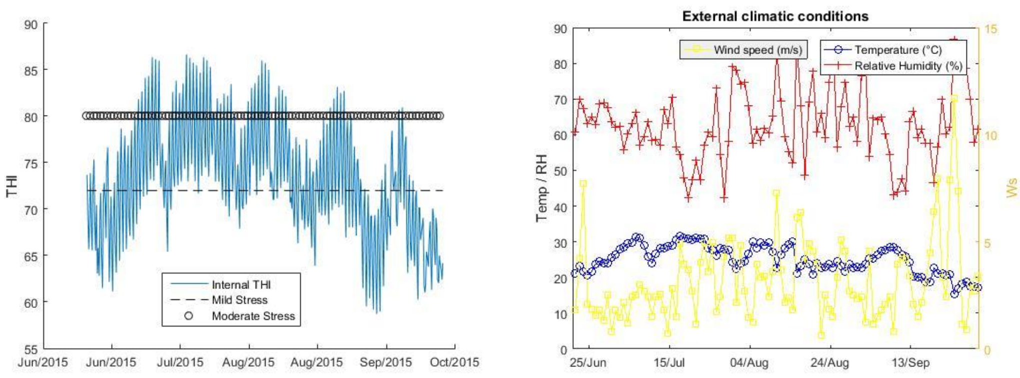

Figure 3.1: Environmental time series. Left: Internal THI with the threshold of moderate and mild stress (Samal, 2013). Right: External climatic condition (temperature, relative humidity and wind speed).

4. Conclusion

The illustrated method represents a clear and simple solution to join a part of the enormous amount of data coming from a modern barn. First, the data are downloaded and processed automatically from the milking robot and other devices working in the barn (pedometers, collars …). It is possible to decide the analyzing time period and which variables have to be included in the model. The final output is one graph where each "physic" characteristic can be easily compared with the environmental condition (external and internal). This method allows the farmer to summarize data yearly, monthly or weekly trends in only one plot without losing important information. In addition, he could decide to analyze the entire herd or to focus on a specific group or single cow. Future developments are including the study of new devices, the enhancement of this system introducing new descriptive indices and the automatic warning of new possible alarms for the farmer.

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Design and implementation of a GNSS/GIS for monitoring transhumant flocks in Lombardy

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Keywords: flocks transhumance, GNSS receiver, GIS

Summary
The consistency of transhumant flocks in Lombardy (Northern Italy) amounts to 60,000 sheep, belonging to about 150 sheepherders. The flocks transhumance remained until today even though, over the centuries, the breeding purposes deeply changed. Nowadays the sheep, so far considered as user of pasture resources, assume a new role of "vegetation controller" and "land resource manager" contributing to improve the biodiversity. Lombardy recently approved (2013) a project to enhance the transhumance and in cooperation with ERSAF developed a plan to maintain and improve this important livestock reality. In this context, our research group designed and developed a system for the flocks territorial monitoring by studying their paths and land utilization.

1. Introduction

The sheep livestock wandering in Northern Italy is based on the giant Bergamo breed. It provides for the flock to live in motion, feeding only with fresh and low-cost forage. Winter is spent in the plain, moving between fields, meadows and uncultivated. In the spring the flocks migrate to the highest and poor alpine pastures where the summer is spent. The return to the plan takes place with the first cold, running the river shafts in the opposite direction to the spring. The wintering areas include the Brianza, the Cremonese Plain, the Lodigiano, the Lomellina, the Piacentina and Parmense Plains, the Alessandria Plain (Corti, 2007). In Lombardy, wandering sheep farms, with about 60,000 adult bred animals, account for about 60% of regional ovine farming (Lombardy Region, Regional Animal Register, 2012). In recent decades, nomadic livestock rearing has changed in two main aspects: a) the single flock number of heads is nearly increased tenfold, exceeding even the 1000 animals; b) more and more often the spring and autumn transhumance phases are carried out by means of motorized means. Besides economic, the causes of such changes are: a) decreasing of potentially grazing areas for high anthropic pressure; b) the Park Entities expansion, with regulations restricting the grazing possibilities. The common sensitivity related to the environmental problems has started in the '80s of the last century and the environmental studies on the animal habitat has generate interest also in the sheep farm sector to know the exactly animal position using GNSS (Global Navigation Satellite Systems). The tracking animal movement by using GNSS-collar receivers is common in wildlife studies (Moen et al., 1996; Rempel and Rodgers, 1997; Sibbald and Gordon, 2001), while more recently GNSS and GIS technologies have been used to assess livestock grazing behavior and management with greater spatial and temporal resolution (Agouridis et al., 2004; Barbari et al., 2006; Clark et al., 2006). Other applications have concerned the control of the grazing goats (Tangorra et al., 2009), the flocks epidemiological monitoring (Marchesi et al., 2012), the combating of cattle thefts (Tangorra et al., 2013) and the calving monitoring (Calcante et al., 2014). By using GNSS collars Anderson (2007) developed a virtual fence to reduce labor costs associated with fence construction in rotational grazing. For transhumant flocks the greatest difficulties associate with the use of GNSS-collars are inherent the GNSS accuracy, the autonomy and the possibility of an easy integration with devices of data recording, memorization, elaboration and transmission. The aim of the present study, supported by Lombardy-DG Agriculture was to design and develop a GNSS-collar, called OVItrace, able to feed a GIS with the flock position data allowing: the identification of the transhumant flocks yearly tracks; the calculation of the territorial dimension of the grazing areas (batide); the determination of the pasture surface required by the flocks.

2. Materials and Methods

By using an autonomous radiolocation unit (KT CHASE ME® - GuardOne Italia S.r.l.), the OVItrace has been assembled. Major hardware components of the OVItrace included an integrated GPS/GSM antenna, a GPS receiver, and a GSM/GPRS quad-band module powered by a Li-Ion battery 13 Ah/3.6V. The radiolocation unit was housed in a box (70x70x48mm) with very high (IP67) environmental protection grade and then applied to a nylon collar. To secure more than 6 months of battery life, fixed positions were sent every two hours. The OVItrace collar weighted less than 1 kg and it was small enough to put on the sheep's neck. Only the dominant adult animal of the flock, called "batidora", was equipped with the OVItrace collar in such a way making possible to afford an economic investment of relative small entity (less than 1000 €/flock).

A Web application (WGPSNET App, GuardOne Italia S.r.l.) was used to connect the OVItrace to the Web and to program the Web interface in order to select: graphic context; real time flock position on the map; flock tacking report data; historical tracking from the database; measurement units for latitude, longitude, data, time, place and distance, battery charge performances. By using the same Web app associated with the Short Message Service (SMS) technology, short alphanumeric text messages were sent to selected users when alarm situations occurred (e.g. a flock out of his track). The Web app has also been used to transfer the data into both .txt and .KML formats (for analysis with spreadsheets and Earth browsers). The tracks territorial distribution has been analyzed by using QGIS software (Quantum GIS Development Team). Taking into account some agronomic and animal parameters [liveweight, kg; daily dry matter intake (DMI), kg/100 kg liveweight; pasture availability, kg DM of grass/ha] an evaluation model of the grazing area uses has been implemented. The 1-year project (June 2015-June 2016) has involved 10 flocks, selected in collaboration with the shepherds association in order to have a homogeneous territorial distribution and a representative sample of the management forms.

3. Results and Discussion

As it is shown in Table 1, altogether 9000 sheep has been monitored, equal to more than 15% of the Lombardy transhumant flocks consistency. In Figure 1 the recorded positions for the 8 flocks monitored during the "batide" periods (October 2015- June 2016) are shown. The two flocks marked with green and violet points (flocks 4 and 7) show winter grazing areas more spread on the territory, overcoming the regional boundaries (flock 7) and arriving to Ferrara (Emilia-Romagna). These two flocks belong to pastoral farms of recent foundation that are still consolidating their own activities, based on relatively small flocks (600-800 sheep). The transhumance from winter pasture areas to alpine pastures and vice versa occurs without using any motorized vehicles for transporting animals.

The other six flocks (Figure 2) belong to families of "bergamini", the Italian traditional cow boys, for generations and show "batide" more concentrated into small areas where the most specialized agriculture leaves space to uncultivated surfaces, and the secondary roads structure constitutes a network that allows an efficient flocks circulation without necessarily employing the principal streets of communication. These winter grazing areas appear well delimited and usually do not overlap thanks to informal agreements between shepherds.

Table 1 – Flocks and pasture areas characteristics

ID	Farm Foundation	Sheep (n)	Alpine Pasture	Track	Winter pasture area (Batida)
1	Multi generational	650	VAL VIOLA	Yes	MILANO NORD – EST (MARTESANA)
2	Multi generational	850	PASSO del VIVIONE	Yes	MILANO NORD-EST (BRUGHERIO)

3	Last Generation	1100	VAL GROSINA	No	MILANO EST (PAULLESE - ADDA)
4	Last Generation	800	VAL TROMPIA	No	OLTREPO'
5	Last Generation	1000	GAVIA-CAVALLORO	Yes	MONZA (TREZZO – ADDA E LAMBRO)
6	Multi generational	1000	VAL BOGNANCO	Yes	MILANO OVEST (RHO-VILLORESI)
7	Last Generation	800	VAL TROMPIA	No	FERRARA
8	Last Generation	1000	VAL CAMONICA	Yes	MANTOVA
9	Last Generation	500	ALPE VENANO	Yes	MILANO SUD (CHIARAVALLE)
10	Multi generational	1200	MONTE PORA	Yes	CREMA (SERIO)

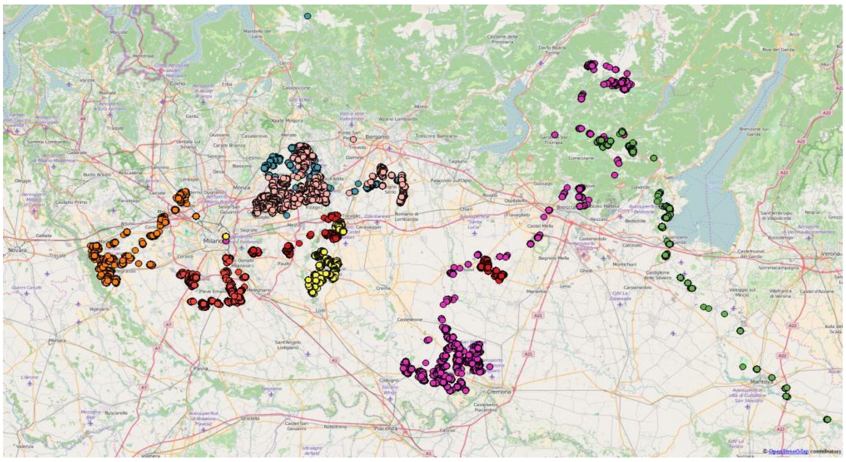

Figure 2 - Grazing areas of the 8 flocks monitored (October 2015 - June 2016).

The different type of management (with or without motorized vehicles) is clear analyzing the annual tracks. When the transhumance is carried out without motorized vehicles there is no discontinuity in the flocks tracks (Figure 3), being the winter grazing areas and the alpine pasture connected through continuous corridors, often walked during the night.
Nevertheless, the valley floor can show limited permeability to the flocks' passage. This is the case of Val Trompia, for example, crossed by flock number 4. In proximity of the more urbanized areas, a discontinuity of the grazing surfaces is evident and the only practicable way to pass is to use the principal communication roads. This entails that the vehicular traffic must be stopped during the transhumance producing potential conflict with the local populations and administrations. Today, the only way to overcome such limitations is to use motorized vehicles, even if this practice causes that the forages from the piedmont areas are no longer used and the forests prevail permanently modifying the traditional landscape. This problem is not of interest for the shepherds that adapt their behaviour to the imposed bonds. If the mechanized transhumance implies higher costs, in comparison with the tradizional one, it allows the shepherds to have a greater operational flexibility, being able "to load and to unload" the alpine pasture at the most opportune time and to better organize their staying in the winter grazing areas.

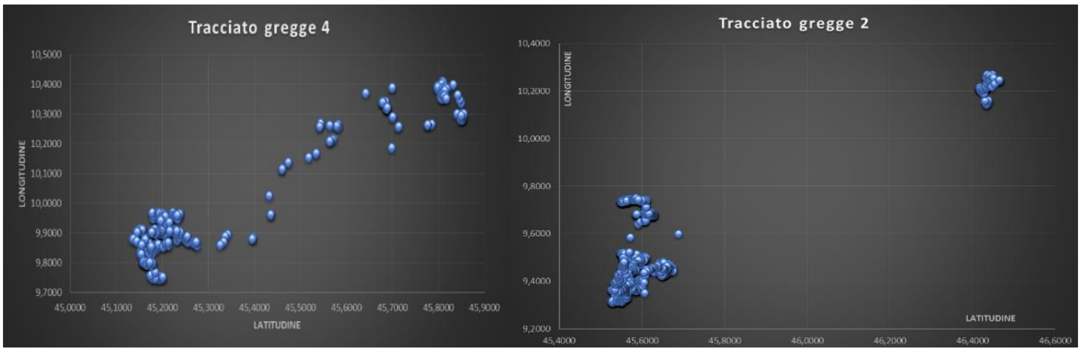

Figure 3. On the left, traditional transhumance of the flock 4: the winter grazing area (batida) and the alpine pasture are connected by a continuous track; on the right, mechanized transhumance of flock 2: the winter grazing area and the alpine pasture are completely separated.

The grazing areas used by the flocks are summarized in Table 2. Data refers to only 6 flocks. Flock 3 was excluded from the analysis because the recorded data covered only a limited period, due a technical problem with the GPS receiver; for the flock 7, overcoming the regional boundary, it was difficult highlighting just one winter grazing area.

Table 2 – Grazing areas used by 6 of the monitored flocks

ID	Starting date (dd/mm)	Endly date (dd/mm)	Grazing area (ha)	Track (km)	Daily DMI (kg/flock)	Daily land use (ha)	Days	Total land use (ha)
1	07/08	27/05	42600	710	4420	8,84	294	2600
2	07/08	27/05	9800	1200	3395	6,79	294	2000
3	24/11	29/04	10200	260	3590	7,18	157	1130
4	08/08	22/05	31000	705	2950	5,9	288	1700
5	24/11	29/04	4250	200	3525	7,05	157	1100
6	24/11	29/04	10800	325	3525	7,05	157	1000

The actual transhumant sheep farming in Lombardy interests a territory of 100 - 150.000 ha, as such sufficiently large to ask for a careful territorial planning.

4. Conclusion

The selected GNSS/GIS technical solutions used to develop the OVItrace collar have shown their effectiveness in monitoring and recording the flocks tracks on yearly basis. Potentially they can be used to support the operational, directive and strategic decisions of the different actors (researchers, veterinarians, breeders, etc.) involved in the transhumant sheep breeding.

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Toward a dynamically configurable and upgradable greenhouse environment simulation PC platform

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Keywords: greenhouse environment model, Excel-based simulation, interactive courseware

Summary
A computing platform is the environment in which a piece of software is executed. It may be the operating system (OS) or other application, as long as the code is executed in it. Platforms may also include software frameworks that provide ready-made functionality. During the past decades, several greenhouse environment simulation and climate control models have been investigated. Regardless the type, the development of a good predictive model is compulsory to achieve adequate control performances. In order to provide a flexible interactive tool, the Xnumbers Excel® addin by L. Volpi, along with the Visual Basic for Applications (VBA), allowed to customize a workbook to fit the simulation of the greenhouse environment. Within this extent, the first workbook of the dynamically configurable and upgradable platform for the simulation of a greenhouse environment has been provided. The paper presents the relationship among Xnumbers Excel® addin, VBA code and the Excel workbook threads within the application developed in MS Excel Environment.

1. Introduction
Many greenhouse characteristics such as structural shapes, types of glazing materials, heating/cooling systems, shading devices, CO_2 enrichment, and different operational strategies have been designed aiming to achieve favorable environmental conditions for plant growth. Greenhouse environment simulation and climate control models have been investigated and classified into four groups: a) First principles models, with physical phenomena described by differential equations, and with parameters having a physical interpretation; b) Black box models. The simulation may follow different techniques, such as polynomial fitting, neural networks, Fuzzy sets, etc., c) Hybrid models, by combining black box techniques with a physical model framework. Hybrid models are especially suited to describe highly nonlinear behavior over a large operating domain; d) Criteria based on optimization strategies, i.e. aiming to reduce energy and water consumption, and optimal CO_2 usage, optimal economic control, adaptive and multi-objective hierarchical control, or nonlinear predictive control.
Thus, the understanding of the complexity and dynamic behavior of greenhouse environments becomes a priority among students. In order to provide a flexible educational tool, an Excel® based software for Greenhouse Environment Simulation (GHES)© has been developed, following energy and mass balance principles.
A differential equations system has been integrated numerically with a 2.5 sec step, by the Predictor-Corrector $P(EC)^2$ schema of 4th order of Adams-Bashforth_Moulton, a function implemented in Xnumbers Excel® addin, a free software by L. Volpi.
The GHES software produced realistic approximations of the dynamic behavior of greenhouse environments with different design configurations and operational strategies for 24-h simulation periods. Moreover, it gives the opportunity to change the ventilation control algorithm, i.e. the logic that governs vent openings.

2. Materials and Methods

Any computer having hardware at 32-bit can perform arithmetic operations with 15 significant digits (Volpi, 2007). Excel reports a maximum of 15 digits, but for numerical calculus they are not enough. The only way to overcome this finite fixed precision is to adopt special software that extends the accuracy of the native arithmetic. The ways in which long numbers are stored vary from one method to another. The two most popular methods use the "string" conversion and the "packing". The Packet Extended Numbers is the method used in Xnumbers, an Excel addin (xla) that performs multi-precision floating point up to 200 significant digits for arithmetic, complex, trigonometric, logarithmic, exponential and matrix calculus covering the following main subjects. It is compatible with Excel® and consists of a set of more than 270 functions.

Xnumbers contains functions for solving the differential problem of the 1st order with initial conditions (Cauchy's problem), and the 1st order ordinary differential system. The 4th order P(EC)^2 schema predictor-corrector of Adams-Bashforth-Moulton is faster than the Runge-Kutta formula of 4th order, and for this reason it was chosen.

The current simplified greenhouse environment model, based on energy and mass balance equations, follows the models proposed Takakura and Fang (2002) that involves a differential equation system with at least three equations. Starting from an arrow of temperature, absolute humidity, and solar radiation (T_{out}; W_{out}; Q_{Grout}) for external variables, the average temperature, absolute humidity , and ground surface temperature (T_{in}; W_{in}; T_f) inside the greenhouse can be numerically calculated by the ODE_PC4 function (Fig. 2.1), setting the integration step (i.e. 12.5 sec, for 5-minute simulation period between progressive time values; 2.5 sec, for 1-minute simulation period) and the initial conditions. At the beginning, variable values are set as: T_{in}=T_{out}; W_{in}=W_{out}; T_f =Constant temperature at boundary layer, at 0.15m.

VBA is a programming language that enables the developer to control any Excel operation. A customized macro was written, in order to copy the solution of the differential equation system to the subsequent row in the main worksheet, allowing for the next calculation of variables (Fig. 2.2). The 'control logic' can be written in a 'cell' along the row, using nested 'if' conditions. In this way, the subroutines written in the macro are much lighter to be set and even dynamically configurable and upgradable. The code forces Excel to calculate values only under the command 'calculate', thus refreshing all the dependent values at requested step. Via a classic 'For...Next' loop, the macro goes on up to the end of the period chosen for the simulation (Fig. 2.3).

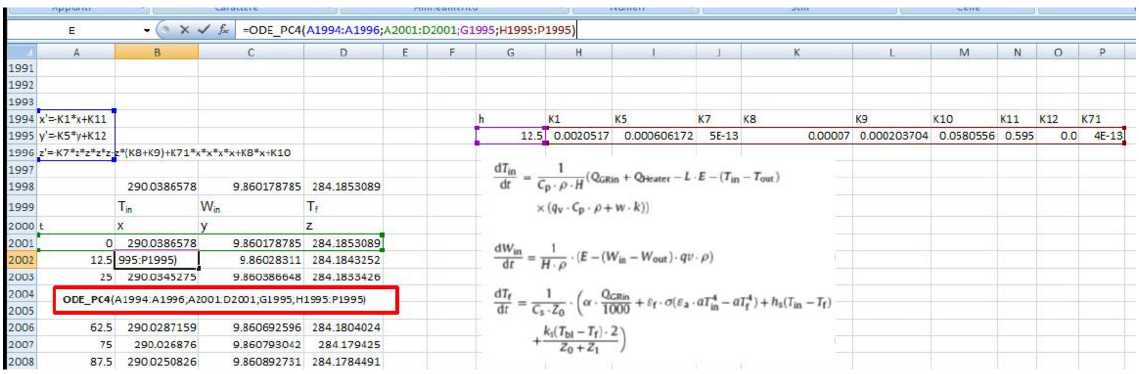
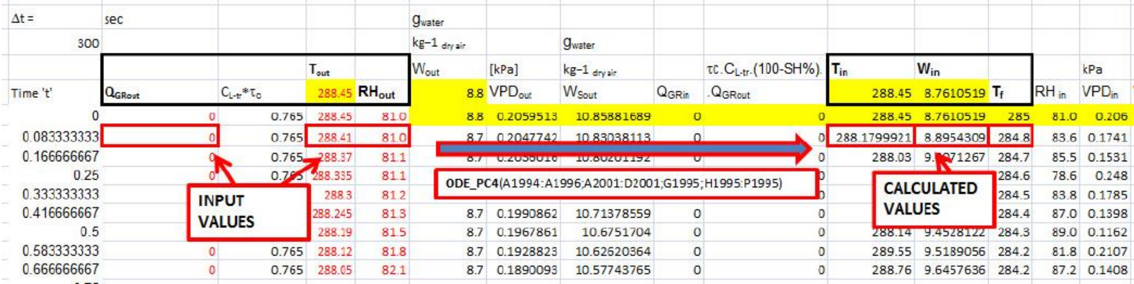
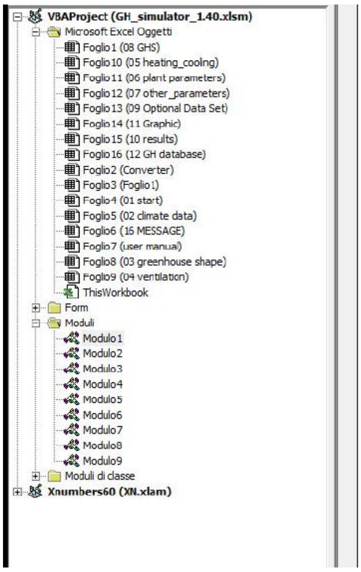


Figure 2.1: Set up of ODE_PC4 function for the numerical calculation of T_{in}, W_{in}, T_f variables.



Δt =	sec				g_{water}									
300					kg−1 dry air		g_{water}							
			T_{out}		W_{out}	[kPa]	kg−1 dry air		$\tau c.C_{L\text{-}tr}.(100\text{-}SH\%)$	T_{in}	W_{in}			kPa
Time 't'	Q_{GRout}	$C_{L\text{-}tr}*\tau_c$	288.45	RH_{out}	8.8	VPD_{out}	W_{Sout}	Q_{GRin}	$.Q_{GRout}$	288.45	8.7610519	T_f	RH_{in}	VPD_{in}
0	0	0.765	288.45	81.0	8.8	0.2059513	10.85881689	0	0	288.45	8.7610519	285	81.0	0.206
0.083333333	0	0.765	288.41	81.0	8.7	0.2047742	10.83038113	0	0	288.1799921	8.8954309	284.8	83.6	0.1741
0.166666667	0	0.765	288.37	81.1	[illegible]	[illegible]	[illegible]	[illegible]	0	288.03	[illegible]	284.7	85.5	0.1531
0.25	0	[illegible]	288.335	81.1								284.6	78.6	0.248
0.333333333			288.3	81.2								284.5	83.8	0.1785
0.416666667			288.245	81.3	8.7	0.1990862	10.71378559	0	0			284.4	87.0	0.1398
0.5			288.19	81.5	8.7	0.1967861	10.6751704	0	0	288.14	9.4528122	284.3	89.0	0.1162
0.583333333	0	0.765	288.12	81.8	8.7	0.1928823	10.62620364	0	0	289.55	9.5189056	284.2	81.8	0.2107
0.666666667	0	0.765	288.05	82.1	8.7	0.1890093	10.57743765	0	0	288.76	9.6457636	284.2	87.2	0.1408

Figure 2.2: Sequence in calculation of T_{in}, W_{in}, T_f variables.



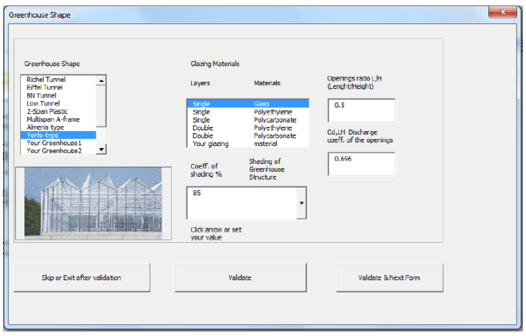

```
Have = Cells(12, 36)
Dim C1 As Double

For rwindex = 201 To 300
Range(Cells(rwindex, 18), Cells(rwindex, 25)).Select
Selection.Copy
Range("H1995").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
Range(Cells(rwindex, 12), Cells(rwindex, 14)).Select
Selection.Copy
Range("B1998").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
Calculate
Range("B2025:D2025").Select
Selection.Copy
Cells(rwindex + 1, 12).Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
Calculate
 'verifica se CO2 enrichment = off
If Cells(17, 13) = 0 Then
Cells(rwindex, 54) = 0

'verifica se la pianta consuma CO2
ElseIf Cells(rwindex, 52) < 0 Then
  Cells(rwindex, 54) = 0

Else:
I = 1
Do
'calcola la dose di CO2 per arrivare al CinSP = Set Point concentraz. CO2in
 C1 = dt * 7.64505119453925E-05 * Cells(rwindex, 12) / Have * (I * dCdos - Cells(r
 I = I + 1
Loop Until (C1 >= CinSP)
```

Figure 2.3: VBA Macro for calculating subsequent values of T_{in}, W_{in}, T_f variables.

3. Results and Discussion

A "quantitative" interactive (Excel) workbook, QIW, is an interactive workbook that can be used to train a student to solve a 'mathematical problem' by performing a quantitative method, that is, by performing an algorithm that terminates with the solution of the problem (DuPort, 2012). The workbook presented in this paper can be seen as a quantitative interactive workbook: any climate control model can be fruitfully explained students, providing continuous binding of theory and exercise, by an illustrative tool to both illustrate the method and perform it. The workbook has undergone a license approval process, thus getting an Italian Copyright protection.

The workbook produces realistic approximations of the dynamic behavior of greenhouse environments with different design configurations and operational strategies for 24-h simulation periods. An user interface enables easier manipulation, and editing the technical data. Results can be shown as graphs, or numerical data (Fig. 3.1).



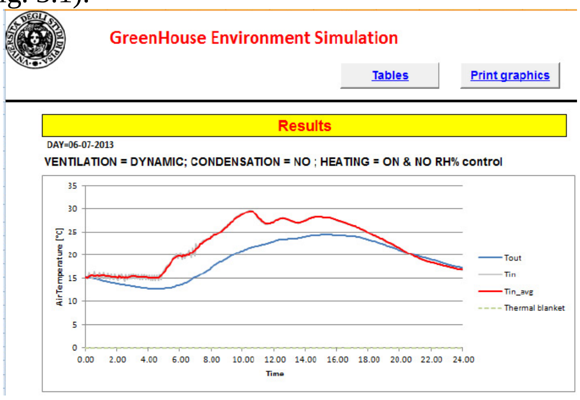


Figure 3.1: Example of an User Form set up in the worksheet (left); Simulation results (right).

4. Conclusion

The present paper describes the first workbook of the a dynamically configurable and upgradable platform for the simulation of a greenhouse environment developed via the Xnumbers Excel® addin and VBA code in MS Excel Environment. Xnumbers addin, can solve arithmetic, trigonometric, logarithmic, exponential, differential, integration, and matrix calculus problems, among others. The complex system represented by the greenhouse environment can be simulated with a model based on energy and mass balance differential equations, and performed with the Greenhouse Environment Simulation (GHES)© software for Excel®. This software can be used as a base for an 'Interactive courseware' on a desktop, or laptop computer, for teaching a course, even with a self-paced eLearning material. QIW courseware (QIWC) has many distinct advantages over other course presentations. It provides engagement, involvement, participation, and interaction with students (DuPort, 2012). Moreover, QIWC content are easily augmentable or even changeable, thus highly matching the educational purposes.

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UAV's multispectral remote sensed imagery for precision agriculture. A case-study in a olive orchard

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Keywords: Unmanned Aerial Vehicle (UAV), multispectral imagery, olive orchard, precision agriculture

Objectives

The objectives of this paper refers to the potential in using multispectral UAV imagery at cm-level resolution in the precision farming domain. The present work reports some experiences and critical considerations using new multispectral camera Tetracam Micro-MCA6 Snap in a photogrammetric workflow aimed at the generation of high-resolution orthophotos and vegetation index maps for olive orchard management and monitoring.

Material and Methods

The proposed workflow has been synthesised in Fig. 1 that shows the main steps of processing and extraction of useful information to obtain the expected results.

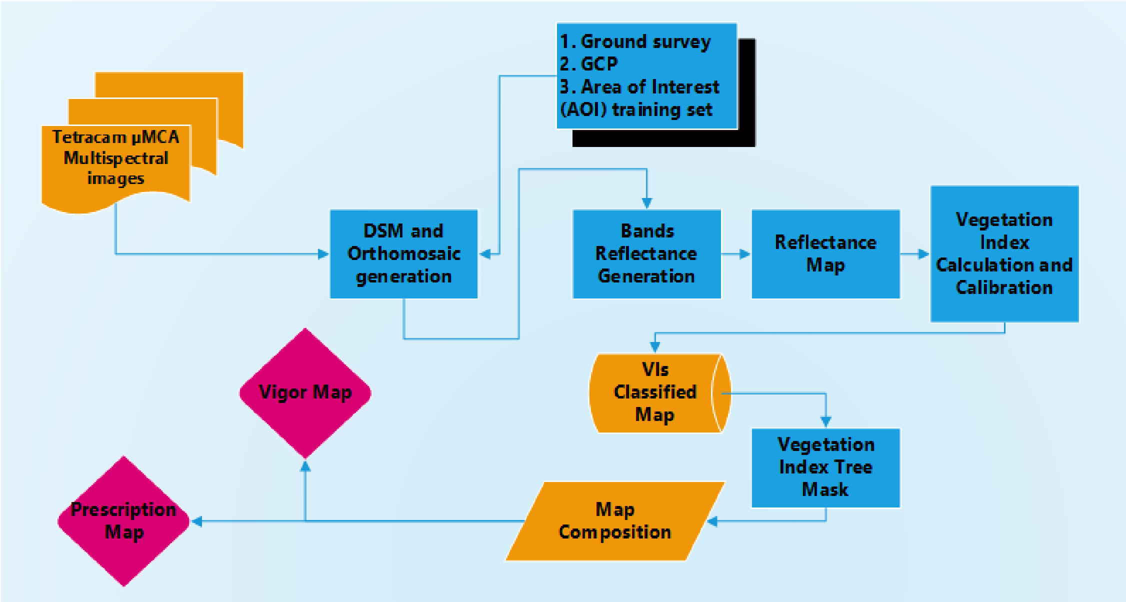

Figure 1 - Geoprocessing workflow showing the principal steps of the adopted methodology.

Study area, UAV platform and data collection

The UAV system was tested in two olive orchards with a traditional single-tree distribution and situated in the "Barone Macrì C.R." farm located in the Gerace municipality (Province of Reggio Calabria – Italy). An experimental plot of 5600 m^2 with an average slope of 20% was established to perform surveys. The UAV platform used was a Multirotor G4 Surveying-Robot (Service Drone GmbH), equipped with six high-efficiency electric motors, brushless gimbal and flight control with dual 32-bit processor, able to correct the position 512 times per second of flight, thus ensuring a much more stable flight (Fig. 2). A flight mission was first planned with UAV Planner 3D tool implemented in QGIS 2.18 "Las Palmas" software (QGIS Development Team, 2016), over the study area. The flight was performed within an altitude of 80 m above the ground level at 2 m s^{-1} cruise speed for images acquisition. Total overlap was set to 80% and side lap to 75%.

The miniature multiple camera array, known as the Micro-MCA6, is a multispectral camera produced by Tetracam Inc (www.tetracam.com). The multispectral camera consists of 6 individual sensors housed in one unit, one named as "master", responsible for synchronising the other named as "slaves" (Table 1). Each sensor is constituted of an objective lens with interchangeable band pass filter, progressive shutter and a digital CMOS (Complementary metal-oxide-semiconductor) sensor. Each of the 6 CMOS sensors has a dimension of 6.66 x 5.32 mm and had a pixel size of 5.7 microns (Fig. 4). Each exposure of the sensor captures 1.3 megapixels per channel giving a total of 7.8 megapixels across the 6 bands. Each pixel in the MCA6 capture data at either 8 or 10 bit.

Table 1 - Tetracam MicroMCA 6 sensor bands specification and wavelength sample values.

Slave	**Channel**	**Wavelenght (central value) [nm]**
Master (0)	NIR 1	810
1	Visibile – Blue	490
2	Visibile – Green	550
3	Visibile – Red	680
4	Red-edge	720
5	NIR 2	900

Figure 2 - Multirotor G4 Surveying-Robot (Service Drone GmbH) equipped with Tetracam MicroMCA multispectral camera (left); camera mounted on UAV gimble and ready to capture images (right).

Ground Control Point and data processing

Within the study area, 40 x 40 cm white boards with a black cross in the centre were used as ground control points (GCPs). GCPs were distributed all over the field, trying to cover the maximum surface as possible and along the corner of the entire study area. Every GCP was georeferenced in the field with a RTK-GNSS in coordinate system WGS84/ETRF1989 UTM33N (EPSG 32633) (planimetric accuracy ±2.5cm). The acquired images in *.RAW native format, produced with a ground sample distance (GSD) of 3 cm/pixels, were converted to 10-bit TIFF format using Tetracam's software PixelWrench2 (version 1.2.2.8, Tetracam, Inc., Chatsworth, USA). Single TIFF's (single band images) were then stacked with a specific script implemented in R software 3.2.5, to provide a 7-mutispectral bands image. Single multispectral images were then processed with Pix4Dmapper Pro version 3.1.22. Classical photogrammetric parameters were calculated: internal and external camera orientation, errors of the verification points. Next, 3D point cloud and the DSM were derived. Finally, the separated images were projected over the DSM and the orthomosaic was generated (Fig. 3). Finally, radiometric calibration and reflectance maps were produced. For each band, Pix4Dmapper produces one reflectance map. The created orthoimages were the base for successive processing.

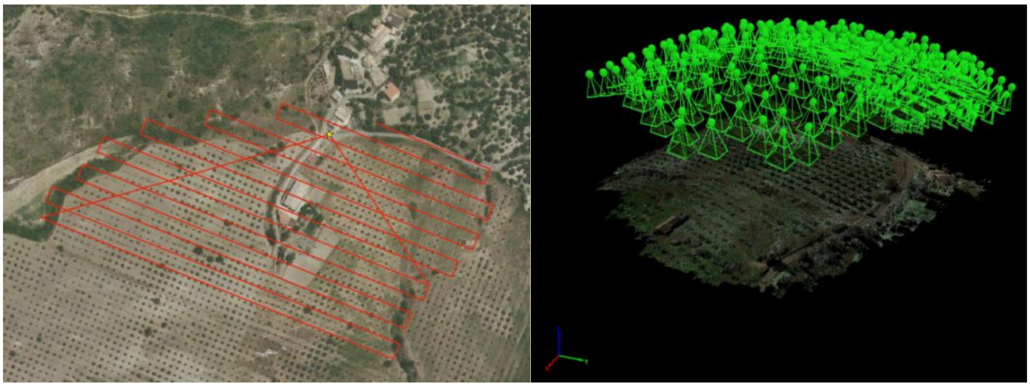

Figure 3 - Study area flight plan visualization: red lines indicates UAV flight route (left); point cloud generation after single multispectral TIFF images photogrammetric processing.

Vegetation Indices (VIs)
In order to investigate the olive trees biophysical characteristics, a set of two vegetation indices (Vis) were derived from the multispectral image (Table 2): normalized difference vegetation index (NDVI) and normalized difference Red-edge index (NDRE).

Table 2 - Vegetation index formulation used in this study.

Index denomination	**Index formula***	**References**
Normalized Difference Vegetation Index (**NDVI**)	$\frac{(NIR - Red)}{(NIR + Red)}$	(Rouse et al., 1974)
Normalized Difference Red Edge Vegetation Index (**NDRE**)	$\frac{(\rho 750 - \rho 705)}{(\rho 750 + \rho 705)}$	(Barnes et al., 2000)

*where ρ is the reflectance at that wavelength.

Multispectral datasets of olive orchards were evaluated in discriminating vegetation reconstruction and properties without any ground radiometric measure. However, careful descriptions of the agricultural characteristics provided by farmers were used to validate our findings.

Results
For every dataset multiband orthoimages was produced and analysed in relation to different olive orchard conditions (Fig. 4). The VIs analysis showed detailed information about olive tree vegetation properties (Fig. 5). In particular, a good performance has been achieved by all calculated indices. The NDVI identified the entire green component in the surveyed area, discriminating the different degree of coverage by the different plant species found in the scene. Referring only to olive trees, the index values range from 0.38 to 0.60. Moreover, it is already possible to distinguish the different areas of the olive orchard where there is an increased tree biomass.

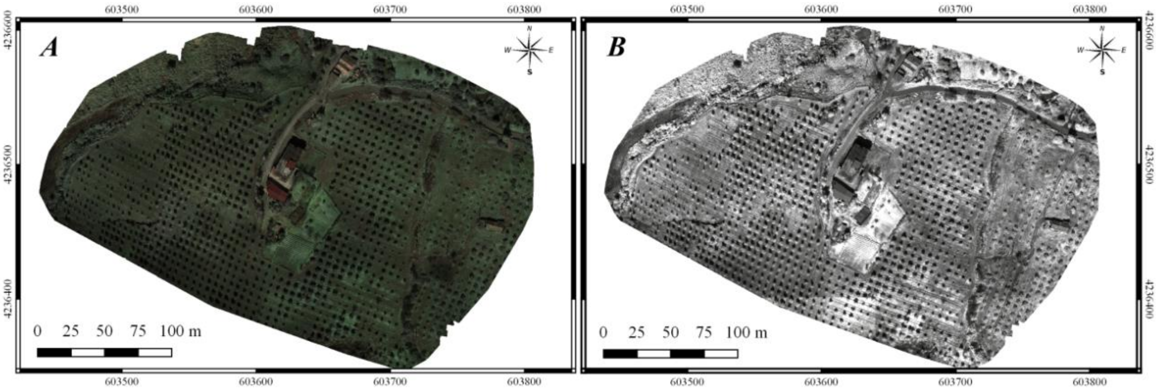

Figure 4 - (A): Multispectral high resolution orthophotos of the study area in RGB colour composite; (B): derived reflectance map obtained by processing original multispectral ortho-images.

More information was obtained using the NDRE index, which investigates in the Red-Edge electromagnetic region and thanks to the high geometrical resolution of the obtained imagery, it was able to discriminate in a very precise way the different green component structure, useful in describing the actual state of vigour of the olive trees. In addition, the index highlights the differences in structure of the tree and shrub layer, with the first reaching values slightly above 0.44, clearly indicating the unhealthy state of the crop.

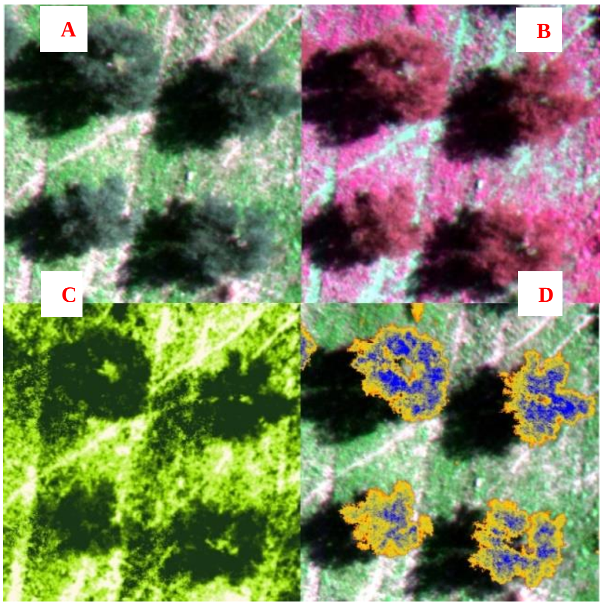

Figure 5 - Detailed sample maps view: (A): RGB image composite; (B): false infrared colour composite; (C): NDVI colour map; (D): NDRE colour map at canopy scale.

Conclusions

The use of an UAV platform, coupled with a multispectral camera as Tetracam MicroMCA6 Snap, has proved flexible and reliable in obtaining the photogrammetric reconstruction at the farming scale. Vegetation is easily detectable manipulating original bands (false infrared vision in Fig. 5) in high resolution map (3 cm GSD). The NDVI map showed an improved possibility in green biomass detection. The NDRE index significantly improved the estimation results compared to NDVI in our research (Fig. 5). Therefore, using high-resolution contents from UAV data, more focused analyses were performed only on the cultivated areas, excluding ground and shadows, in order to obtain a good reconstruction of the olive orchard and the description of the crop conditions.

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Semi-automatic vine rows detection and NDVI calculation from UAV images in precision viticulture

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Keywords: Unmanned Aerial Vehicle (UAV), tree detection, precision viticulture, precision agriculture

Summary
Remote sensing in precision viticulture is attracting growing interest thanks to the availability of modern Unmanned Aerial Vehicles (UAV) characterized by low operational costs, high operational flexibility and high spatial and spectral resolution of imagery. UAV multispectral sensors produce images measuring spectral response of canopy useful to calculate vegetation indices which show vine vegetation status related to various kind of stresses. The proposed approach, integrating open-souce and free GIS software, allow the identification, segmentation, and numbering of vine rows and sections along the rows. The subsequent NDVI calculation within these sections gives information about vegetation health of vines which can be analyzed and aggregated at different levels (section, multi-section, row, plot). Results, similarly to previous studies, confirms the importance to increase the precision with which individual vines and vine rows should be identified within an UAV remote-sensed image. Moreover, they shows how a vineyard zoning and related management based on ordinary NDVI, calculated using all field data, could be misleading. However, further applications are needed to better assess the actual effectiveness of the proposed methodology.

1. Introduction

Precision viticulture is growing substantially thanks to the availability of improved and cost-effective instruments and methodologies for data acquisition and analysis. In this field, the increasing use of modern Unmanned Aerial Vehicles (UAV) has opened new possibilities for data acquisition due to their low operational costs, high operational flexibility and high spatial and spectral resolution of imagery.

The use of vegetation indices (VIs), calculated using UAV remote sensing multispectral sensors, measuring spectral response of canopy in the wavelength of green, red, red-edge and near infrared (NIR) is attracting growing interest for assessing and monitoring vineyard vegetation status related to various stresses and yield parameters (see e.g. Di Gennaro et al., 2016, Baluja et al. 2012, Zarco-Tejada et al. 2013). Despite the wide range of VIs available in literature, the most commonly used one for assessing vegetation status remains the NDVI - Normalized Difference Vegetation Index (Weier et al., 1999). It is calculated as follows (1):

$$NDVI = (NIR - R)/(NIR + R) \quad (1)$$

where NIR and R are the reflectance (reflected energy on incident energy, at canopy level) in the near-infrared and in the red portion of the EM spectrum. The NDVI usually varies between -1 (water) and +1 (dense and vigorous vegetation).

In order to achieve a more objective and effective analysis of vineyard vegetation status, limiting soil or grass influence, also in view of a plot zoning, is important to increase the precision with which individual vines and vine rows can be identified within an remote-sensed image (Hall et al., 2003; Poblete-Echeverría et al., 2017). However the majority of such studies (see e.g. Nolan et al 2015, Comba et al 2015, Rabatel et al 2008, Wassenaar et al 2002) are based on rather complex methodologies that could be hardly integrated in widely available free or open-source GIS software. In this direction, starting form UAV high-resolution multispectral ortho-images, we propose a semi-automatic approach, completely based on open-source or free software, to identify and isolate vine rows and to define consecutive numbered sections along each vine row. This segmentation process allows us to calculate an NDVI index considering only the most representative part of vine vegetation and to develop an effective spatial scheme supporting vineyards geo-informatization.

2. Materials and Methods

The study area is a "Sagrantino" vineyard located in Montefalco, Umbria, central Italy. The UAV data collection was performed on September, 14th, 2016 using a compact, light and robust carbon hesacopter (SR-SF6, Skyrobotic, Italy) equipped by a stable flight controller, a GPS, and a multispectral sensor (Sequoia™, Parrot, FR). This sensor is composed by four single-bands cameras, detecting green (550 BP 40), red (660 BP 40), red edge (735 BP 10), and NIR (790 BP 40), with a pixel resolution of 1280 x 960 and a radiometric resolution of 10 bit. The sensor includes a 16 Mpix RGB camera as well. Flight height was set to 80 meters above ground with an average flight speed of 8 m/s. Thanks to the gimbal system, the camera was able to collect stable and nadiral images with an on-ground spatial resolution of 8.2 cm. Images were mosaiked and orthocorrected using the Pix4D Mapper Pro™ Software (Switzerland). Calibration coefficients were calculated using a picture taken before the flight on an Airinov calibration tag.
The semi-automatic vine rows detection methodology and subsequent NDVI calculation was tested on a rectangular image subset of 60 x 50 meters. It includes the following steps, developed both in QGIS (Quantum GIS Development Team, 2017) and SAGA (Conrad et al., 2015) software:

1. NDVI calculation (QGIS) using red and NIR bands of UAV orthomosaic;
2. Seed generation (SAGA) to identify locally higher NDVI areas;
3. Polygonal grid generation (QGIS) considering vine rows spacing;
4. Geoprocessing (QGIS) to generate a geometrically adjusted grid containing vine rows and row sections;
5. Grid statistics within polygons (SAGA) to calculate average NDVI values within row sections (RW-NDVI);
6. IDW interpolation (QGIS) to calculate a continue NDVI layer showing spatially only vines vegetation status (IRW-NDVI).

The resulting index was compared to the initial NDVI (based on all-field data) through a visual and a correlation analysis to assess the advantages related to the application of the proposed methodology.

3. Results and Discussion

The proposed approach, starting from an UAV remote sensed multispectral image, allow the identification, segmentation, and numbering of vine rows and sections along the rows (Figure 1). The subsequent RW-NDVI calculation within these sections (Figure 2) gives information about vegetation health of vines which can be analyzed and aggregated at different levels (section, multi-section, row, plot) and possibly compared in detail with other field data. Visual comparison (Figure 2) and pixel by pixel correlation analysis between NDVI and IRW-NDVI (R^2 = 0.61) show clearly their marked differences highlighting how a vineyard zoning and related management based on ordinary NDVI could be highly misleading.

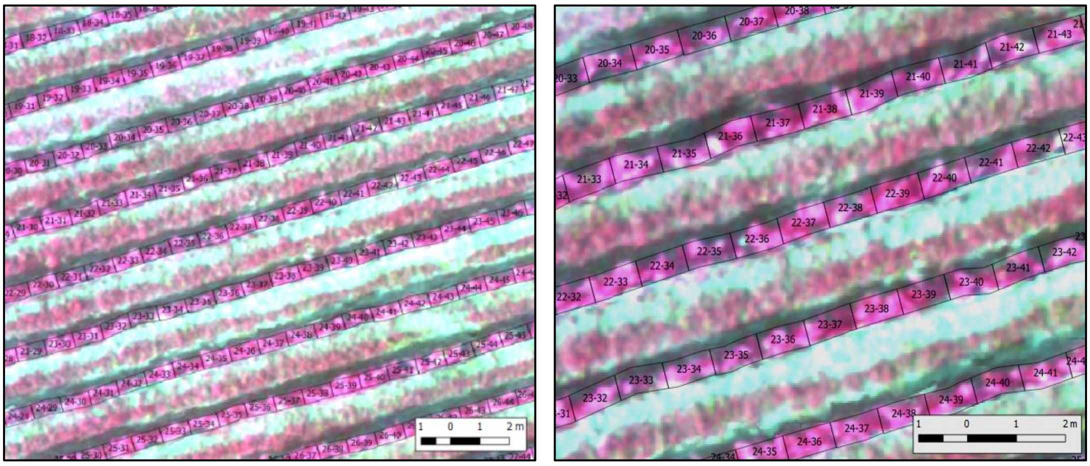

Figure 1: Numbered vine rows and row sections superimposed over the multispectral ortho-mosaic (RGB 532).

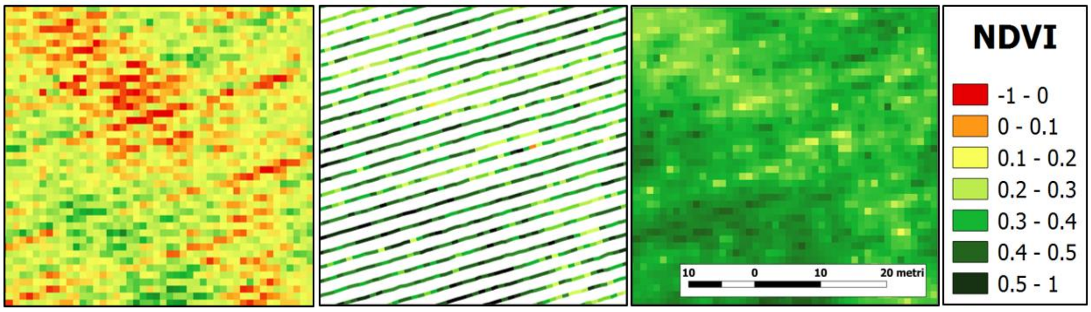

Figure 2: NDVI from UAV resampled to 1 meter (left), average NDVI calculated within row sections (RW-NDVI, center), 1 meter NDVI interpolated using RW-NDVI value (IRW-NDVI, right).

4. Conclusion

The approach results particularly useful to extract very informative data related to vines vegetation status eliminating the influence of inter-row cover (including e.g. soil, grass) on final index calculation. The analysis, similarly to previous studies, confirms the importance to increase the precision with which individual vines and vine rows should be identified within an remote-sensed image to calculate vegetation indices more informative of vine status. Compared to other similar approaches aimed to tree detection, the proposed methodology is completely based on open-source and free software and appears simpler and more intuitive. Moreover, the polygonal grid scheme, based on a proper numbering of rows, inter-rows and sections along them, can support a complete geo-informatization of vineyard. However, this step requires a quite time-consuming initial polygonal grid generation that, anyway, could be performed only once per vineyard. Additional applications are needed to better assess the effectiveness of the proposed methodology.

Acknowledgments

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TOPIC 3

ENERGY, WASTE AND BY-PRODUCTS SMART USE

Effects of polyphenols on biogas production from olive oil mill wastewater

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Keywords: anaerobic digestion; oil residues; inhibiting compound; methane yield; microbial adaptation.

Summary
In order to identify the polyphenols (PP) concentration inhibiting the anaerobic digestion of olive oil mill wastewater and explore the advantages of possible microbial adaptation, batch tests have been carried out on three blends of olive oil mill wastewater and inoculum (digestate of animal origin) with PP concentrations of 0.5, 1.0 and 2.0 g/L in mesophilic conditions. The tests have shown total inhibition at PP concentration of 2.0 g/L. The positive effect of adaptation to substrate in the blends with 1.0 and 2.0 g/L of PP has been demonstrated (methane yield increases from 70% to 400% compared to not adapted blends).

1. Introduction

In order to improve the anaerobic digestion of wastewater with high concentration of polyphenols (PP), produced by various industries and specifically from olive oil mills, it is necessary to investigate the toxicity of these phenolic compounds on methanogenic activity. Literature report several studies on the effects of PP on anaerobic digestion of olive oil mill wastewater (OMW), but often data are dispersed due to the different conditions adopted for the process and specifically for the different inocula used (Gonzàlez-Gonzàlez et al., 2015). The majority of studies have mainly focused on the possibility of increasing biogas production and methane yield by using OMW co-digestion with other waste/by-products on pre-treatments for phenolic compounds removal. The number of investigations on the inhibiting limits of PP and the possibility of microbial population adaptation to phenols is lower.
In order to fill this gap, this paper provides a contribution to the comprehension of the biochemical process in the anaerobic digestion of OMW; through batch tests, the PP concentration in OMW, which induces partial or complete inhibition by using non-adapted and adapted inocula, respectively, has been evaluated.

2. Materials and Methods

Raw OMW, drawn by a 3-phase olive oil mill, was blended at different concentrations with digestate, used as inoculum, to obtain different PP contents. OMW showed a low PP concentration (1.05 g/L) - presumably under the expected inhibition limit - and thus was concentrated in oven at 60 °C (in any case, under the evaporation temperature of PP).
In the first series of tests (BMP1), digestate was taken from a commercial biogas plant, fed mainly with manure and other agricultural residues. The BMP1 series consisted of three tests (each one in triplicate) evaluating the biogas/methane yield reduction at increasing PP concentrations (0.5, 1.0 and 2.0 g/L, indicated below as $PP_{0.5}$, $PP_{1.0}$ e $PP_{2.0}$). Subsequently, the digestate of BMP1 tests was used as inoculum of BMP2, to evaluate whether an inoculum, already subject to anaerobic digestion of significant PP concentration, plays positive effects on biogas production and bacteria tolerance to PP, compared to a not adapted inoculum. BMP2 tests were carried out (each one in duplicate, due to the insufficient amount of acclimated inoculum) at PP concentrations of 1 and 2 g/L. For each of the two series of tests, a fourth test, assumed as control, was carried out using only inoculum, to evaluate endogenous biogas yields.
Digestate and OMW were previously characterised in triplicate, by measuring Total Solids (TS,

by oven drying the wet biomass at 70 °C until weight stabilisation), Total Volatile Solids (TVS, by calcination of the dry matter) and pH (by portable pH-meter, XS Instruments). On OMW also COD and PP concentrations were measured in triplicate; COD was determined on diluted (1:10 v/v) effluents by cuvette cap tests (WTW, code 1.14555, photometer WTW, PhotoLab S12), while PP concentration was measured by the Folin-Ciocalteu colorimetric method (Folin and Ciocalteu, 1927), expressed as g/L of gallic acid and measured by spectrophotometer (PerkinElmer, Lambda 35 UV-VIS).
Table 2.1 reports the characteristics of the four blends subject to BMP1 and BMP2 tests.

Table 2.1: Main physico-chemical parameters of blends subject to anaerobic digestion tests.

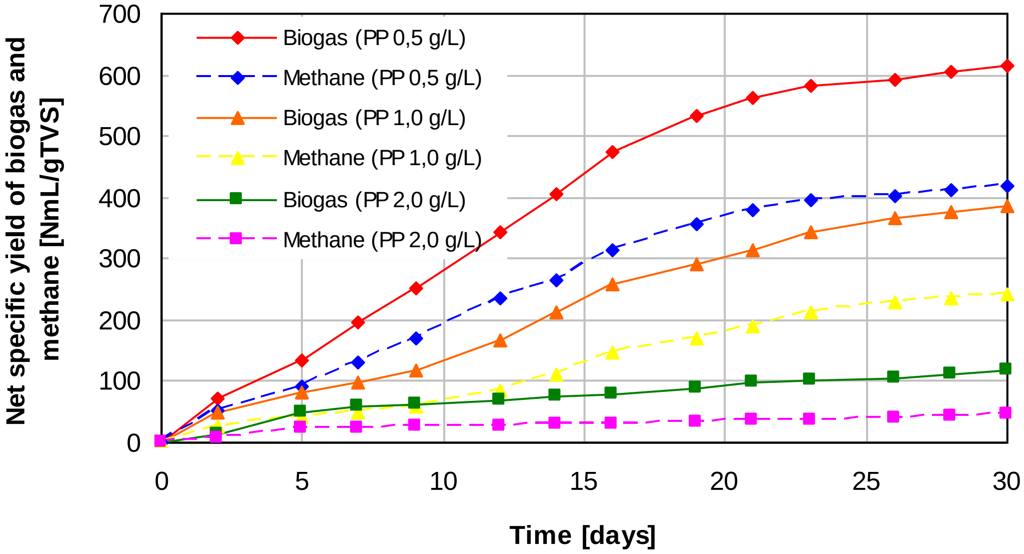
Substrate	Parameter	Test series						
		BMP1				BMP2		
		Inoculum	*$PP_{0.5}$*	*$PP_{1.0}$*	*$PP_{2.0}$*	*Inoculum*	*$PP_{1.0}$*	*$PP_{2.0}$*
Inoculum	*Volume (mL)*	200						
	TS (g)	11.8				14.6		
	TVS (g)	8.9				9.2		
Concentrated OMW	*Volume (mL)*	-	26	60	170	-	63	183
	TS (g)		3.4	7.6	21.6		6.3	18.4
	TVS (g)		2.4	5.5	15.6		4.5	12.9
	COD (g)		2.8	6.6	18.6		6.7	19.7
	PP (g/L)(*)		0.5	1.0	2.0		1.0	2.0

Notes: TS = Total Solids; TVS = Total Volatile Solids; (*) expressed as g/L of gallic acid.

All batches were kept for 30 days under mesophilic conditions (35 °C). Before test starting, sodium bicarbonate was added to increase the buffering capacity. Each test was carried out in a hermetic bottle, continuously stirred by a magnetic bar.
Throughout the experiment, biogas production (by fluid displacement method, Calabrò et al., 2016) and methane content (by CO_2 precipitation in a 3M solution of NaOH) were measured three times a week. Average methane yields were estimated as the product of produced biogas volume by methane content. Methane yields of control tests were subtracted to the corresponding values of the other tests, in order to estimate the net specific value. The time needed to get 50% and 90% of the maximum of methane yield ("T_{50}" and "T_{90}") was also evaluated.

3. Results and Discussion

As regards the BMP1 tests (raw inoculum), the maximum cumulative value (0.419 NL/g_{TVS}) of net specific methane yield was observed in the batch $PP_{0.5}$. With 2-fold and 4-fold PP concentrations (blends $PP_{1.0}$ and $PP_{2.0}$) methane yields were 43% (0.244 NL/g_{TVS}) and 89% (0.045 NL/g_{TVS}) lower, respectively. The batches with the highest PP concentration got 50% of the maximum methane yield just after 5.6 days, thus showing an early blockage of methanogenic activity; the other blends showed T_{50} of 11.1 ($PP_{0.5}$) and 14.6 ($PP_{1.0}$) days, while the methane production rate was practically depleted after 20-25 days (Table 3.1). The methane production shown by batches $PP_{1.0}$ increases almost constantly throughout the experiment, while batch $PP_{0.5}$ produced methane with a higher rate compared to $PP_{1.0}$ until the 20th day, while subsequently the production rate was similar (Figure 3.1).



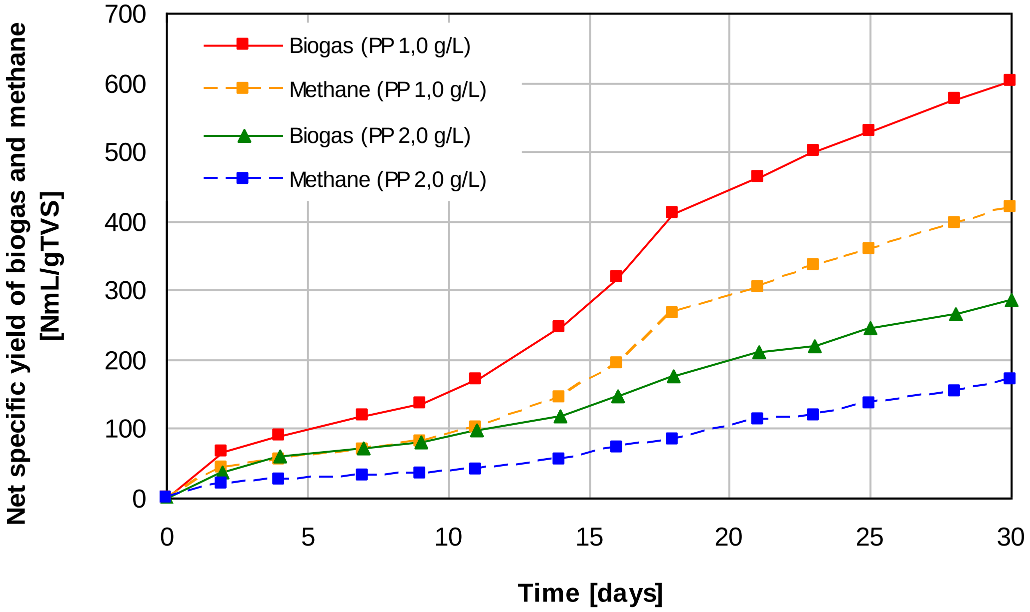


Figure 3.1: Net specific biogas/methane yield in BMP1 (upper) and BMP2 (lower) tests.

Biogas cumulative production was similar to that of methane; biogas yield was 0.614, 0.385 and 0.116 NL/g_{TVS} for blends $PP_{0.5}$, $PP_{1.0}$ and $PP_{2.0}$, respectively (Figure 3.1). The highest methane content, averaged during the overall process, was detected for the blends $PP_{0.5}$ (58%) and $PP_{1.0}$ (47%), while, compared to the other blends, a noticeable reduction of methane content was observed in $PP_{2.0}$ (28%).

In the BMP2 tests (adapted inoculum), the cumulated net specific methane yields measured for the two blends, $PP_{1.0}$ and $PP_{2.0}$, were 0.419 and 0.170 NL/g_{TVS}, respectively. T_{50} and T_{90} were higher than in the BMP1 tests (Table 3.1), probably due to non-degraded PP in the digestate derived from BMP1; however, methane production rate quickly recovered after adaptation phase for both blends. A slow increase of net specific methane yield was detected for batches

$PP_{1.0}$ e $PP_{2.0}$ in the first ten days of the experiment; this production increased with a higher rate throughout the subsequent ten days (Figure 3.1).
The biogas yield was 0.602 and 0.286 NL/g_{TVS} for blends $PP_{1.0}$ and $PP_{2.0}$, respectively (Figure 3.1). Both blends had a high content in methane (65%, $PP_{0.5}$, and 58%, $PP_{2.0}$). This outcome suggests a possible adaptation of the microbial population to the inhibiting compounds in the batch.

Table 3.1 - Net specific methane yield (in NL/g_{TVS}) after 30 days and time (days) to 50% (T_{50}) and 90% (T_{90}) of maximum yield.

Test	Net specific methane yield			Time	
	Maximum	**50% of max**	**90% of max**	**T_{50}**	**T_{90}**
		BMP1			
$PP_{0.5}$	0.419	0.210	0.378	11.1	20.8
$PP_{1.0}$	0.244	0.122	0.219	14.6	24.4
$PP_{2.0}$	0.045	0.022	0.040	5.6	27.3
		BMP2			
$PP_{1.0}$	0.419	0.209	0.377	16.4	26.4
$PP_{2.0}$	0.170	0.084	0.153	18.0	27.8

For all the batches pH values (6.72 to 8.52) were always in the optimal range required for a balanced anaerobic digestion (6.5-8.5, Gonzàlez-Gonzàlez et al., 2015). The lowest final pH was measured for $PP_{2.0}$ (6.72), presumably because of the higher concentration of acids (not consumed by methanogenic bacteria).

4. Conclusion

This study has identified the concentration of polyphenols inhibiting the anaerobic digestion of OMW and has analysed the advantages of microbial adaptation to phenols. The outcomes of the batch tests carried out under mesophilic conditions suggest that, for a noticeable methane yield, raw OMW should be subject to anaerobic digestion at PP concentrations not higher than 1.0 g/L; moreover, given the benefits of adaptation of microbial population to significant concentrations of PP, it is advisable to blend OMW with an inoculum of the same substrate previously subject to anaerobic digestion.

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Gas heat pump for greenhouse heating in a stand-alone hydrogen plant: a mathematical study

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Keywords: Gas heat pump, stand-alone hydrogen plant, Greenhouse heating

Summary
Nowadays, diesel, LPG and natural gas are the main energy sources used for greenhouses heating. Alternative solutions are represented by the integration of renewable energy plants in agriculture. The aims of this research is to analyzed the energy performance of a photovoltaic, hydrogen and ground source gas heat pump (GSGHP) integrated stand-alone system during the winter season. The results showed that the system had a total energy efficiency to 12%. The performance of the system was low because the efficiency of the photovoltaic panels was low. In fact, starting from the energy available from the PV, the system has an efficiency of 96% if the COP of the heat pump is equal to 4. Finally, the heating system increased the greenhouse air temperature about 8°C respect to the external air temperatures.

1. Introduction

In according with the new European Directive 2010/31/CE and the Near Zero Energy Building (NZEB) concept, several current research are focus on the micro-generation systems based on renewable energy sources. Some attractive solutions are represented by the geothermal heating systems and stand-alone hydrogen plant in agricultural sector (Anifantis, 2016; Anifantis 2017). However, in the case of solar energy for greenhouse heating applications, the energy production and consumption are non-simultaneity and the renewable energy produced during the daylight hours must be stored during the night. In this paper a photovoltaic and hydrogen stand-alone systems integrated with a ground source gas heat pump (GSGHP) for greenhouse heating was studied. The GSGHP is composed by an internal combustion engine feed by hydrogen and drive shaft connected to a compressor of a geothermal heat pump. A performance analysis was conducted in order to define the total efficiency and the power production of the integrated system.

2. Materials and Methods

The behavior of the gas heat pump was mathematical modeled using the technical manuals provided by the manufacturer AISIN (TOYOTA group). Instead the rest of the system components have been analyzed using the data of an hydrogen plant implemented at the experimental farm of the University of Bari, located in Valenzano, Italy. In particularly, the electricity generated by 56 m^2 (A_{PV}) of polycrystalline photovoltaic panels (PV), during day time from 08:30 to 17:30, fed a electrolyzer which produces hydrogen by water electrolysis. The hydrogen was stored in a pressure tank at 30 bar. The ground source gas heat pump heated an air-inflated, double layer polyethylene film tunnel greenhouse of 106 m^2 of cover surface (A_{cf}) and 48 m^2 of area. The diagram of the plant is shown in Fig. 1 and the specifications of the plants are reported in Tab. 1. The experimental test was carried out in a winter day of February.

Table 1: Specifications of two renewable energy hydrogen plant.

Components	Specifications
Photovoltaic array	BYD 240P6-30, 34 module, 8.2 kW peak
Electrolyser	Monopolar alkaline electrolyzer 2.5 kW, 0.4 Nm^3/h – H_2Nitidor S.r.l.
H_2 storage	30 bar, 0.5 m^3
Gas heat pump	Model AXGP224E1 8HP, Aisin (TOYOTA)
Geothermal borehole	120 m vertical double U-bend ground heat exchanger
Fan-coil unit	Carisma CRC53MV, Heating capacities: 3.59 kW; air flow rate 495 m^3/h
Greenhouse	Air inflated, double layer polyethylene film tunnel greenhouse

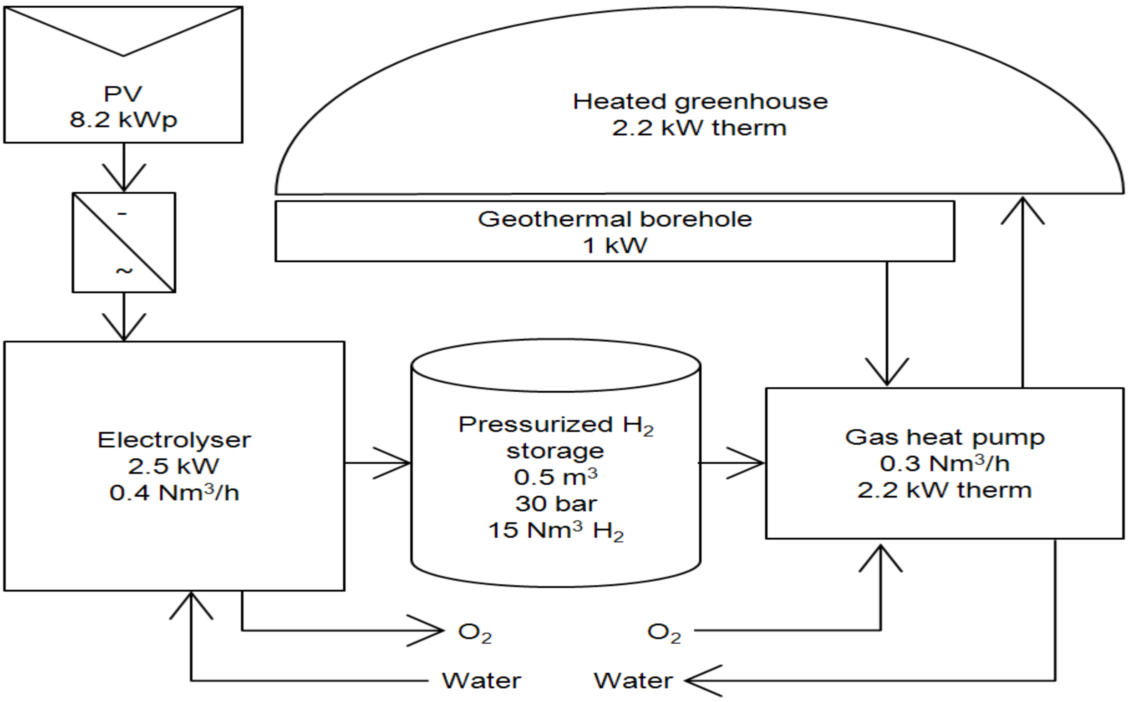

Figure 1: PV, GSGHP in a stand-alone hydrogen system for greenhouse heating.

Considering a clear day, the fraction of the instantaneous PV array power output used through electrolyzer input (P_{el}) is given by (Anifantis, 2017):

$$P_{el} = \Phi \eta_{vr} A_{PV} I_T \eta_r [1 - B(T_c - T_r)] \quad (1)$$

where η_r(=0.15) is the efficiency of the solar cell at a referenced solar radiation, T_c(~35°C) the solar cell temperature, T_r(=25°C) the referenced temperature of the cell and B(=0.005°C^{-1}) the temperature coefficient of a solar cell, A_{PV} the PV array surface, I_T the solar radiation, η_{vr}(=0.97) the DC/AC converter efficiency and Φ the solar radiation usability. Φ was necessary because the peak power of the PV array should be increased to assure enough available power to cover the needs of the electrolyzer.

Instead, the energy efficiency of the electrolysis reaction η_{el} is given in terms of the lower heating value of hydrogen (LHV_{H2}=119.96 [MJ kg^{-1}]), the overall hydrogen production rate $q_{el,H2}$ [=0.00011 Nm^3 s^{-1}] and the hydrogen density at standard condition (δ_{H2}=0.09 [kg Nm^{-3}]) by the expression (Calderóna et al, 2011):

$$\eta_{el} = \frac{\delta_{H_2} \cdot q_{el,H_2} \cdot LHV_{H_2}}{P_{el}} \quad (2)$$

Gas driven heat pumps performance was calculated by using the Gas Utilization Efficiency (GUE) given by the manufacturer:

$$GUE = 0.64 + 0.32 \cdot COP \quad (3)$$

$$Q_1 = GUE \cdot Q_{1\_burner} \tag{4}$$

where the equivalent thermal power supplies by a hydrogen burner Q_{1_burner} is given by:

$$Q_{1\_burner} = \delta_{H_2} \cdot q_{fc,H_2} \cdot LHV_{H_2} \tag{5}$$

The GSGHP has the same coefficient of performance (COP) of a common GSHP:

$$COP = \frac{Q_1}{Q_1 - Q_2} \tag{6}$$

where Q_1 is the thermal power supplies by the heat pump and Q_2 is the heat power extracted from the ground through the borehole-probe heat exchanger. Q_2 is given by:

$$Q_2 = q_r \cdot l_t \tag{7}$$

where q_r is the heat exchange rate and l_t is the total active length of the borehole. Considering the steady state and the overnight winter conditions, the thermal power demand of the greenhouse was assessed with the equation(Ozgener & Hepbasli, 2005):

$$Q_1 = \left[\frac{A_{cf}}{R}\right](f_w)(f_c)(f_s)(T_i - T_a) \tag{8}$$

Assuming 1, 0.9 and 1 for the wind factor (f_w), construction type factor (f_c) and system factor (f_s), respectively and 0.28 m^2 °C/W for the greenhouse thermal resistance (R).

3. Results and Discussion

The results show that the use of a ground source gas heat pump unit integrated with a photovoltaic stand-alone hydrogen systems allows to have a total energy efficiency of 12%, starting from the sun to the GSGHP. The major limitation to the performance of the whole system was represented by the performance of photovoltaic, in fact, starting from the energy available from the PV, the system has a 96% efficiency with a heat pump COP of 4. The heating system increasing the greenhouse temperature by about 8°C compared with the ambient conditions in a representative winter day of February.

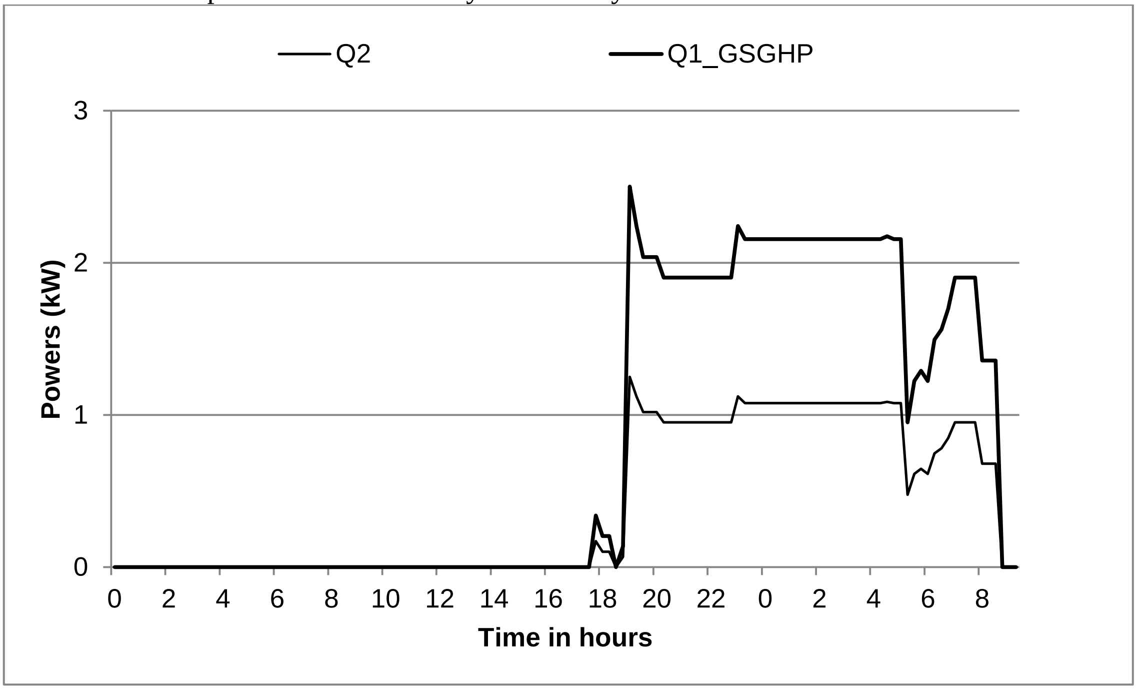

Figure 2: External layout of the stand-alone hydrogen plant and electrolyzer internal stack.

At night the fuel cell and the GSHP worked from 18:30 to 08:30 and start when the temperature decreased to 10°C. The thermal power output (Q_1) and input (Q_2) of the GSGHP is 2 kW and 1 kW respectively (Fig. 2). The heat exchange rate of the geothermal borehole required (q_r) for a double U-bend pipe is 10 W m^{-1}. The difference between the indoor and outdoor greenhouse temperatures ($T_{i\ GSGHP}$-T_a) was 8°C (Fig. 3).

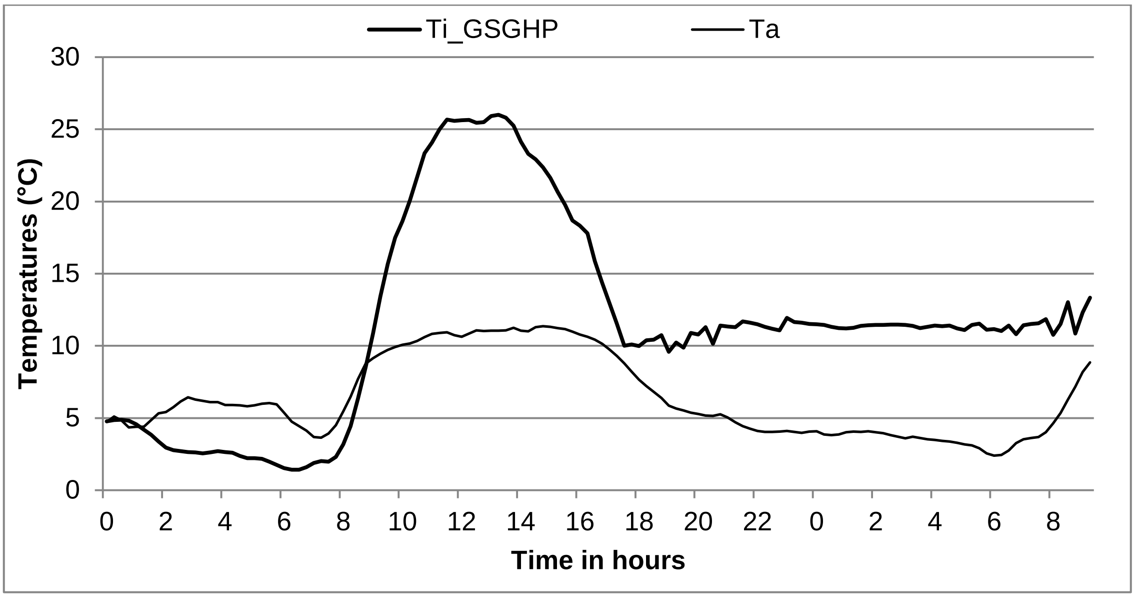

Figure 3: External layout of the stand-alone hydrogen plant and electrolyzer internal stack.

4. Conclusion

The present paper analyzed the overall performance efficiency of a ground source gas heat pump integrated with a stand-alone renewable energy plant. The energy efficiency of the plant is strongly affected by electrolyzer and heat pump management. Considering the energy efficiency of photovoltaic panels of 13%, an electrolyzer energy efficiency equal to 50%, GSGHP COP and GUE of 4 and 192% respectively, the overall system efficiency is 12%.

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Aquatic plant treatment system (APTS) based on duckweed for cleaning the liquid fraction of digestate

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Keywords: Duckweed, Wastewater treatment, Environmental Assessment

Summary
Composting plants combine compost and energy production using the Anaerobic Digestion (AD). However, the AD process generates residue whose liquid fraction is polluting and therefore needs to be subjected to expensive waste treatments with the loss of the value of the mineral elements. Therefore, it is necessary to develop technologies allowing the treatment of liquid digestate fraction and the uptake of those minerals as plant nutrients. The purpose of the project DUCK-TECH has been to provide a solution through an integrated biological system, i.e., an aquatic plant treatment system (APTS). An APTS for the liquid digestate fraction treatment has been implemented using duckweed *Lemnaceae* aquatic plant species, taking advantage of their ability to recover nitrogen and phosphorous and to reduce COD. The aim of this study is to evaluate the phytoremediation and environmental performances of the APTS based on duckweed. The preliminary results highlight that the environmental impact of liquid fraction treatment with APTS deeply ranges, depending on the duckweed growing. A further increase of the performances could be achieved through the valorisation of the duckweed biomass as a starch source for new bio-products.

1. Introduction

Our society is generating an increasing quantity of organic wastes, such as industrial, urban and agricultural ones. However, the opportunity of shifting the view of waste streams from pollutant to renewable resource exists. Waste treatments create a unique chance to generate additional fuels, chemicals and bio-products, while simultaneously recycling nutrients and water. Nowadays in Italy, the separated urban solid waste fraction reaches the 39%, 42.2% of which (4.81 million tons) is represented by the organic fraction of municipal solid waste (OFMSW). The OFMSW can be re-used to produce energy by means of anaerobic digestion (AD) and to recover organic material. The number of AD plants is currently increasing, new ones are planned for the next future and consequently a large amount of digested residue will probably be produced. This residue can be divided in a solid fraction and in a liquid one (De Baere et al., 2014). After the composting process, the first one is usually used as a fertilizer. The second one is considered as wastewater and, consequently, requires a process of purification that implies economic and energetic costs and the loss of macronutrients, particularly nitrogen (N) and phosphorous (P), as well.

Aquatic plants treatment system (APTS) represents an attractive way to purify wastewater and recover mineral elements. Moreover, it is worth mentioning (i) the positive impact on atmosphere in terms of sequestration of greenhouse gas (CO_2) due to plant growth and (ii) the consequent production of biomass that is gaining a market demand from green chemical industry. The *Lemnaceae*, or duckweed, is a family of aquatic plants that can be exploited to recover nutrients from wastewaters. Because of its large nutrient uptake ability (e.g., N and P) and its tolerance to high nutrient concentrations, duckweed has been used to treat domestic wastewaters. Duckweed grows faster than most of other plants by proliferation through

vegetative budding of new fronds at a doubling time of 16–24 h (Landolt, 1986; Peng et al., 2007).
In this context the purpose of the DUCK-TECH project is, on one hand, to develop research strategies in order to support the use of duckweed in APTS, and on the other hand, to provide knowledge for developing an integrate biological system able to purify wastewater coming out from an AD plant and to generate added value biomass.
The DUCK-TECK will survey the available duckweed germplasm collection to identify genotypes with the best growth, nutrient uptake and biomass quality performances. The Life Cycle Assessment (LCA) is a transparent methodology for estimating the potential environmental impacts of products and processes; within this project, a preliminary LCA will be performed in order to evaluate the environmental impacts of duckweed phytoremediation of digestate liquid fraction.

2. Materials and Methods

A pilot plant, consisting of 10 independent purification tanks (0.7 x 1.0 x 0.35 m) and one control tank, was assembled and connected downstream to an OFMSW AD plant from which 5 dm^3/day of diluted wastewater fraction (i.e., one part of liquid digestate fraction and four parts of tap water) were periodically added to each tank (Figure 1). The volume of water inside the tanks is maintained constant.

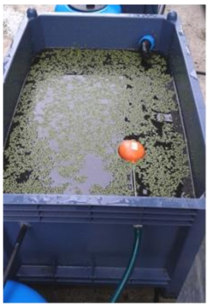

Figure1: The pilot plant for Lemnaceae growth on diluted wastewater. On the left a general view is showed, on the right a particular of a tank with growing Lemnaceae fronds.

From the *Lemnaceae* collection available at CNR-IBBA, some genotypes were added in each tank and let grow. The experiments were carried out during the summer-autumn 2016 season. Every week duckweed biomass was harvested with a net to evaluate the fresh weight increase. After the harvesting, 100 g of duckweed were put again in the treatment tank, whereas the remaining duckweed was used for biochemical and physiological characterization. At the same time, mineral and nutrient content (N-total, N-NH_4, N-NO_3, P and COD) in samples of (i) the diluted wastewater in the control tank and of (ii) the water after the duckweed growth were analysed to evaluate wastewater purification. Data concerning the environmental and the technological fluxes were collected to fill a database for the preliminary LCA focused on the eutrophication category. The inventory is translated into environmental impacts through the use of the CML-2001 impact assessment method and the calculations are performed with the PRéConsultants SimaPro. The functional unit considered is 1 dm^3 of digestate liquid fraction. The system boundaries include water consumption, land use and water emissions (Figure 2). Duckweed biomass is considered as a surplus of the system. Air emissions, which might provide high contributions to global warming category (Maucieri et al., 2017), are not included due to lack of primary data.

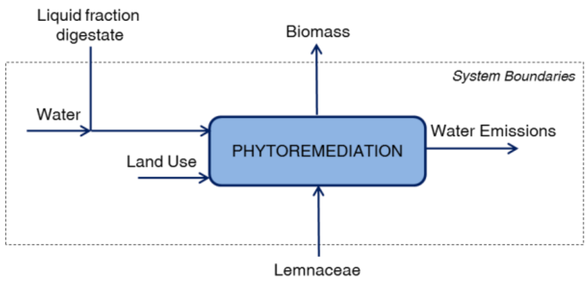

Figure 2: The system boundaries of the LCA

3. Results and Discussion

Several species from the duckweed collection were selected and tested. The experiment were mainly concentrated on three species: *Spirodela polyrhiza* (genotype code in collection: SPP), *Lemna gibba* (LEG) and *Lemna minor* (LA).

At the beginning of the experiments, the influence of the nutrient concentration on the *Lemnaceae* growth has been assessed. The results show that the AD wastewater fraction had to be diluted at least 20 times: a less dilution rate turns out to be toxic for all duckweed genotypes tested. Moreover, considering the overall experimental period, the effect of temperature was evaluated: all duckweed stopped growing when air temperature dropped to 10-15°C. In Table 1 the main data over a 15 days period (i.e., second half of July) of phytoremediation are shown. The biomass of duckweed increased 3-4 times the original weight and, at the same time, the content of the main nutrients (e.g., N_{tot}, P) in the tank water showed a decrease. The comparison between the pollutant concentration in the phytoremediation tank and in the control tank could be seen as an index of wastewater treatment.

Table1: Comparison of fresh weight increase and changes of wastewater quality outgoing the tank in two weeks of growing period

		Fresh weight at day zero (g)	Fresh weight at day 15 (g)	NH_4 (mg/dm^3)	N_{tot} (mg/dm^3)	COD (mg$_{O2}$/ dm^3)	P (mg/dm^3)
Control tank				129.8	206.4	279.5	0.356
L. minor	LA	100	360	65.4	63.9	98.3	0.102
S. polyrhiza	SPP	100	377	31.8	36.8	53.0	0.169
L. gibba	LEG	100	467	45.8	52.7	99.9	0.250

In fifteen days of treatment, the diluted wastewater in-flow is 75 dm^3 (i.e., 5 dm^3/day) equal to the flow outgoing the tank. Considering the dilution, 15 dm^3 of digestate liquid fraction are treated requiring 0.7 m^2 surface (i.e., 0.019 m^{2}a/FU). It is possible to calculate water emissions of N_{tot}, COD and P (g),.from the out-flow and the concentration of the main pollutants In Figure 3, the impacts of three different *Lemnaceae* treatments on the eutrophication category are showed and compared to the control tank. *S. polyrhiza* shows the lowest impacts on eutrophication category: its impact is 18% of the control tank and 58% of the wastewater outgoing the *L. minor* tank. *L. gibba*, which has the highest biomass production, contributes to eutrophication with 0.126 g PO_4^{3-} eq. The emissions of total nitrogen cause almost 90% of the impacts on the category. The consumption of water is 4.0 dm^3 per FU in the three scenarios.

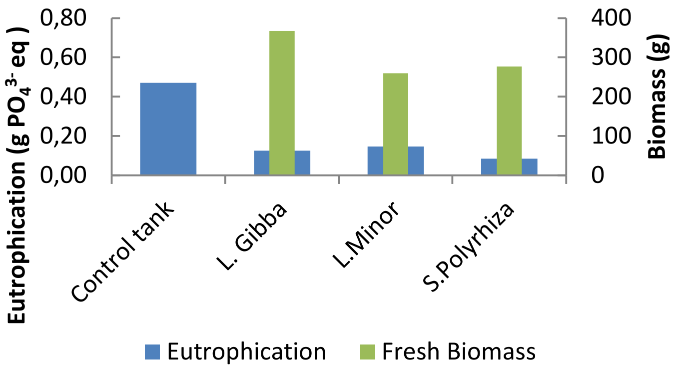

Figure 3: Impact of the three scenarios on eutrophication category (kg PO_4^{3-}) and relative biomass production (g) in fifteen days.

Duckweed growing rate depends on meteorological condition (e.g., air temperature and rainfall) and on pollutant concentration; for this reason, impacts on eutrophication category and purification efficiency could widely vary.

4. Conclusion

The first year of experimental tests provide interesting insights into the use of duckweed for phytoremediation of AD wastewater fraction. In this preliminary assessment, *S. polyrhiza* shows the lowest impacts on eutrophication category and, simultaneously, almost triplicates its fresh biomass in fifteen days. In the three scenarios the reduction of pollutants ranges from 31.5% (P with *L. gibba*) to 82.2% (N_{tot} with *S. polyrhiza*). Further developments are required to: (i) improve the quantity and quality of primary data (e.g., air emission), (ii) consider more environmental categories (e.g., global warming, land use change) and (iii) evaluate the influence of starch production on the overall assessment.

Acknowledgements

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Characterization of biochar obtained from pyro-gasification of *Jatropha Curcas* residues through an updraft reactor

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Keywords: *Jatropha Curcas*, Biochar, E.B.C., Updraft, Pyro-gasifier

Abstract
This study concerns the characterization of the biochar produced through the pyro-gasification of Jatropha Curcas residues obtained from the mechanical pressing of Jatropha seeds for oil production. Jatropha is a crop that can grow up in sandy and saline soils, with low levels of rainfall and at the same time it represents a valuable tool in order to reduce the soil erosion and desertification phenomena. The system used for the pyro-gasification test was an updraft fixed bed reactor. The biochar showed a carbon content of about 66%$_{db}$ that is greater than the minimum value required by the European Biochar Certificate (E.B.C.) and it was consistent with the values reported in the literature. In particular the high carbon content suggests the potential use of the biochar as tool for a stable soil carbon sequestration.

Introduction

Biochar is a product, characterized by high carbon content, that is obtained from the thermochemical conversion of biomass, through processes such as pyrolysis and gasification. The thermochemical processes can be managed in order to obtain several products in terms of combustible gases such as hydrogen, carbon monoxide and methane, volatile oils, tarry vapors, and biochar. Characteristics of biochar are linked to the biomass and to the process conditions in terms of temperature, residence time and heating rate. In particular the increase of temperature determines the increase both the carbon content, up to about 90% on dry basis at 800°C, and the specific surface area, up to 460 m^2/g at 900°C, but at the same time the reduction of yield of biochar [1,2]. The yield of biochar depends on the type of process. Slow pyrolysis, that is characterized by temperatures of 400-600°C and long residence time, from minutes to days, gives a char yield of 20-40% in weight. Fast pyrolysis that is characterized by a very short residence time, of about 1 second, gives a char yield of 10-20% in weight. Gasification that is characterized by very high temperatures, from 800 to 1000°C, and residence time from 5 to 20 seconds gives a char yield of 10% in weight. Hydrothermal carbonization that is characterized by low temperatures, from 180 up to 250°C, and high residence time up to 12 hours gives a char yield of 30-60% in weight [3]. Various studies on use of waste agro-forestry biomass for production of biochar were carried out. Biochar with values of carbon content of 78% and 90% were obtained from pyrolysis of hazelnut and olive prunings respectively [4] while carbon content of 74 and 72% were obtained from pyrolysis at 500°C of pellets of grape vine and sunflower husk respectively [5]. The biochar could have a key role in the agricultural sector because it represents a soil

improver able to increase the water retention and the surface area of soil. In addition, the use of biochar determines an increase in the nutrient use efficiency. The biochar represents a useful tool in terms of carbon sink as consequence of the resistance of the biochar to the microbial degradation that means a long-term storage of carbon in soil [6,7,8]. This study concerned the recovery of the solid residues, obtained by mechanical pressing of Jatropha seeds, to produce biochar through the pyro-gasification process.

Material and methods

For the pyro-gasification test, pellet of about 5 centimeters, resulting from the mechanical pressing of Jatropha seeds for oil production, were used as feedstock. The biomass characterization concerned the evaluation of the moisture content, the heating value and the ash content. The moisture content was established according to the UNI- EN 14774-2010. The biomass sample was dried in a stove at about 105°C and the moisture content on wet basis (M) was calculated with reference to the difference between the weight of the sample before and after the drying process. The higher heating value on dry basis (db) was measured according to the UNI-EN 14918:2010 through the isoperibolic calorimeter Anton Paar 6400. The lower heating value on dry basis was calculated taking into account the higher heating value and the hydrogen content. The ash content was measured according to the UNI-EN 14775:2010 through the muffle furnace Lenton EF11/8B. The percentage of ash content on dry basis was determined as a result of heating the dried biomass sample up to about 550°C. The content of carbon, hydrogen, nitrogen and sulphur was measured according to the UNI- EN 15104:2011 through the Costech ECS 4010 elemental analyzer. The oxygen content was calculated by difference. The system used for the biochar production was an updraft fixed bed pyro-gasifier, characterized by an airflow from the bottom to the upper part of the reactor. The airflow can be set for different values starting from zero value, that corresponds to the pyrolysis condition, to higher values or in natural draught condition. The biochar production is the consequence of the movement of the pyrolysis flame front from the upper part of the reactor to the bottom part (fig. 1). The pyro-gasification of biomass was characterized by the production of flue-gases that were rich in water vapor, tar and with the presence of combustible compounds such as carbon monoxide, methane and hydrogen.

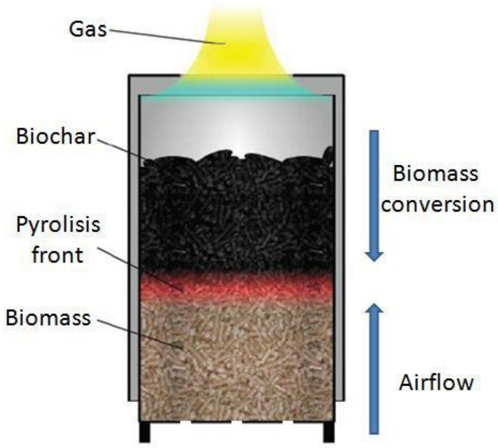

Figure 1: Scheme of the biochar production process.

After filling the reactor with pellet, the biomass was ignited using a piezoelectric torch in order to provide the heat for initiating the process. During the experiment, the test duration and the process temperature were monitored.

Results and discussion

Results of the ultimate analysis, on dry basis, of the biomass used for the test of pyro-gasification are shown in the following table. The moisture content on wet basis was of 10.0 % while the ash content was of 5.75 %db. The HHV and LHV were equal to 18.93 MJ/kgdb and 17.82 MJ/kgdb, respectively.

Table 1: Elemental composition of residues of the Jatropha seed pressing.

C (%db)	H (%db)	N	S	O (%db) by
44.22	5.39	4.92	-	39.72

By observing the biomass composition, it can be noticed that the sulphur content was negligible, according to the typical composition of the lignocellulosic biomass [9]. In particular the elemental composition is comparable to that of the de-oiled cake resulting from the oil extraction process of Jatropha seed [10]. The experiment was carried out in natural draught condition. The monitoring data of the process, regarding the weight variation of biomass and the time required for the complete conversion of biomass in biochar, showed a biochar yield of about 0.25 and a conversion rate of 70 g/min while the temperature was about 360°C. Comparing these data with those related to other tests on different lignocellulosic biomasses, it was observed that the increase of the bulk density and of the degree of compaction of the biomass used as feedstock determines the increase of the biochar yield and the decrease of the conversion rate. The biochar was characterized by a HHV and LHV of 24.55 MJ/kgdb and 24.01 MJ/kgdb respectively, while the ash content was equal to 18.90%db. The elemental composition is shown in the following table.

Table 2: Elemental composition of biochar.

C (%db)	H (%db)	N (%db)	S (%db)	O (%db) by diff.
66.02	2.61	5.14	-	7.33

Comparing the chemical characteristics of the biochar with those of the initial biomass (fig.2), it was noticed the increase of carbon content and ash content. In particular the value of carbon content is more than 50%db that represents the minimum value prescribed by European Biochar Certificate (E.B.C.).

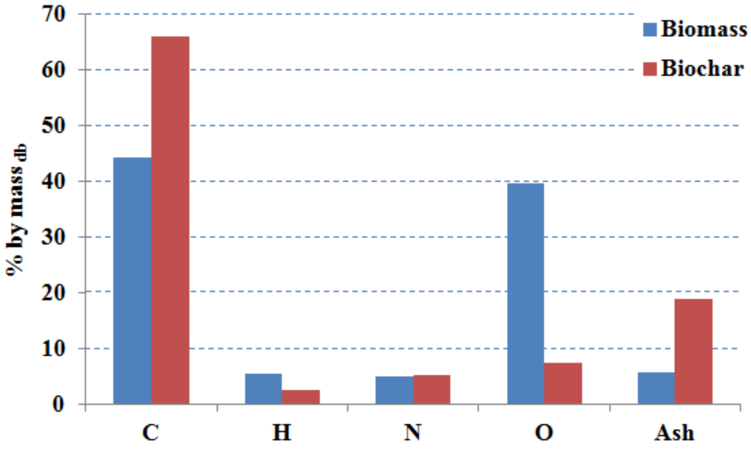

Figure 2: Comparison of elemental composition between residues of Jatropha and biochar.

Conclusion

The results of this work showed that the pyro-gasification of residues from Jatropha seed pressing for oil production represents a useful method for the recovery of this type of waste biomass. The chemical characteristics of the biochar were consistent with those of biochar obtained from pyrolysis of different types of waste biomass. The biochar showed good properties such as the high carbon content of about 66%db and hence higher than the minimum value prescribed by European Biochar Certificate. The high carbon content makes it possible the use of biochar as tool for soil carbon storage. Further studies will be necessary to evaluate the potential advantages resulting from the use of biochar as soil improver with particular reference to positive effects such as the improvement of the water retention and the increase of soil surface area.

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Investigation over the parameters affecting the mechanical behaviour of small prismatic straw bales for use in construction

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Keywords: Straw bale construction, stress-strain diagrams, Elastic modulus, Poisson's ratio.

Summary
Straw bale construction is a building technique offering many advantages: it provides excellent hygro-thermal insulation; it ensures good performance against earthquakes; and it is sustainable. From a mechanical point of view, straw bales can act as a surviving cell for the building in case of calamity. For this reason, measuring the mechanical properties of straw bales is important for the comprehension of the behaviour of straw bale buildings. Despite the fact that the use of straw bales in construction has been constantly increasing since the '80s, the behaviour and the performance of straw bale buildings have not been fully assessed so far.
Using a recently developed test methodology (Maraldi et al., 2016), an analysis of the performance of small prismatic straw bales under monotonic compressive loads has been conducted. Force-displacement curves obtained from the tests have been fitted with a two-parameter rheological model to extract bales performance indicators.
Results show that bales laid flat are stiffer than bales laid on-edge. However, if the influence of bales initial geometry is disregarded by considering stress and strain instead of force and displacement, no difference in the elastic modulus between flat and on-edge orientation appears. Furthermore, bales stiffness and elastic modulus are dependent on the initial density of the bale. It has been also found that straw bales exhibit a typical deformation pattern which depends on the baling process and that the Poisson's ratio does not remain constant along the longitudinal direction during loading, whereas it is null along the transverse direction.

1. Introduction

Straw bale construction is a building technique offering many advantages: it provides excellent hygro-thermal insulation; being straw bale buildings lightweight, it ensures good performance against earthquakes; and it is sustainable. Indeed, from the point of view of sustainability, the use of straw allows to avoid costs and emissions related to the production of conventional building materials on one hand, and the disposal of excess straw on the other hand. From a mechanical point of view, straw bales can act as a surviving cell for the building in case of calamity. For this reason, measuring the mechanical properties of straw bales is important for the comprehension of the behaviour of straw bale buildings. Despite the fact that the use of straw bales in construction has been constantly increasing since the '80s, the behaviour and the performance of straw bale buildings have not been fully assessed so far.
In 1993, Bou Ali presented the results of a study on the mechanical properties of straw bales (Bou Ali, 1993). In the study, compression tests on wheat bales laid both flat and on-edge were performed. In a similar fashion, Zhang (2000) presented the results of compression tests performed on flat and on-edge straw bales. Load was applied as a series of incremental steps of 0.5–2 kN of amplitude up to a maximum value, and for each load increment the test was stopped and a deformation reading was taken. Ashour (2003) presented the results of compression tests performed on wheat and barley straw bales laid both flat and on-edge. Similarly to Zhang (2000), after an initial compression with a 200 kg load, bales were loaded through incremental load steps of 100 kg were applied up to a maximum load of 1000 kg. At

each step, the loading device was stopped and measurements performed. Krick (2008) presented the results of a test campaign conducted on straw bales made with different materials: wheat, barley, spelt, switchgrass and rye straw. Compression tests, as well as cyclic, creep and relaxation tests were performed. Vardy (2009) presented the results of compression tests conducted on two wheat bales, one laid flat and one on-edge. Load was applied at a constant rate using a ultimate testing machine.
More recently, Maraldi et al. (2016) developed a test methodology able to determine the mechanical behaviour of straw bales. The method proposed in the paper allows to measure the overall stress-strain behaviour and the lateral deformation of the bales in both the longitudinal and the transverse direction. Applying the methodology proposed, measurements can be performed in real time and without stopping the test. This represents an advantage over most of the test methods proposed in literature, since it allows to deal at best with the time-dependent nature of straw bales mechanical response. In the following, results of compression tests performed on single unplastered straw bales using the methodology described in Maraldi et al. (2016) are presented and discussed.

2. Materials and Methods

A test apparatus comprising a hydraulic press for loading plus digital cameras for Digital Image Correlation measurements and a 3D Laser Scanner for measuring bale's lateral displacement has been used for the experiments (Fig. 2.1). Tests have been performed on bales of different materials (namely: wheat, rice, oat, barley, corn, sorghum and millet) and density, at different loading rates and with different loading orientation (flat and on-edge).
Force-displacement curves obtained from the tests have been fitted with a two-parameter, non-linear rheological model to extract bales performance indicators. The equations are the following:

$$u = \begin{cases} C\,P, & if\ P < P_t \\ u_l - 3\left(\dfrac{u_l^4}{256\,C\,P}\right)^{\frac{1}{3}}, & if\ P > P_t \end{cases} \tag{2.1}$$

where C is the elastic compliance, u_l is the model asymptotic displacement and P_t is the threshold load triggering the transition between the linear and the non-linear stage:

$$P_t = \frac{u_l}{4C}\,. \tag{2.2}$$

From Eq. 2.1, the stress-strain relationship can be determined:

$$\begin{cases} s = \dfrac{P}{W_0 L_0}\ ; \quad e_V = \dfrac{u}{H_0} & \text{for flat bales} \\ s = \dfrac{P}{H_0 L_0}\ ; \quad e_V = \dfrac{u}{W_0} & \text{for on-edge bales,} \end{cases} \tag{2.3}$$

being H_0, W_0, L_0 the initial height, width and length of the bale, respectively.
The model has been presented in a paper by Molari et al. (2017) and is designed to reproduce the behaviour of straw bales of varying density and geometry. In its original formulation, the model comprised five parameters; in the results proposed here, a simplified two-parameter version has been used.

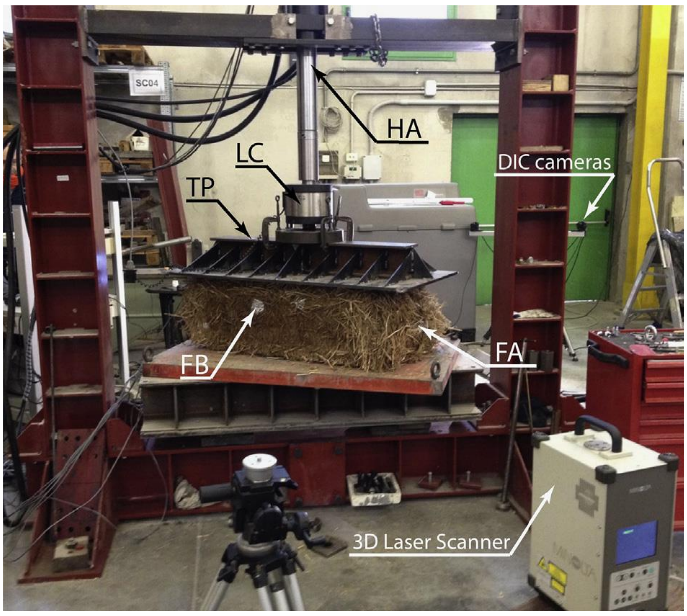
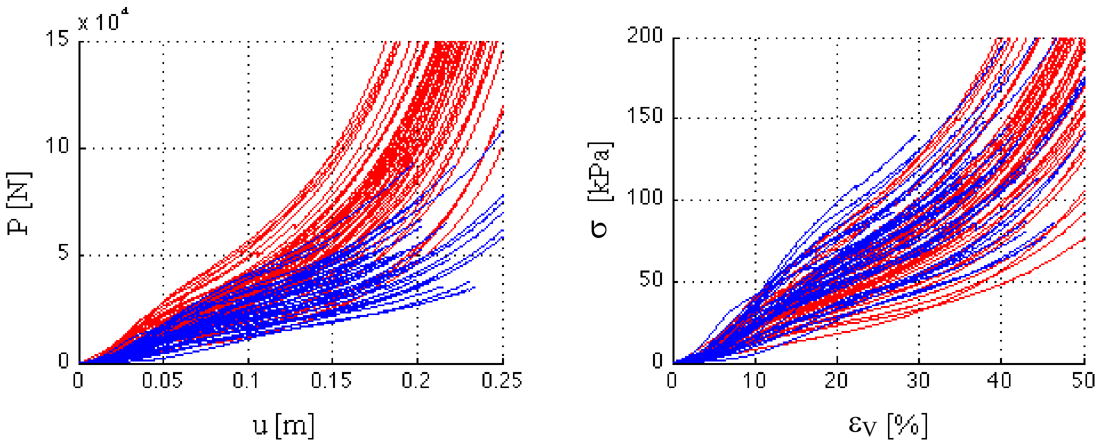


Figure 2.1: The test apparatus. HA is a hydraulic actuator; LC is the load cell; TP is a custom-designed top plate. The laser scanner has been placed so that the entire face FA and half of face FB could be acquired.

3. Results and Discussion

Results show that bales laid flat are overall stiffer than bales laid on-edge (Fig. 3.1a). However, if the influence of bales initial geometry is disregarded by considering stress and strain instead of force and displacement, there is no difference in the elastic modulus between flat and on-edge orientation (Fig. 3.1b).

Furthermore, Maraldi et al. (2017) showed that bales stiffness and elastic modulus are dependent on the initial density of the bale. It has been also found that straw bales exhibit a typical deformation pattern which depends on the baling process and that the Poisson's ratio does not remain constant along the longitudinal direction during loading, whereas it is null along the transverse direction (Maraldi et al., 2017; Maraldi et al., 2016).



(a) (b)

Figure 3.1: (a) Force-displacement and (b) stress-strain diagrams for all the tested bales.

4. Conclusion

The test methodology developed by Maraldi et al. (2016) has been applied to the analysis of the performance of small prismatic straw bales under compressive loads. From the stress-strain response of all the tested bales, it can be concluded that the elastic modulus depends on the initial density of the bale, whereas there is no difference in the elastic modulus between flat and on-edge orientation. It has been also found that the Poisson's ratio does not remain constant along the longitudinal direction during loading.

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Mass and heat balance in a production line of fresh mozzarella aimed at assessing energy recovery solutions

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Keywords: Fresh mozzarella line, Mass balance, Heat balance, Energy recovery

Abstract
It is well known that most food industries consist of Small Medium Enterprises (SMEs) often characterized by a considerable potential, in terms of energy efficiency improvement. In the present paper a study was carried out on the production and use of thermal energy at each stage of the production process of "pasta filata" cheese.

1. Introduction

In cheese-making plants the Specific Energy Consumption (SEC) has been used as a metric to characterize energy usage (Xu et al., 2009). The SEC value can be applied to any specific process step within a cheese plant:

$$SEC_1 = \frac{E_i}{P_i} \quad (1)$$

and can be used to quantify the overall energy intensity of a cheese plant:

$$SEC_1 = \frac{\sum_{i=1}^{n} E_i}{P} \quad (2)$$

where:
Ei= actual energy usage for i-th process;Pi = production quantity for i-th process step;n = number of process steps to be aggregated;P = total actual cheese production.
Currently, for most medium and big dairy farms, heat recovery is the most immediate way to achieve energy saving (Sanford, 2003); other solutions concern the use of renewable energy produced by photovoltaic system, while the cogeneration is still not much adopted, despite the considerable amount of by products with high organic and potential energy to be disposed of on a daily basis. Scientific research is primarily focused on energy-saving solutions to be adopted in the process of pasteurization (Modi et al, 2014): heat exchanger to heat recovery and using of thermal energy contained in milk heated to pre-heat the raw).
Two major areas for energy conservation in dairies are fuel fired equipments (boiler) and refrigeration system (Gurumurthy et al., 2006); for the energy saving, waste heat recovery system, economizers, cogeneration and vapor absorption system have been considered, which would lead to a saving of approximately 4% of fuel (Gurumurthy et al, 2006).
In the present paper a mass and heat balance in a production line of fresh mozzarella was carried out, with the goal of proposing energy recovery solutions.

2. Materials and Methods

The experimental trials were carried out on a plant which daily transforms 140-160 q of milk in "pasta filata" cheese.It consists in the following machines:refrigerated tanks for storage of milk and whey; n.2 cylindrical and overturning cheese vats with maturation tanks and table portioning; n.1 continuous cooking-stretching and moulding machine; static firming-cooling tanks; horizontal flow pack machine; steam generator.
During the experimental trials were monitored the operative parameters of the machineries composing the studied production plant, in order to acquire experimental data to perform calculations about mass and energy balance of the whole production process of the pasta cheese produced in the studied company.

Have been studied the mass and energy currents in entrance and in exit from the production process. Then were defined the outlines of the system within the balance can be resolved; finally, followed the mathematical solution of the balance. Particular attention has been put on the operating conditions of the machineries that make heat exchange, such as the steam generator, the overturning cheese vat and the continuous cooking-stretching and moulding machine.

The data acquired by cheese vat were:mass (kg) and temperature (T °C) of the milk in entrance;mass (kg) and temperature (T °C) of the steam in entrance and in exit;mass (kg) and temperature (T °C) of the curd in exit;mass (kg) and temperature (T °C) of the whey in exit. The data acquired by continuous cooking-stretching and moulding machine were:mass (kg) and temperature (T °C) of the curd in entrance;mass (kg) and temperature (T °C) of the "fior di latte" in exit;mass (kg) and temperature (T °C) of the spinning water in entrance and in exit; mass (kg) and temperature (T °C) of the steam needed to heat the spinning water. The temperatures were detected by reading machines sensors and using the BABUC/A/M, a portable instrument for acquisition, display, storage and processing of environmental physical quantities (temperature, relative humidity, thermal flow, radiation, illumination, atmospheric pressure, gas concentration). The measure of masses has been evaluated by using of balances, known capacity containers and flow meters opportunely installed along the line of the milk, whey, steam and spinning water.

During the experimental trials analytical determination of the chlorides was made through a titration with a known normal nitrate solution and potassium chromate as an indicator. The result was expressed in mg/l of Cl^-.

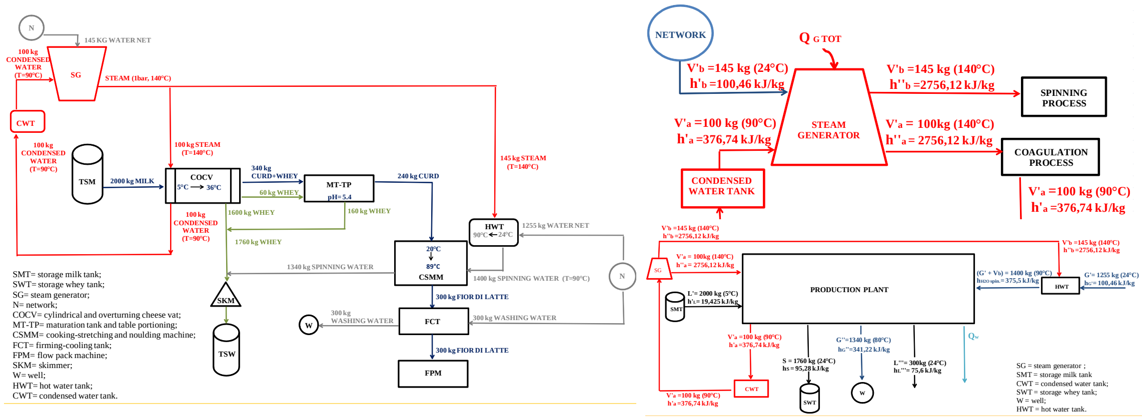

Figure 1: blockdiagram of mass flow (left), energy flow related to the steam (up), energy flow related to the production process (down) in the studied dairy plant.

3. Results and Discussion

The results of the mass (figure 1-left)and energy balance (figure 1-up and down)refer to a production of 300 kg of "Fior di Latte" corresponding to 2000 kg of milk processed, with a yield of 15%.

Input mass (figure 1-left): 2000 kg of milk (L'), 245 kg of steam (V': 100 kg used to heat the milk and 145 kg to prepare the cooking water), 1255 kg of water net (G') required for cooking-stretching, 300 kg of cooling-hardening water (G_r');total input mass: 3800 kg.

Output mass (figure 1-left): 300 kg of "fior di latte" (L'''), 1760 kg of whey (S), 100 kg of condensed water(V_c'') in exit from the cheese vat, 1340 kg of cooking water (G''), 300 kg of cooling-hardening water (G_r'');total output mass: 3800 kg.

The equation of mass balance resolves as follows:

$$L' + (V_a' + V_b') + G' + G_r' = (Z + G''') + [(G' + V_b') - G'''] + S + V_c'' + G_r'' \qquad (1)$$

As result of the mass balance we register that in the cooking-stretching process are used 6 kg of water for each kg of curd, approximately two times the quantity indicated in the literature (Ghiglietti et al, 2004).

The equation of thermal energy balance related to the process steam resolves as follows:

$$Q_{Gtot} = Q_{Ga} + Q_{Gb} - Q_{Ga(rec)} - Q_{Gb(ret)} = 623008{,}7\ kJ \quad (2)$$

Where: $Q_{Gtot}$is the total energy absorbed by the generator;Q_{Ga} is the energy of steam at 140 °C employed in the vat, fully recovered; Q_{Gb} is the energy of steam at 140 °C which is employed in a tank for obtaining cooking water at 90 °C (figure 1); $Q_{Ga(rec)}$ is the recovered energy by the cheese vat, as water of condensation at 90 °C, $Q_{Gb(ret)}$ is the energy of water from a mains water pipe at 24 °C for the steam generator.

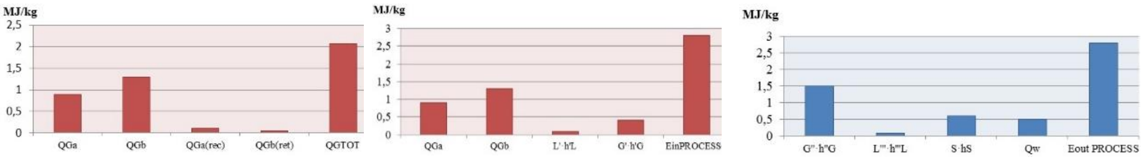

Figure 2: specific thermal energy absorbed by the steam generator (left: Q_{Ga}=heat into the cheese vat; Q_{Gb}=heat for the spinning machine; $Q_{Ga(rec)}$=heat of condensed water from the vat; $Q_{Gb(ret)}$ = heat of mains water; Q_{Gtot}=total specific value);specific thermal energy at the inlet of the process(centre: Q_{Ga}=heat for the cheese vat; Q_{Gb}=heat for the spinning machine; $L^{'}\cdot h^{'}_{L}$=heat of inlet milk; $G^{'}\cdot h^{'}_{G}$=heat for spinning water; $E_{inPROCESS}$=total specific value); specific thermal energy at the outlet of process (right: $G'' \times h^{''}_{G}$=heat from the spinning machine;$L''' \times h^{'''}_{L}$=heat of the product; $S \times h_S$=heat of whey; Q_w=heat losses;$E_{outPROCESS}$=total thermal energy at the outlet of process).

The specific values of thermal energy balance related to the process (300 kg fior di latte) steam are showed in fig. 2 (left).The total thermal energy "Q_{Gtot}" absorbed by the steam generator is 2.07 MJ/kg(Fig.2-left), calculated on net of the recoveries already made in the dairy: condensed water at 90 °C out of the production chain allows an energy recovery of 0.1 MJ/kg ($Q_{Ga(rec)}$). Referring to the diagram in fig. 1 (down), the equationof thermal energy balance related to the production process resolves as follows

$$L^{'} \times h^{'}_{L} + V^{'}_{a} \times \mathrm{h}^{''}_{a} + \left(G^{'} + V^{'}_{b}\right) \times h_{H_2O spin.} = L^{'''} \times h^{'''}_{L} + V^{'}_{a} \times h^{'}_{a} + G^{''} \times h^{''}_{G} + S \times h_S +$$
$$+ Q_w \rightarrow Q_w = 154880{,}4\ kJ \quad (3)$$

The total specific thermal energy "$E_{inPROCESS}$" used in the production process is 2.8 MJ/kg (fig. 2: centre). The spinning process absorbs the biggest part: 1.3 MJ/kg(46.6% of total thermal energy input), because the thermal exchange in this phase having a ΔT higher than coagulation phase, which requires 0.9 MJ/kg of thermal energy (32.1% of total heat input). The low temperature thermal input energy of the process (Q_{inLT}) is equal to 17.9% of the total thermal energy: heat of input milk (0.1MJ/kg, 3.6% of the total input heat) and heat of the mains water (0.4 MJ/kg equal to 14.3% of total input heat). The total specific output heat "$E_{outPROCESS}$" is 2.8 MJ/kg (fig. 2: right). The biggest part is the output heat of spinning water at 80 °C: 1.5 MJ/kg, equal to 53.6% of the total output heat; this date suggests there's a low uses of the steam's enthalpy putted in the spinning water. The specific thermal energy of condensed output water from the van at 90 °C is 0.1 MJ/kg (17.9% of the total output heat). The low temperature thermal energy at the outlet of process (Q_{outLT}) is equal to 24.2% of the total thermal energy:thermal energy of the finished product (0.08 MJ/kg equal to 2.8% of the total output heat), thermal energy of discharged whey (0.6 MJ/kg equal to the 21.4% of the total thermal energy at the outlet of process). The spinning phase resulted a critical point and it is possible to propose recovery solutions in terms of mass and energy.

About the mass, it could be regulated the flow rate of spinning water, with reduction of water consumption and of the "$E_{inPROCESS}$".

About the energy recovery, it could be achieved by using the high recoverable thermal energy of the spinning water at 80 °C in exit from the process. It would be used as exchange fluid to pre-heat the mains water (24 °C) which is sent to the pressure tank to rise the spinning water temperature until 90 °C using a direct injection of steam in the tank (figure 1: left and down). This solution would bring to reduction of ΔT of the spinning phase and modification of the plant design and process lay-out: the spinning water at 80 °C, before being skimmed and stored, should pass through an appropriately designed heat exchanger.

A limit of this solution could be the presence in the spinning water of curd residues, proteins, fats and chlorides which would cause fouling phenomena in the exchanger. Determining the quantity of chlorides we had as result that for each kg of "fior di latte" were used 6 kg of spinning water: it means that in each kg of spinning water in output from the process there are 15 g of chlorides.

Table 1. Analytical determination of *NaCl.*

PRODUCT		WASTE	
Spinning water input (6kg/kg$_{product}$)	*Pasta filata output*	*Spinning water output*	*Wasting water*
25 g/kg$_{product}$	10 g/kg$_{product}$	15 g/kg$_{product}$	284 mg/l

4. Conclusions

The lack of knowledge is an important barrier to improving energy efficiency in cheese-making plants, understanding of these opportunities and the available information. Local dairies which produce typical products not have the staff, resources, guides, or tools to perform a detailed energy assessment. The present heat and mass balance was carried out considering two thermodynamic systems: process steam and production process. The spinning phase resulted a critical point, then recovery solutions have been proposed: reduction spinning water flow and employing of outlet spinning water as exchange fluid to pre-heat the mains water.

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Technical and energy analysis from the recovery of vineyards pruning residues in an agro-energetic supply chain

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Keywords: LCA, winter pruning residuals, energetic sustainability, harvester yards.

Introduction

The energy valorization of vine prunings means that what is currently a problem could be turned into an opportunity to create income for farms, and may be successful through the activation of local short chains (ENAMA, 2012). Considering that the total area dedicated to the cultivation of vineyards in Italy is approximately 530,000 ha, vine prunings do not represent a source of income for the firms involved, and in fact are, in most cases, both a problem and a production cost. There have been two common practices up to now to dispose of these prunings; mulching along the borders of the field with subsequent interment or burning of the same along the field boundaries. As regards this second choice, the burning of woody debris on the boundaries is often banned by many municipalities (Gurney *et al*. 2010).

The solution of harvesting this byproduct for the purpose of energy valorisation, with regards to the technical-agronomic and technical aspects, and where the soil conditions and characteristics of the land allow the operation of the necessary machinery, are now based on efficient and tested models (AA.VV, 2011).

Limiting the areas to a maximum radius of a few tens of kilometers means that transportation costs can be contained, significantly affecting the calculation of how economically efficient the production process is. Giving the job of collecting to contractors is an optimal solution, since it allows the equipment (harvesters, balers, transport means, shredders, etc.) to be used over at least a few hundred hectares for at least 400-600 hours per year, as well as to amortize the investment, or alternatively, in the case of associations, the said association may acquire the machinery and make it available to shareholders (AA.VV, 2011).

As regards the energy characteristics of vine wood, the PCI (lower calorific value) referring to dry matter, is 19.8 MJ/kg, higher than spruce (18.8 MJ/kg DM) and beech (18.4 MJ/kg DM), and has an ash content, referring to dry substance, of between 3% and 4% with a fusibility point higher than 1,400° C (Negrin, 2014) consequently the ash content and nitrogen and copper levels tend to be higher than the average values of untreated wood. (Francescato *et al*., 2007). The studies carried out on the quality of the emissions into the atmosphere indicate that the combustion of this biomass is also sustainable from an environmental point of view; this seems to apply to the emissions of any pesticide residues too, which result at low levels, although it is still necessary to pursue this matter further.

The aim of this work therefore was the assessment of the sustainability, in technical, economic and energy terms, of the use of vine prunings for the production of wood chips, briquettes and pellets. To achieve these objectives we proceeded to analyze:

-the technical aspects with the analysis of the amount of retractable biomass through tests on the harvest from various sites, and the calculation of its moisture content;

-the economic aspects with the analysis of the relative costs of each operation undertaken for the collecting, processing and production of the final product with the subsequent estimate of the cost value of each sector analyzed;

- the energy aspects, with the analysis of the difference between the energy consumed in each singular operation and the energy content of the wood chips and pellets.

Methods

The field samples were taken in 2014 and 2015 the following data was collected: type and characteristics of the harvesting chain, working time, amount of potentially harvestable prunings, harvesting losses, moisture content of the samples. As for the weighing operation of the material, an acquisition data card was created, with reference to legislation: UNI EN 14778/2011. At each sampling the following were noted: the firm data; vineyard management techniques with the characteristics of the vines and pruning management. 16 vineyards were sampled with 4 repetitions each and the diameters of both the vine prunings collected and those not collected by the machines were measured. For the overall collection of evidence, 4 work sites were analyzed as follows:

- lineal shredding yard (referred to as TCL);
- parallel shredding yard (referred to as TCP);
- baling yard for large bales of 1.2 m x 1.5 m (referred to as BG);
- baling yard for small bales of 0.6 m x 0.4 m (referred to as BP).

Once the technical aspects, essential for the analysis and the formation of production chains had been taken carefully into consideration, the economic aspects related to: the harvesting chain; the production of wood chips; transport costs; storage costs; densification processing costs were analyzed.

To evaluate the energy balance of the formation of a solid fuel destined for the production of thermal energy, the energy used during the entire life cycle was quantified through CED (cumulative energy demand) and compared with the energy used for the production of a similar fossil fuel adopting the LCA (Life Cycle Assessment).

The values of differing systems (biomass and diesel), were taken from the database "Ecoinvent v2" contained in SimaPro code 7.2.4., while for the output data, those found in literature or taken from specific studies in the industry were used. The efficiency of the supply chain system was also evaluated through the "Energy Return On Investment" index (EROI), comparing the ratio of the energy found in the final product of the analyzed chain with the total energy consumed during the manufacturing process.

Results

The amount of vine prunings per hectare comprises of 1.73 to 3.92 t/ha of vine shoots of which the same have a moisture content of between 37.3% and 47.63%. Depending on the variety, there appears to be no correlation between vine shoot production and grape variety or to the way in which the vines are trained. Measuring the shoots with a gauge showed results ranging from 3-28 mm. The quantity of vine prunings remaining on the ground after the machine has passed varies from 0,12 to 0,87 t/ha, of which the same have a moisture content of 33.6% to 46.3%. There appears to no correlation between losses and the type of yard used; in fact, losses vary greatly and seem rather to depend on a set of factors related to the preparation of the swath during pruning. After the harvesting machines have passed the measured shoots have a diameter of 2-22 mm.

The working time varies remarkably in the various tests undertaken, due mainly to numerous hold ups at the yard. The entry and leaving times from the firm also vary greatly and are mainly related to the maintenance done by the contractor on the machines.

The cost of producing wood chips (tab. 1) varies from a minimum of 37 €/t (TCL) to a maximum of 98 €/t (BP).

Table 1: Calculation of the costs of harvesting and processing into wood chips.

Cost per item (€/t)	**TCL**	**TCP**	**BG**	**BP**
	min - max	min - max	min - max	min - max
harvesting	20 - 30	64.5 – 64.5	25 - 30	34 - 40
transport	10 - 15	10 - 15	10 - 15	10 - 15
storage drying and handling	7- 10	7 - 10	7 - 10	7 - 10
shredding	0 - 0	0 - 0	25 - 33	25 - 33
total cost	37 - 55	81.5 – 89.5	67 - 88	76 - 98

average total cost	46	85.5	77.5	87

Regarding the harvest of wood chips, the cheapest yard is that of TCL, with a value ranging from 37 to 55 €/t thanks to the use of compact machines that greatly reduce harvesting costs. The TCP yard has a total cost that varies from 81.5 to 89.5 €/t, being higher than the other sites due to the use of two tractors simultaneously and therefore to the need for two operators. Transforming wood chips into briquettes at the TCL yard has the cheapest production cost at 117 €/t (tab. 2), with the BP yard, at 193 €/t**,** being the most expensive as a lot of labour is required to handle the bales.

Table 2 - Calculation of the costs of harvesting and processing into briquettes.

Cost per item (€/t)	**TCL**	**TCP**	**BG**	**BP**
	min - max	min - max	min - max	min - max
Wood chip production	37 - 55	81.5 – 89.5	67 - 88	76 - 98
shredding pre-densification	5 - 10	5 - 10	5 - 10	5 - 10
briquetting	75 - 85	75 - 85	75 - 85	75 - 85
total cost	117 - 150	161.5 – 185.5	147 - 183	156 - 193
average total cost	133.5	173	165	174.5

The production of pellets (tab. 3) taken from vine prunings costs between 127 €/t (TCL) and 218 €/t (BP), and the same considerations surfaced in the production of briquettes. The largest single cost, on all sites however, is that related to pelletisation.

Table 3 – Calculation of the costs of collection and transformation into pellets.

Cost per item (€/t)	**TCL**	**TCP**	**BG**	**BP**
	min - max	min - max	min - max	min - max
Wood chip production	37 - 55	81.5 – 89.5	67 - 88	76 - 98
shredding pre-densification	5 - 10	5 - 10	5 - 10	5 - 10
pelleting process	85 - 110	55 - 110	85 - 110	85 - 110
total cost	127 - 175	171.5 – 209.5	157 - 208	166 - 218
average total cost	151	190.5	182.5	192

Looking at the energy analysis of the chains for woodchip production, the results show that the most energy saving chains are those of the BG and BP yards which have very similar energy inputs and EROI indices. TCL has a total input of 1.86 MJ/kg S.S. and an EROI of 10.63 while the most energy-consuming sector is that of the TCP site. This is due to the fact that shredding on a fixed point, using an electric powered machine, consumes less energy than the use of a tractor in the field.

Table 4 - Comparison between the chipping production chain.

Harvesting chain	**TCL**	**TCP**	**BG**	**BP**
Energy Input MJ/kg s.s.	1,86	3,61	1,61	1,21
Energy Input MJ/ha	3.184,4	6.167,3	2.756,7	2.064,7
EROI	10,63	5,49	12,30	16,36

The same considerations apply to the transformation of wood chips into pellets. In this case the EROI indices are lower since the formation of pellets is an energy consuming operation (Tab. 5).

Table 5 – Comparison between the pellet production chains.

Harvesting chain	**TCL**	**TCP**	**BG**	**BP**
Energy Input MJ/kg s.s.	2,61	4,35	2,36	1,95
Energy Input MJ/ha	4.460,2	7.443,1	4.032,5	3.340,5
EROI	7,59	4,55	8,39	10,15

Conclusions

The tests carried out have shown that harvesting vine prunings is worthwhile, also when using different types of yards. The most cost effective transformation is into wood chips which can however, only be used in industrial boilers. Transformation into densified forms (briquettes and pellets) has a higher cost in both terms of energy consumption and systems required for the transformation. Taking into consideration the EROI index, all sectors analyzed have their positive points, both that of chips as well as that of pellets (even if to a lesser extent).

The densified forms of vine chips, however, do not meet the minimum requirements regarding household emissions. Therefore they can be used for industrial purposes only.

Nevertheless, harvesting the vine prunings instead of burning or shredding them on the vineyard, also where wood disease is present, has its positive aspects. It is clearly worth using contractors capable of harvesting hundreds of hectares and who have a deposit for the pruning bales, which can then be utilized when convenient.

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Full-scale drying of digestate with acid scrubbing of exhaust air

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Keywords: digestate, drying, dryer, nitrates, ammonia, ammonium sulphate, biogas, scrubbing, cogeneration.

Summary
The present research was conducted on the first full-scale digestate drying plant realized in Italy in order to verify the efficiency of the process and its environmental sustainability. The plant operated recovering heat from the combined heat and power units (CHP), in particular, from the cooling circuit and (in a second configuration) also from the exhaust of the CHP. The exhaust airflow from the evaporator was treated in a scrubbing unit to reduce the emissions of ammonia. The inputs and outputs of the process were subject to characterization, mass flows and energy consumption were determined and exhaust emissions were monitored.
The treatment capacity was influenced by the availability of thermal energy and by the configuration (with and without recovery form the exhaust): at optimal conditions the plant was capable of treating 47% of digestate, diverting 47% of nitrogen in dry digestate and in ammonium sulphate. These fractions were produced in small quantities, compared to digestate, about 4% for dry digestate and 1% for ammonium sulphate, and are characterised by high nutrients content.
The dried product, in particular, resulted characterised by total solids content of about 90%, with a total nitrogen content of about 28.5 g/kg. Ammonium sulphate was produced in a 35% solution, with ammonium concentration in the range 31.0-124.0 gNH_4^+/kg.
The results showed that an effective removal of ammonia can be achieved, but a proper setting of the system is essential, with reference to the control of pH and density of ammonium sulphate.

1. Introduction

Anaerobic digestion of organic waste and/or livestock manure represents a great opportunity, not only for the revenues related to the production of energy from renewable sources, but also from social and environmental points of view. Nitrogen content of digestate, however, is not affected by the process in terms of quantity: where surplus nitrogen is a problem, dedicated solutions must be implemented. Nitrogen reduction and/or its concentration in different fractions, in limited quantity and easier to store and transport, is becoming a key factor for the land spreading of livestock manure in many Nitrate Vulnerable Zones of Europe (Flotats and Magrì, 2011).
Drying represents a possible solution to this problem and allows an enhancement of the nitrogen content in the digestate (Ghaly and Alhattab, 2013; Ghaly and MacDonald, 2012b). The drying process consists in removing a part of the water contained in digestate by using a flow of hot air. This process requires heat and is, therefore, economically advantageous if placed downstream of an anaerobic digestion process, in order to exploit the excess heat, normally dissipated in the atmosphere, to treat the material in output from the fermenters. Digestate drying can be considered as one of the "conservative" processes, since nutrients are conserved in the outputs of the system, represented by a dry organic fraction and by a solution of ammonium sulphate.
The present research was conducted on the first full-scale digestate drying plant realized in Italy in order to verify the efficiency of the process and its environmental sustainability.

2. Materials and Methods

The farm in which the tests were carried out was located in the Veneto Region, in the drainage basin of the Venetian Lagoon, considered as area vulnerable to nitrates. The business was dedicated to the fattening of beef cattle, with an average presence of 670 heads (1500 heads produced per year).

The farm featured a biogas plant for energy recovery from manure and additional biomasses, mainly silages. The biogas from the anaerobic fermentation was used to produce heat and electricity by two combined heat and power units (CHP), of 300 KWe and 500 respectively (later on replaced by a single CHP unit).

The drying plant (by Dorset Group, NL), specifically developed for biogas plants, allows to dry digestate or the solid fraction of digestate by taking advantage of the excess thermal energy produced by the co-generation system, waste heat that would otherwise be released into the environment.

In the monitored unit, in particular, the product that entered the drying plant was represented by thickened digestate, obtained by mixing a part of the digestate with the solid fraction produced by solid / liquid separation. This operation allowed to obtain, on one hand, clarified digestate that could be recirculated in the biogas plant to achieve optimal dry matter content in the input, on the other hand, a solid fraction to be sent to drying. Thickened digestate, still in liquid phase, was mixed with a fraction of recirculated dry product, serving as absorbing media to obtain a solid mixture. The solid mixture was then loaded on perforated metal belts, subject to forced aeration.

The plant was monitored for an extended period of time, approximately one year, from January to January: the configuration of the system was improved during the monitoring. In the first configuration (before May) the drying air was heated by exchangers recovering thermal energy from the water circuit of the CHP units. In a second phase of the monitoring (from May), additional thermal energy was recovered by conveying the exhaust fumes of CHP units directly to the drying plant, in order to increase air temperature and, hence, the efficiency of evaporation.

The system was enclosed and maintained in negative pressure by means of the operation of fans mounted on the chimneys. The exhaust air from the drying beds was subject to water/acid scrubbing (with a solution of sulfuric acid) to control the emissions of ammonia, with consequent production of ammonium sulphate.

The plant was subject to a comprehensive monitoring to determine the performance of the system, in terms of treatment capacity and production of dry product, as well as efficiency of exhaust air cleaning and consequent ammonium sulphate production. The inputs and outputs of the process were subject to characterization (APHA, AWWA, WPCF Standard methods, 1992), mass flows and energy consumption were determined and exhaust emissions were monitored by means of a photoacoustic multigas analyser (Bruel and Kjaer 1302).

3. Results and Discussion

The operative temperature of the dryer varied during the monitoring, as effect of ambient climate, that affects the thermal energy demand for heating the digesters and, hence, the available energy, and the configuration. Air temperature (figure 1) was in the range 80-100°C, optimal for the reduction of most of microbial populations (Ghaly and MacDonald 2012a, 2012b; Ghaly and Alhattab 2013).

The drying capacity of the full scale plant (figure 1) was determined mainly by the availability of thermal energy: in fact, the throughput of the system, in terms of dry product, resulted variable, with minimum performance without heat recovery from CHP exhaust and during winter months (February), when the availability of excess heat results reduced by the increased demand by the digesters.

In particular, during the first configuration (without the recovery of exhaust gas) the plant was capable of treating an average of 7.5 t/day, with a maximum load of 10 t/day and a minimum load of 4.0 t/day; recovering exhaust fumes the plant was able to treat a maximum of 17.60

t/day, with an average of 12.60 t/day, equivalent to 46.7% of digestate produced by the biogas plant.

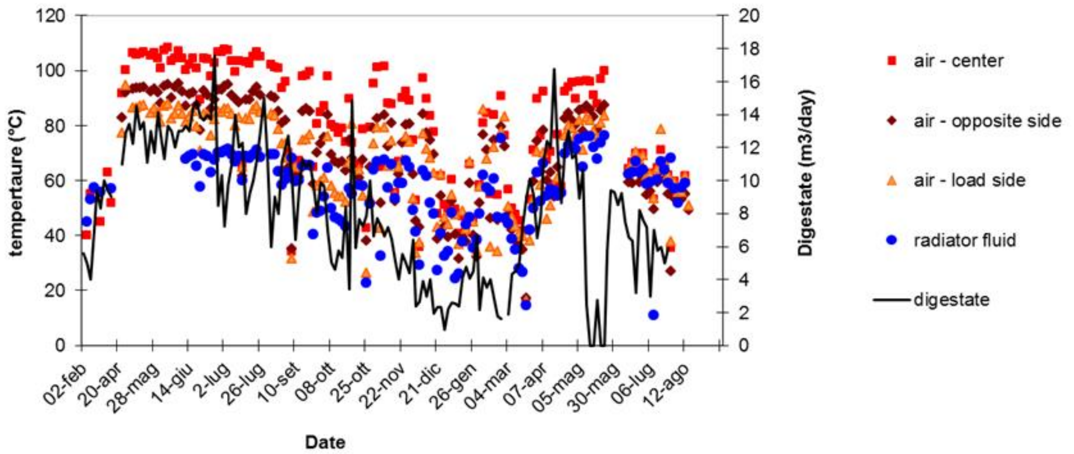

Figure 1: Treatment capacity, and operative temperatures.

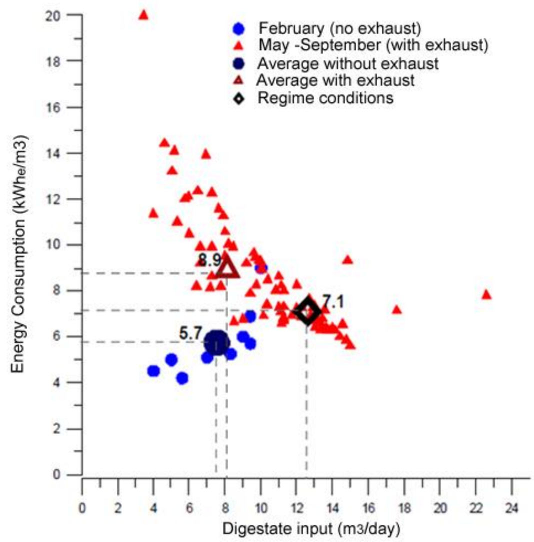

Figure 2: Energy consumption in function of treatment capacity, in different operative conditions (with exhaust and without).

Energy consumption (figure 2) resulted of 5.7 kWh/m^3 of treated digestate in the first configuration, while in the second configuration resulted of 7.1 kWh/m^3.

The plant diverted from the main stream also 47% of nitrogen, that resulted contained both in dry digestate and in ammonium sulphate. These fractions were produced in small quantities, compared to digestate, about 4% for dry digestate and 1% for ammonium sulphate, and are characterised by high nutrients content.

The dried product, in particular, resulted characterised by total solids content of about 90%, with a total nitrogen content of about 30 g/kg. Ammonium sulphate was produced in a 35% solution with a pH in the range 3-4, and with ammonium concentration in the range 31.0-124.0 gNH_4^+/kg.

The results showed that an effective removal of ammonia can be achieved, but a proper setting of the system is essential. The main aspects that affect the effectiveness of the scrubbing are the pH settings and the density of ammonium sulphate: these two parameters determine when the solution is discharged/replaced.

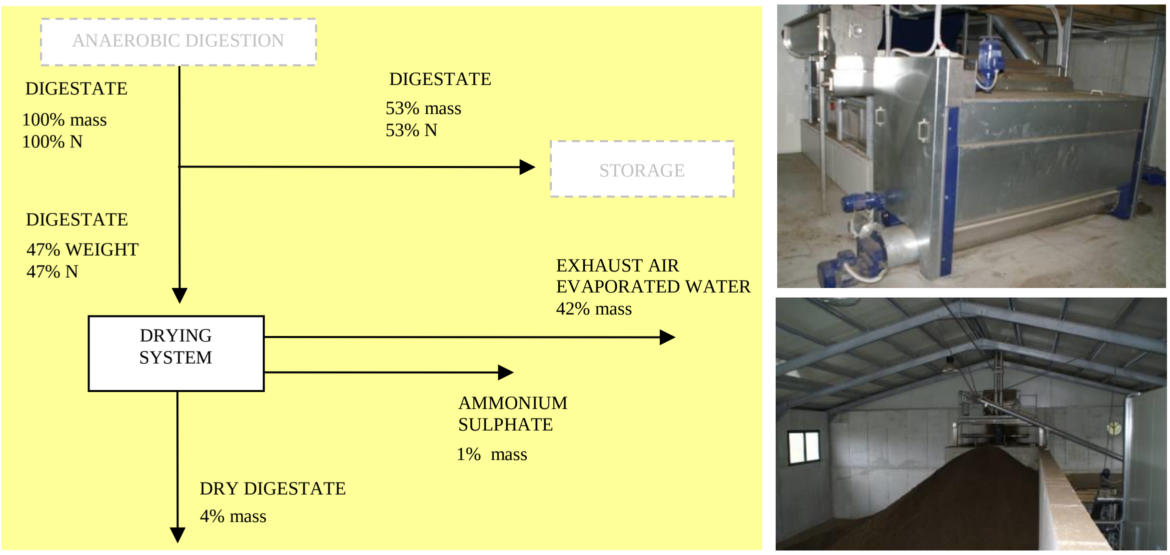

Figure 3: Mass and nitrogen balances for digestate drying (left). Details of a full-scale plant (right).

Table 1: Average characteristics of the input (digestate) and of the outputs (ammonium sulphate and dried digestate)

	TS (%)	VS (%TS)	pH	N-$NH4^+$(g/kg)	TKN(g/kg)
Input	8.7	84.5	7.8	3.4	6.3
Dry product	92.5	78.5	n.d.	n.d.	28.5
Ammonium sulphate	n.d.	n.d.	3.05	31.0-124.0	31.0-124.0

4. Conclusion

The treatment capacity of the system was influenced by the availability of thermal energy and by the configuration (with and without recovery form the exhaust): at optimal conditions the plant was capable of treating 47% of digestate, diverting 47% of nitrogen in dry digestate and in ammonium sulphate. These fractions were produced in small quantities, compared to digestate, about 4% for dry digestate and 1% for ammonium sulphate, and are characterised by high nutrients content.

The results showed that an effective removal of ammonia can be achieved, but a proper setting of the system is essential, with reference to the control of pH and density of ammonium sulphate.

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A different approach to limit the pollutants' emissions of agricultural engines

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Keywords: agricultural engines, engines' environmental performances, biodiesel, biofuel mixes

Summary
The work presented here arises from an intuition corresponding to a completely-different approach to reduce pollutants: altering the fuel used in the engine rather than further complicating the engine. Indeed, in recent years, diesel engines have undergone a surely-remarkable evolution, dictated by the need to fulfil the anti-pollution regulations that came into force in the meantime. Focusing the attention on agricultural tractors, however, the result was the introduction of a number of devices that are certainly effective but cost-expensive; they also require maintenance and occupy quite room under the bonnet, which is already heavily-crowded.
This preliminary experimental investigation has made use of a commercial diesel engine, as representative of the diesel engines used in agriculture, and of a complete equipment for testing the engines (dyno, gas analyser). This engine was first fuelled with commercial diesel oil and then with biodiesel coming from agricultural residues.
It has been observed that the performance drop (expressed in terms of power and torque) is substantially not relevant for the utilizer, while it is certainly significant and very encouraging the recorded drop in NOx emissions in the exhaust gases.

1. Introduction
The many regulatory changes dictated by the roadmap of TIER and EURO norms, begun in 1996, have forced and continues to force the manufacturers of agricultural machines (tractors in particular) to continue working on the engine, developing technical systems to respect the increasingly-stringent limits on carbon monoxide (CO), unburned hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter (PM). The choice common to all manufacturers was to firstly use solutions already present in the automotive industry (e.g., common rail, EGR), and subsequently to develop other technologies explicitly-thought for the agricultural sector. If the first solutions had all, as common denominator, to be focussed on the system-engine, subsequently there were efforts to develop systems that did not penalize engine performances. The use of urea-based after-treatment systems downstream of the engine to lower the NOx can be framed within this latter type of solutions: a solution of urea (at 32.5%, the "AdBlue") is injected, under the control of a dedicated electronic control unit, into the exhaust pipe just before an SCR-catalyst.
Another possibility not to decrease the engine performances is instead represented by intervening on fuelling, e.g. by using advanced fuels having a greater environmental-friendliness. Two reviews on the effects of biodiesel fuels on compression ignited (CI) engine performance and emissions report the following main outcomes (Pullen & Saeed, 2014a; Pullen & Saeed, 2014b): (i) fuel consumption increases proportionally to the loss of heating value of the fuel; (ii) PM emissions show a consistent reduction; (iii) a minimal or absent loss of power is reported except when maximum power is required.
As regards brake thermal efficiency (BTE), its value is not significantly affected with biodiesel but slight increases and reduction in the BTE can be noted depending on the engine load, the typology of biodiesel and the blend with mineral diesel (Mani et al., 2011): improvements in the efficiency are mainly due to synergic blending effects that could be caused by reductions in

friction losses (T. Korakianitis, et al., 2011). As regards emissions, all of the authors agree in the fact the CO, HC and PM emissions tend to reduce with the use of biodiesel (Shahir, et al., 2015).
The goal of this work is to investigate the performances and the emissions of a small-sized compression-ignition (CI) internal combustion engine (ICE) fuelled with biodiesel with the aim to evaluate the reduction of the pollutants' formation without affecting the engine performances. In particular, the performances of a 4-kW engine (brake torque, specific fuel consumption) for agricultural appliances are examined. Also the emissions of the engine, in particular the NO_x, are reported.

2. Materials and Methods

The used engine test stand (a "Braker Engine 100/E" by Soft-Engine S.r.l., Falconara Marittima, Ancona, Italy) allows sampling data and elaborating them according to the desired international norms, such as EC, SAE or DIN. The test rig is also equipped with a load cell under the fuel tank to measure the engine fuel consumptions (chrono-gravimetric layout). Furthermore, a specific discharge duct has been designed and realized in order to embed some additional probes. In particular, a LSU 4.9 wide-band lambda sensor and a gas temperature probe have been fitted in the duct. A set of thermocouples are used to monitor the temperatures of the main significant components and fluids of the engine. Finally, the test bench is also equipped with the exhaust gas analyser "*Vario plus Industrial*" by MRU Instruments (Houston, TX, USA). This instrument is able to measure the concentration of pollutants using two different measuring principles; the accuracy of this instrument is reported in *Table 2.1*.

Table 2.1: Measuring ranges of the "Vario plus Industrial" gas analyser.

Chemical specie	**Range**	**Measuring principle**	**Accuracy**
NO_x	0-5000 ppm	Electrochemical	± 5 ppm
UHC	0-5% as CH_4	Optical	± 0.03% reading
CO (H_2 compensated)	0-10000 ppm	Electrochemical	± 10 ppm
CO extra high	0-10%	Optical	± 0.02% reading

The engine used for the tests is a Lombardini 15LD225 air-cooled four-stroke over-head-valve CI engine (*Table 2.2*). This is a widely-used general-purpose internal combustion engine, designed to be used in many indoor and outdoor applications, ranging from transportable energy generation to different types of agricultural equipment, e.g. water pumps for irrigation, tillers, wood chippers and many other operations. In particular, the engine used for this study is structurally very simple and it represents a good example of the ICEs that can be adopted in a broad range of applications.
All the tests have been performed with the motor fuelled with a biodiesel derived from agricultural residues (a rapeseed methyl-ester - RME; *Table 2.3*) and at full-throttle, as prescribed by all international norms when the aim is charachterizing an engine by plotting its main performance curve, as in this case. In each trial, the used dyno (an eddy-current brake) has applied progressively a braking torque by operating on the electric parameters (voltage level, current intensity, frequency) referred to the power supply of some magnets placed closed to a flywheel, made of a conductive material, connected to the engine via a shaft. Starting from the maximum engine speed, corresponding to the motor completely free to rotate (i.e., without any load applied to it), all the operative speed-range is inquired.

Table 2.2: Main engine characteristic and performance parameters of Lombardini 15LD225.

Technical characteristic	**Unit**	**Value/specification**
Engine manufacturer, model	-	Lombardini, 15LD225
Cylinders	-	1
Cooling	-	air
Fuel injection solution	-	In-line pumping system

Max power, max power engine speed	kW (HP), min^{-1}	3.5 (4.8), 3600 rpm
Max torque, max torque engine speed	Nm, min^{-1}	10.4, 2400
Bore, Stroke	mm, mm	69, 60
Displacement	cm^3	224
Min. spec. fuel consumption, min. sp. f. cons. speed	g $(kW\ h)^{-1}$, min^{-1}	240, 2900
Volumetric compression ratio	-	21:1
Cooling water requirement	L min^{-1}	not required

Table 2.3: Main chemical characteristic of the used biodiesel.

Property	Unit	Value	Test method
Ester content	% m/m	98,6	EN 14103
Density at 15°C	kg/m^3	873,9	EN ISO 3675
Viscosity at 40°C	mm^2/s	4,1-4,7*	EN ISO 3104
Flash point	°C	>160*	EN ISO 3679
Sulfur content	mg/kg	<10	EN ISO 20846
Carbon residue (on 10% distillation residue)	% m/m	0,1*	EN ISO 10370
Cetane number		>51*	EN ISO 5165
Sulfated ash content	% m/m	<0,01	ISO 3987
Water content	mg/kg	120	EN ISO 12937
Total contamination	mg/kg	<12	EN 12662
Copper strip corrosion (3h at 50°C)	Rating	Class1*	EN ISO 2160
Oxidation stability,110°C	hours	>8	EN 14112
Acid value	mgKOH/g	0,29	EN 14104
Iodine number	$gI_2/100g$	55	EN 14111
Linolenic acid methyl ester	% m/m	1,2	EN 14103
Methanol content	% m/m	<0,05	EN 14110
Monoglyceride content	% m/m	<0,30	EN 14105
Diglyceride content	% m/m	<0,20	EN 14105
Triglyceride content	% m/m	<0,20	EN 14105
Free glycerol	% m/m	<0,02	EN 14105
			EN 14106
Total glycerol	% m/m	<0,25	EN 14105
Group I metals (Na + K)	mg/kg	<4	EN 14108 (Na)
			EN 14109 (K)
Group II metals (Ca+Mg)	mg/kg	<4	EN 14538

3. Results and Discussion

Figure 3.1 shows the fuel consumption as a function of the rotational speed. The quantity of B100 injected is 8-10% greater than the corresponding Diesel oil quantity, to compensate for the lower heating value. The consequence of this higher fuel consumption is having the same values of the torque in the two inquired cases and, hence, the engine brake-torque curve is substantially the same with the two fuels.

Figure 3.2 reports the comparison of NOx emissions with Diesel oil and RME. With the Diesel oil the NOx concentrations are greater with respect to RME meaning that the combustion temperature with biodiesel is lower and that the thermal NO_X formation mechanism is prevented. Even if the difference reduces with the rotational speed, the percent reduction is however significant, being around 30% at 2000 rpm to 9% at 3000 rpm.

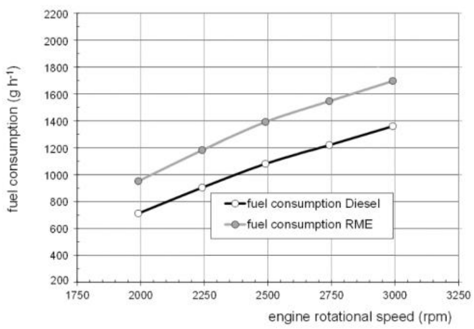

Figure 3.1: Fuel consumption of the tested engine with conventional diesel oil and biodiesel.

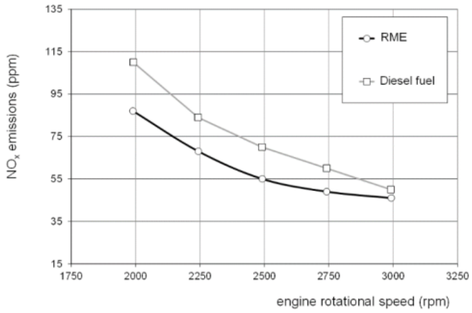

Figure 3.2: NOx emissions of the tested engine with conventional diesel oil and biodiesel.

4. Conclusion

The present work shows an alternative way of approaching the problem of fulfil the limits imposed by international norms on exhaust emissions: a change of the fuel used in the motors, rather than a further complication of them due to the use of other expensive anti-pollution devices. In the example proposed here, a commercial CI engine having many uses in the agricultural sector is fuelled with pure biodiesel and analysed at a test stand. Even if the consumptions have increased, to compensate the lower heating value of the biodiesel, NOx emissions are significantly lower if compared with the diesel oil, recording the highest decreases at the lower engine speeds. This result encourages further experiments on this way, maybe using diesel oil – biodiesel – gasoline mixes in different percentages-

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Sicilian potential biogas production from Citrus industry by-product

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Keywords: Citrus industry, Anaerobic Digestion, biogas, energy

Summary

In Europe, Italy is the second nation after Spain in Citrus production and 49% ca. of national fruit production is located in Sicily. The by-product obtained from the industrial processing of Citrus fruits into juice and essential oils is called "pastazzo" or Citrus Waste (CW). This study is aimed at evaluating the Sicilian potential biogas and energy production from the above "pastazzo" and verifying the possibility of using this by-product for Anaerobic Digestion (AD) process within 30 km from processing plants.

The areas cultivated with Citrus species in Sicily and their distribution in the various municipal districts were mapped and analysed by means of QGIS software, together with the main Citrus processing plants and the three existing AD plants. The statistical data about the amounts of the by-product of Citrus processing industry were evaluated, in order to compute the Sicilian potential biogas and energy production.

In Sicily it is possible to obtain, through the use of "pastazzo", a yearly production of 12,916,800 m^3 ca. of biogas, equal to 24,250,930 kWh of electric energy and 25,463,477 kWh of thermal energy or 6,200,064 m^3 of biomethane. This high potential biogas and energy production is not be currently used in a sustainable way from the energetic and economic points of view, because the existing AD plants are farer than 30 km from Citrus processing plants.

The CW produced in Sicily could be used inside a bio-reactor, together with other raw materials (e.g. pomace and wastewater from olive oil mills, cereal straw, poultry manure and Italian sainfoin or *Hedysarum coronarium*), for AD process.

1. Introduction

The increase in agricultural investments, driven by the growing demand for biofuels, can stimulate the development of a sustainable agriculture through the cultivation of dual purpose crops, integrating food and energy production (FAO, 2013). Moreover, the increasing needs to protect the environment require a correct management of wastes, including the by-product deriving from Citrus industry. In Europe, Italy is the second nation after Spain in Citrus production, with 2,924,531 tons produced per year and 49% ca. of national fruit production is located in Sicily, i.e. 1,418,567 t (of which 40% ca. are processed), mainly orange, followed by lemon, mandarin and clementine, above all in the provinces of Syracuse and Catania (ISTAT, 2015). Yet, the Citrus fruits produced in the provinces of Agrigento, Trapani and Caltanissetta are marketed as fresh ones.

The industrial processing of Citrus fruits produces juice (35-45%), essential oils (0.2-0.5%) and a by-product called "pastazzo" or Citrus Waste (CW) (55-65%), that is composed of peels, squeezed pulp residues, seeds and residual fruits (Interlandi, 2013). It is essentially composed of carbohydrates, acids (mainly citric and malic ones), lipids, mineral elements (mainly nitrogen, calcium and potassium), volatile components (e.g. alcohols, aldehydes, ketones, esters and hydrocarbons), flavonoids, essential oils (d-limonene, 95%), enzymes, pigments and vitamins. This very acid by-product, having a pH ranging from 3.5 to 5.8 (Valenti et al., 2016), is mainly used, both in Italy (especially Sicily) and in other countries, as food for livestock, but recently also in Anaerobic Digestion (AD) process for producing biogas and digestate. Biogas can be used for extracting biomethane, a fuel that can power surface transportation and agricultural machines, or Combined Heat and Power (CHP) plants for co-generating electric and thermal

energy (Comparetti et al. 2014, 2015). Moreover, the digestate, if treated and transformed into a dry form (e.g. pellets), can be used as organic fertiliser.
This study is aimed at evaluating the Sicilian potential biogas and energy production from the above "pastazzo" and verifying the possibility of using this by-product for AD process within 30 km from processing plants.

2. Materials and Methods

By means of QGIS, an open source GIS software, it was possible to use the vector map of land use of Sicilian Region (2012). This map is coded according to the legend Corine Land Cover (CLC) and reclassified from the Corine Biotopes map, selected from EU Corine Biotopes classification manual (EUR 12587/3 EN), where the minimum areas classified are 1 ha. Through the intersecting and sampling tools of QGIS software, a new point layer was obtained for collecting the attribute data of land use, provincial and municipal boundaries, for any area of 1 ha. Thus, the areas cultivated with Citrus species in Sicily and their distribution in the various municipal districts were mapped and analysed, together with the processing plants and the three existing AD plants: Mussomeli (Caltanissetta), Vittoria (Ragusa) and Resuttano (Caltanissetta), having an electric power of 999, 600 and 100 kW, respectively. Moreover, the areas cultivated with Citrus species in the various municipal districts compared with Used Agricultural Area (UAA), according to the 6th General Census of Agriculture, were mapped and analysed (ISTAT, 2012).
CW samples, taken at the processing plant Agrumaria Corleone (Palermo), were subjected to laboratory analysis, in order to determine their main chemical properties.
The statistical data about the amounts of the by-product of Citrus processing industry were evaluated, in order to compute the Sicilian potential biogas and energy production.
The potential biogas production from CW (B_{CW}) was determined according to the following Eq. (2.1):

$$B_{CW} = b_{CW} \cdot m_{CW} \tag{2.1}$$

where: b_{CW} is the specific biogas yield of CW mass unit, $m^3\ t^{-1}$;
m_{CW} is the CW mass, t
The yearly electric energy potential production from CW Ee_{CW} was determined according to the following Eq. (2.2):

$$Ee_{CW} = B_{CW} \cdot ee_B \tag{2.2}$$

where ee_B is the electric value of biogas, depending on the concentration of methane in biogas, $kWh\ m^{-3}$
The yearly thermal energy potential production from CW Et_{CW} was determined according to the following Eq. (2.3):

$$Et_{CW} = B_{CW} \cdot et_b \tag{2.3}$$

where et_b is the thermal value of biogas, depending on the concentration of methane in biogas, $kWh\ m^{-3}$
The yearly biomethane potential production from CW M_{CW} was determined according to the following Eq. (2.4):

$$M_{CW} = B_{CW} \cdot m_{CW} \tag{2.4}$$

where m_{CW} is the biomethane content inside biogas volume for CW, % (Comparetti et al., 2012, 2013).

3. Results and Discussion

Citrus area, also compared with Used Agricultural Area (UAA), the production of Citrus fruits, processed fruits and CW in Sicily are shown in Table 3.1.

Table 3.1: Citrus area (CA), also compared with Used Agricultural Area (UAA), production of Citrus fruits (CF), processed fruits (CPF) and CW in the nine provinces of Sicily

Provinces	CA (ha)	CA / UAA (%)	CF (t)	CPF (t)	CW (t)
Agrigento	3394	2.24	61,092	-	-
Caltanissetta	214	0.18	3852	-	-
Catania	29,425	17.38	529,650	211,860	127,116
Enna	2981	1.63	53,658	21,463	12,878
Messina	5242	3.23	94,356	37,742	22,645
Palermo	3801	1.43	68,418	27,367	16,420
Ragusa	2518	2.77	45,324	18,130	10,878
Syracuse	21,033	18.92	378,594	151,438	90,863
Trapani	1062	0.77	19,116	-	-
Total	69,670	2.24	1,254,060	468,000	280,800

The areas cultivated with Citrus species in the various municipal districts compared with Used Agricultural Area (%), the processing plants and the three existing AD plants are shown in Figure 3.1.

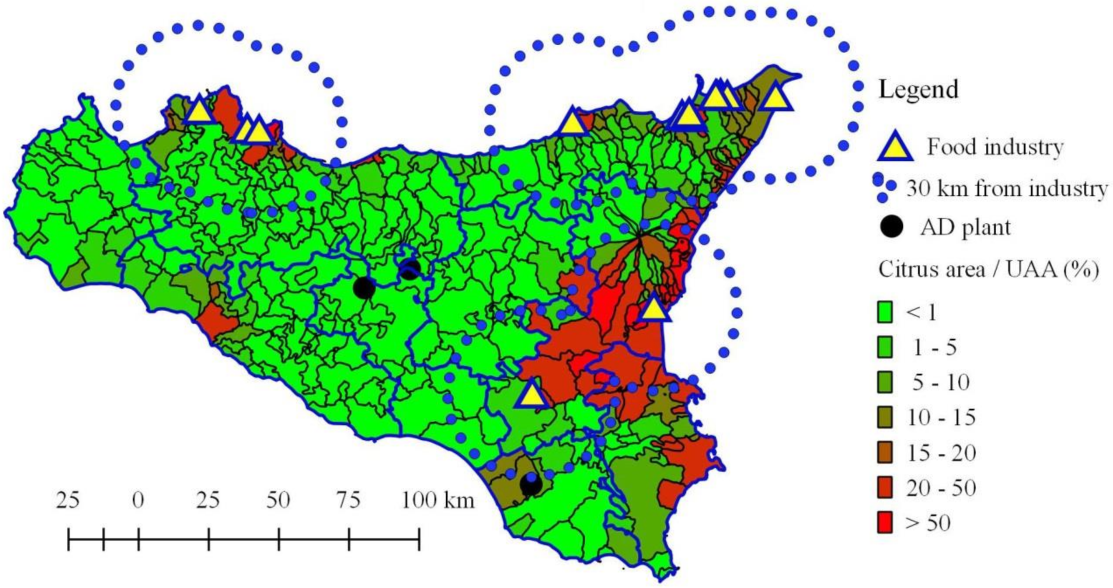

Figure 3.1: Sicily map showing the ratio between the areas cultivated with Citrus species in the various municipal districts and Used Agricultural Area (%), the processing plants and the three existing AD plants.

The results of laboratory analysis of CW samples are: dry matter of 10.26%; ash/dry matter of 4.96%; biogas yield of 45.65 m^3 t^{-1}; biomethane content inside biogas volume of 48%.
By using the above formulas it was foreseen that in Sicily it is possible to obtain, through the use of "pastazzo", a yearly production of 12,916,800 m^3 ca. of biogas, equal to 24,250,930 kWh of electric energy and 25,463,477 kWh of thermal energy or 6,200,064 m^3 of biomethane. This high potential biogas and energy production is not currently used in a sustainable way from the energetic and economic points of view, because the existing AD plants are farer than 30 km from Citrus processing plants.

4. Conclusion

Italian legislation, with the Legislative Decree no. 205/2010, clearly defines when a residue has to be considered waste or by-product (Cerruto et al., 2016). On this basis the Regional Department of Agricultural and Food Resources of Sicilian Region issued the document n° 14843 of 01/03/2012, that defined CW as a by-product rather than a waste and indicated the following uses for it:

• agronomical, as soil organic fertiliser or raw material for compost production;
• energetic, for bioethanol (biofuel) production or as raw material for biogas production;
• human food, for the production of fibres;
• fresh or ensiled or dried feed for livestock (Valenti et al., 2016);
• industrial, for the extraction of pectin (used as jelly in the food industry producing, above all, marmalade and jams).

Yet, the agronomical, human food, livestock feed and industrial uses of CW were not able to consume the high amounts of this by-product produced in Sicily (Interlandi, 2013). Therefore, CW can be considered as a resource rather than a by-product, as it can be used for producing biogas and digestate through AD process. This use contributes to minimise its environmental impact and also allows its energy valorisation. Furthermore, CW is characterised by an optimum attitude to AD process (due to its content of sugars), the above written plentiful availability in Sicily and a low cost of biomass unit (€ 10 t^{-1}) and, therefore, of biogas unit that can be produced from it (€ 0.11 m^{-3}) (Interlandi, 2013). The CW produced in Sicily could be used inside a bio-reactor, together with other raw materials (e.g. pomace and wastewater from olive oil mills, cereal straw, poultry manure and Italian sainfoin or *Hedysarum coronarium*), for AD process.

Yet, the disadvantages of using this by-product for AD process are its seasonal availability (from December to June), the difficult storage (due to its high water content and high fermentation attitude), the rapid acidification, inhibiting the activity of bacteria producing methane, and the presence of D-limonene in the peels and water, both inhibiting the process. Therefore, before AD process, CW must be subjected to a treatment aimed at removing limonene (Interlandi, 2013).

The use of "pastazzo" could be a potential solution to the problem of disposal of organic materials, caused by its high cost (€ 30 t^{-1}) and a significant lack of suitable landfills. Due to these problems some food processing companies illegally disposed the CW (Last Orange operation by police).

Therefore, this work suggests the need for a territorial plan where new AD plants must be located nearer than 30 km to Citrus processing plants, in order to reduce the transportation cost of CW and the environmental impact of its energy valorisation process.

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Energy efficiency in food processing buildings: an integrated approach based on data monitoring, experimental analyses and computer simulations

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Keywords: Energy efficiency, Food processing buildings, Integrated design

Summary
The present research aims to optimize energy efficiency in food processing buildings, by means of integrated design. The work is divided in the following phases: data monitoring, data analyses, computer simulations, and experimental tests in a case-study winery. The goal is to study and design energy saving solutions tailored for farm wineries, and easy to be implemented by the farms. The study proved the effectiveness of the proposed solutions and showed the importance of an integrated design approach to optimize the building and its systems.

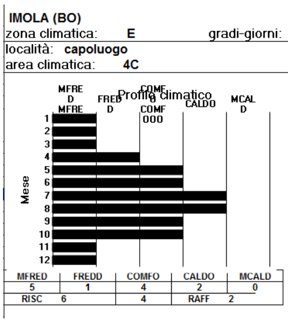
1. Introduction
Since the last decades of the previous century, the rising cost of energy and the increasing sensibility for environmental issues in public opinion have oriented the construction sector to pay increasing attention to energy saving solutions in the design of new buildings and building retrofitting. Moreover, global environmental policies (United Nations 1998) encourage the countries to issue laws aimed to combine the sustainable use of environmental resources with high-quality constructions. In particular, the latest European directives (European Commission 2010) have set the goal of constructing nearly Zero-Energy Buildings (nZEBs) after 2020. In Italy, as in other Mediterranean countries, energy-saving laws subsidize building retrofit, with the aim to reduce the energy demand of indoor temperature control systems for the future years.
Laws and subsidies do not exclude the agricultural sector, in particular food processing buildings, where energy is mainly used to guarantee food quality and safety. In those facilities, reduction in energy demand is significantly important since it can lead to a remarkable reduction in production costs. Mainly for this reason, and also for marketing strategies, in the last years several farms have increasingly used renewable energy sources, reducing the energy taken from the grid. A further contribution to energy demand reduction can be achieved optimizing the process and the building technology, in particular in building hosting ageing or conservation phases (such as wineries, dairy farms, food storages). A construction designed with energy saving criteria can allow a remarkable reduction in energy needs, mainly in conditioned rooms (Benni et al. 2013). In order to optimize food processing buildings for energy reduction, two main issues arise: the management of all disciplines involved in the design of such constructions (and their mutual effects), and the poor availability of systems tailored for the specific needs of food processes, since they are usually optimized for residential of office environments. The design of a winery, for example, besides engineering and regulation-related issues, deals with chemistry, physics, enology, meteorology and more.
Integrated design, being capable of taking into account the mutual relationships of choices in different fields of the design process, can prove to be a useful tool in order to achieve a reduction in energy consumption (Barbaresi et al. 2017). The aim of this work is to show an example of integrated design applied to a winery.

2. Materials and Methods
A case-study food processing building – a winery located in the Bologna metropolitan city, Italy – has been chosen for this work. The work is divided into the following phases: monitoring and

survey of environmental conditions, data analyses, computer modeling, validation and simulation, experimental tests.

2.1 Monitoring and survey of environmental conditions

The first step in this research has been the acquisition of spatial data related to wine production, energy and water needs and consumption, outdoor and indoor environmental conditions, ground temperatures at different depths in different points, harvesting procedures and periods, production, etc.. The main results of the multi-year survey campaign (Tinti et al. 2014; Barbaresi et al. 2015) are shown in Figure 2.1.



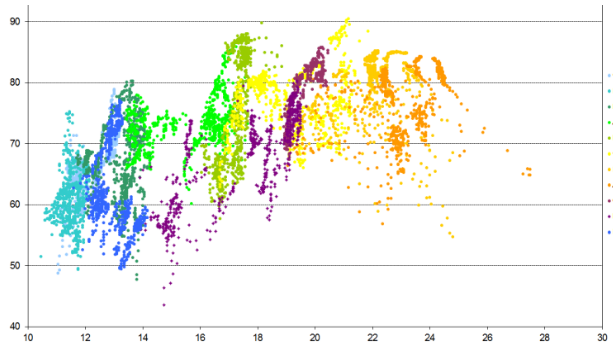
TEMPERATURE MENSILI

MESE	MIN MED	MIN ESTR	MAX MED	MAX ESTR	MED
1	-0,7	-9,0	5,9	13,0	2,6
2	1,3	-4,8	9,3	16,2	5,3
3	4,5	-2,0	14,0	20,6	9,2
4	7,8	1,8	18,1	25,0	13,0
5	11,8	6,0	22,9	29,2	17,4
6	15,6	9,8	26,9	32,8	21,3
7	17,5	12,4	29,8	34,6	23,7
8	17,5	12,2	29,4	35,2	23,5
9	14,6	8,2	25,5	31,2	20,1
10	10,0	3,4	19,4	25,8	14,7
11	4,8	-1,8	12,4	20,0	8,6
12	0,0	-5,8	7,0	14,2	3,5
Anno	8,7	-9,0	18,4	35,2	13,6

Figure 2.1: On the left: the main weather data collected by local weather stations; on the right: the weather station installed in the case-study wine farm.

2.2 Data analyses

Collected data have been elaborated to know the potentials and critical issues of the case-study winery. In particular, data analysis highlighted the main problems affecting wine production, with reference to: high dependence on energy grid, high energy consumption for refrigeration during the fermentation phase, risks of formation of mold on the "barriques" in the ageing room (see Figure 2.2).



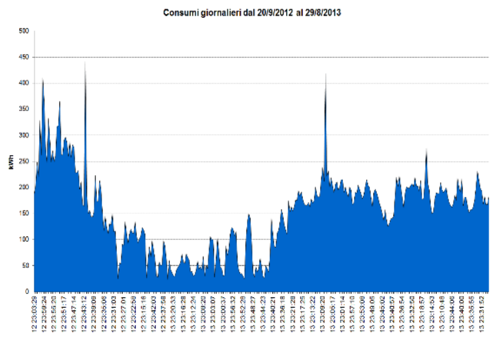


Figure 2.2: On the left: temperature (x) and relative humidity (y) in the cellar; on the right: energy consumption over one solar year.

2.3 Computer modeling, validation, and simulation

The analyses provided data which allowed us to create computer models of the building, for energy simulations, the cellar, for CFD analysis, ground temperatures, for simulation of shallow geothermal systems, and fermentation trends, for energy demand and CO_2 release (see Figure 2.3). The results of all the simulations have been gathered in a single software application, capable of evaluating the interactions among the different simulations. Collected data also allowed to validate and calibrate the computer models.

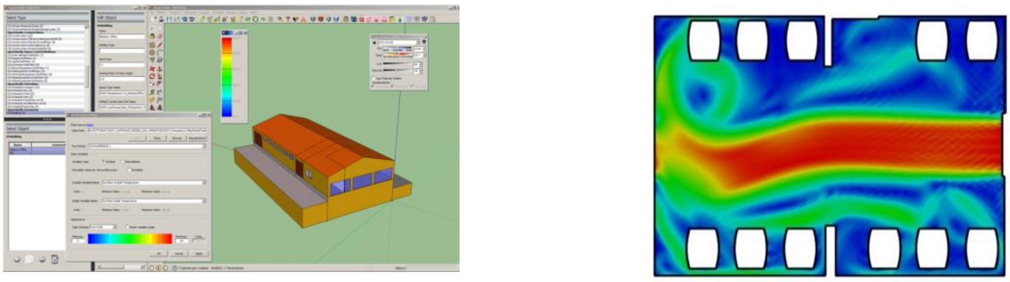


Figure 2.3: on the left: the EnergyPlus winery model; on the right: a frame of the cellar CFD simulation

2.4 Experimental tests

The simulations allowed to evaluate the performance of a large number of building solutions, cellar layouts, and geothermal system configurations, also based on metaheuristics methods (such as genetic algorithms). This method suggested some solutions optimized for the case-study winery. We are here presenting the results of the tests for micro-ventilation in the aging room (cellar), and for shallow geothermal response test. In both cases, two specific machines – and related sensor systems – have been designed and built for the trials (see Figure 2.4).

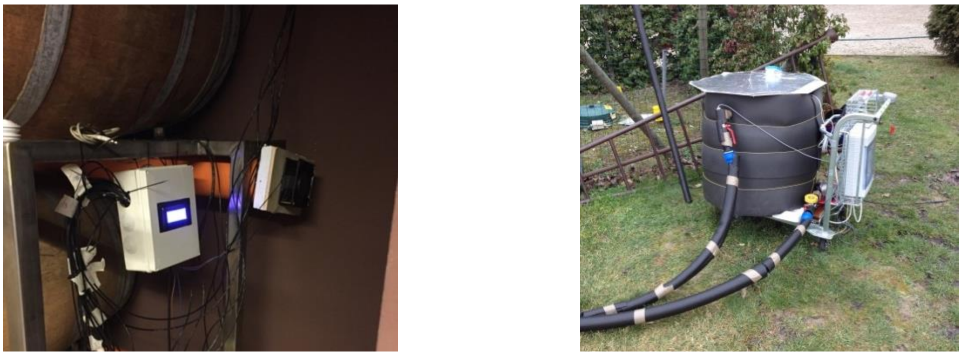


Figure 2.4: on the left: micro-ventilation system; on the right: thermal response test machine

3. Results and Discussion

The combination of computer simulations and experimental tests, evaluated through an integrated approach, allowed to assess the performance of specific solutions for energy demand reduction. In particular, this work shows the results related to micro-ventilation and shallow geothermal systems. The graphs in Figure 3.1 show that relative humidity is more homogeneous (lower standard deviation) when the system is on, this situation easing the prevention of mold formation. Figure 3.2 shows that energy saving che be reached using the shallow geothermal system coupled to air-air heat pump.

4. Conclusion

This procedure has been successfully applied in some case studies, wineries in particular, allowing to test the performances of very shallow geothermal systems, energy saving solutions in building envelopes, and micro-ventilation in wine-ageing cellars.

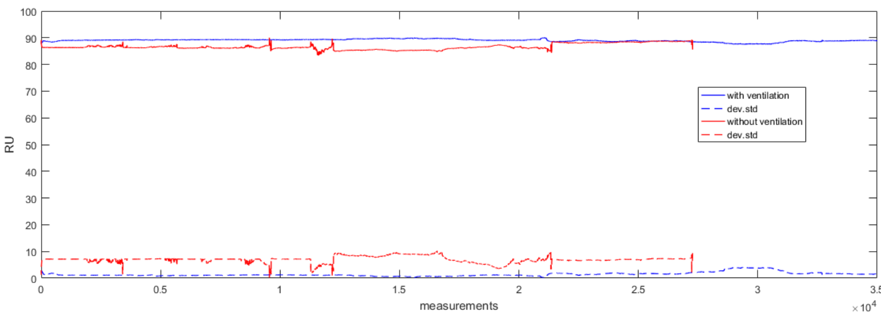


Figure 3.1: Trends of relative humidity and its standard deviation

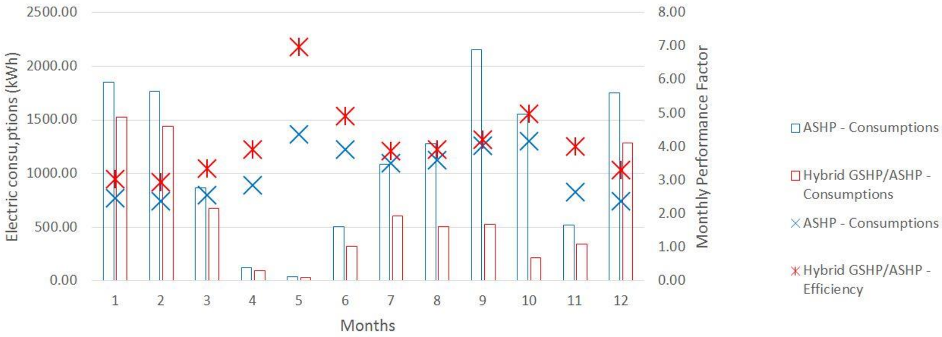


Figure 3.2: Energy consumption and system efficiency: ASHP vs Hybrid GSHP/ASH

Finally, continuous monitoring and computer simulations, performed after the installation of the energy saving solutions, proved to be important tools to evaluate different energy saving scenarios and their integration, identifying their strengths and critical issues, and providing the actors involved in the project with useful information to improve the decision-making processes. A distinctive point of our study is that both systems have been designed considering the specific capabilities, resources and technologies available in small-medium sized wine farms, allowing self-construction and thus to further increase money saving.

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Ammonia emission from pig slurry before and after anaerobic digestion: a preliminary study

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Keywords: anaerobic digestion, slurry, ammonia emission

Summary
The purpose of this work is to compare ammonia emissivity from pig slurry added with biomass in a mesophilic system, before and after the anaerobic digestion.
The digestion plant works in mesophilic conditions, up to 43 °C, with a 56-d retention time. The slurry was sampled for chemical analyses and for ammonia emissions before and after the anaerobic digestion (at the end of the 56 d of retention time). For ammonia emission evaluation, all the samples were kept at 18°C in a climate controlled laboratory, ammonia emitted from the samples was measured through a measuring detector (Gasbadge Pro ammonia) every 2 minutes for 30 minutes. All the chemical analytical values are similar to those found in the available literature. Results showed that ammonia emission rate, measured every two minutes for 30 minutes, was significantly higher from the digestates, in comparison with pig slurry, with mean values of 72.01 mg/m^3 *vs* 50.74 mg/m^3 ($P<0.01$). The higher amount of total ammonia emitted during the 30 minutes of trial was estimated in around + 32.5%, $P<0.001$. As it was expected, the trial confirmed that the downstream effluent of the anaerobic digestion of animal waste presents different chemical-physical and emissive characteristics from the untreated slurry. Despite, it seems that greenhouse gases reduction induced by the anaerobic treatment cannot be guaranteed for ammonia. Therefore, the simultaneous reduction of greenhouse gases and ammonia could be obtained only if good management practices will be applied during manure spreading on field.

1. Introduction

During the last decades, the livestock systems has changed its set-up with a significant decline in family run farms units (in Italy -53%) and a growing presence of large scale farms. This "industrialization" of livestock farming leaded to an increase in environmental risks for the rising levels of pollutants as ammonia, greenhouse gases, odors and dust released into the atmosphere, soil and water.
According to the Italian Inventory of Ammonia and Greenhouse Gases Emissions, agricultural practices contribute respectively to 94% NH_3, 50% N_2O emissions and 37% of national CH_4 emissions (ISPRA, 2014).
As other European countries, the Italian agriculture sector is responsible for the greatest emission of greenhouse gases, methane and nitrous oxide, as well as ammonia into the atmosphere:
Moreover, the Po Valley, in Northern Italy is considered as a "vulnerable" area characterized by intensive animal rearing and related agriculture practices, with an elevated use of manure and fertilizers applied to lands. The high density of reared animals implies an excessive load of nitrogen, coming either from manure or from fertilizers, both applied to cultivated soils.
The treatment of animal manure by anaerobic digestion for the production of biogas was identified as a priority measure by the government as a means of mitigating greenhouse gas emissions.
The anaerobic digestion consists in a biological process of stabilization of an organic substrate in which bacteria break down biodegradable material in the absence of oxygen. This process allows the stabilization of the wastewater and the energy enhancement.

Usually digested wastes differ from untreated slurry in its dry matter content, lower, its pH and the amount of mineral nitrogen (as NH_4+ and NH_3) increase. These changes account for the different GHG and ammonia emission pattern observed from digestate.
A limited literature is available for experimental studies about GHGs and ammonia emission from digestate of animal waste in laboratory conditions.
Ammonia emission evaluation in laboratory conditions through a dynamic chamber avoid the potential undesired effect of season, and climate generally speaking, on ammonia volatilization (Sommer et al., 1997; Misselbrook et al. 2005).
For this reason, the purpose of the work is the compare ammonia emissivity from pig slurry added with biomasses in a mesophilic system, before and after the anaerobic digestion.

2. Materials and Methods

The farm chosen for sampling is located in Northern Italy, it is a full cycle pig farm with 800 sows. The digester, with the capacity of 1 MW, is fed with liquid pig manure and biomass (75 %: 25%), usually corn silage. It works in mesophilic conditions, up to 43 °C, with a 56-d retention time. The slurry was sampled before and at the end of the anaerobic digestion process. Total Solids, Organic Solids (Volatile), pH, Total N, N Ammonia, Nitric N, P Total (P_2O_5), Total K (K_2O), AGV and FOS/TAC were analyzed on samples.
In order to represent ammonia emission of the waste (before and after digestion) to be spread on soil, during the trial, 3 samples (200ml) of slurry and 3 samples of digestate (200ml) were collected as pooled samples from 3 tanks of 20 l of volume for fresh and digested slurry, the trial was repeated for 5 digestion cycles.
The 200 ml samples were kept at 18°C in a climate controlled laboratory, ammonia emitted from the samples was measured through a measuring detector (Gasbadge Pro ammonia) every 2 minutes for 30 minutes, from Pyrex tanks set up to work as a dynamic chamber with an inlets for fresh air and an outlet for ammonia measurements.
Data were submitted to variance analysis (Proc GLM, SAS 9.2) to evaluate the effect of anaerobic digestion on ammonia emission by samples.

3. Results and Discussion

All the analytical values (Total Solids, Organic Solids (Volatile), pH, Total N, N Ammonia, Nitric N, P Total (P_2O_5), Total K (K_2O), AGV and FOS/TAC are similar to those found in the available literature (see Figure 3.1a and b for pH and Total ammonium Nitrogen). Our data are in agreement with findings by Sung and Liu (2003), total ammonia nitrogen (TAN) concentration and the ratio TAN/total Kjeldahl nitrogen (TKN) increases in all reactors after the anaerobic digestion, as a result of the urea and protein hydrolysis; anaerobic digestion causes the pH-value and the ammoniacal N (NH_3 and NH_{4+}) to rise (Messner, 1988).

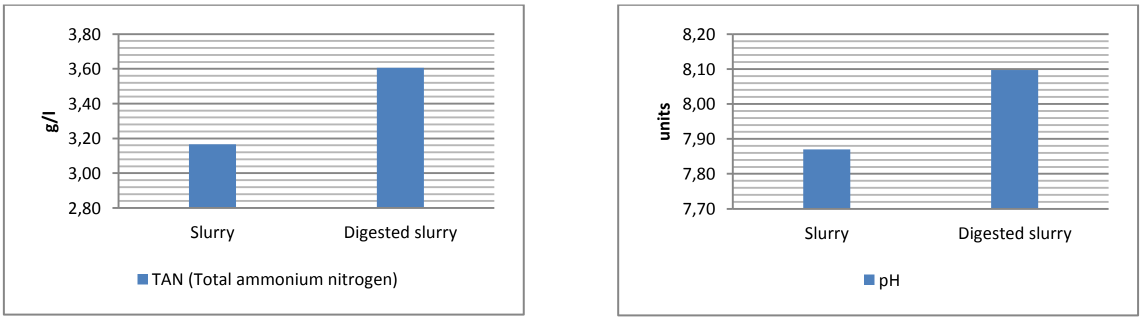

Figure 3.1a and b: Mean values of pH and ammonium nitrogen of untreated and treated (through anaerobic digestion) samples

In this specific case, the rising of ammonium nitrogen content could also depend on the amount of corn silage (25 %) added to the reactor.

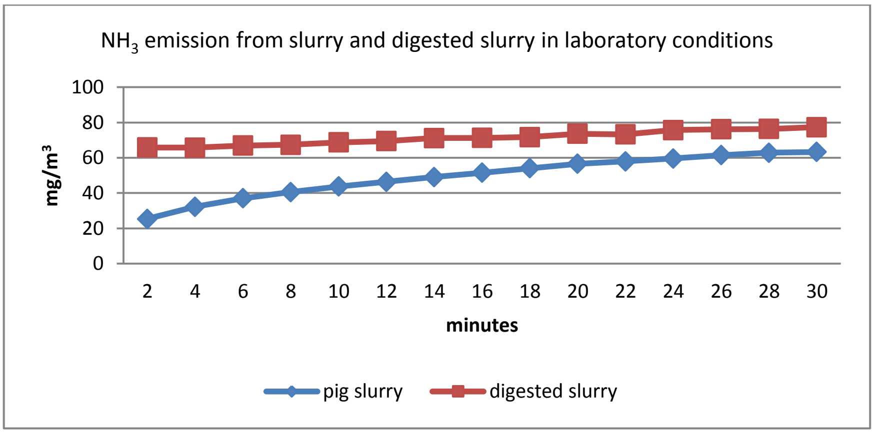

Figure 3.2: NH_3 emission measured every two minutes at 18°C from slurry and digested slurry in laboratory conditions

Results obtained during the part of the trial regarding ammonia emission, showed that, during the first 30 minutes, ammonia emission measured every two minutes was significantly higher from the digestates, in comparison with pig slurry, with mean values of 50.74 mg/m^3 vs 72.01 mg/m^3 (Figure 3.2; $P<0.01$).

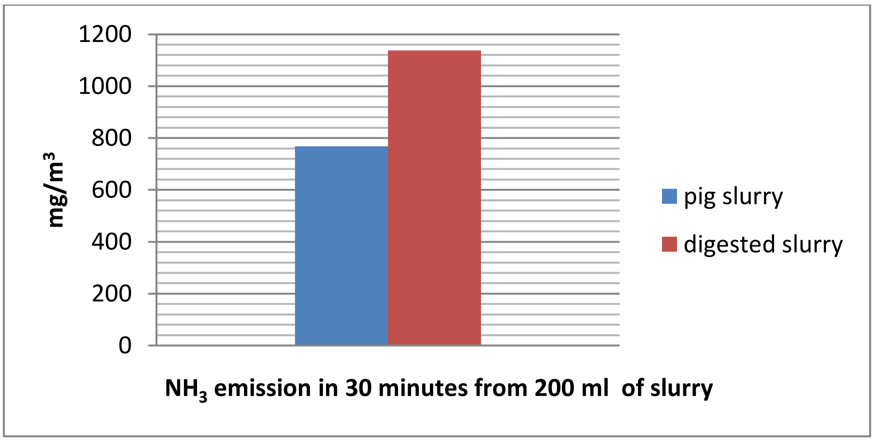

Figure 3.3: NH_3 total emission measured in 30 minutes from 200 ml of slurry

For digestates, the total higher quantity of ammonia emitted during the 30 minutes of trial (see Figure 3.3) was estimated in around + 32.5%, $P<0.001$.

As it was expected, the test confirmed that animal wastes present different chemical-physical characteristics and different emission levels after the anaerobic digestion.
In agreement with Moitzi et al.,2007, anaerobically digested slurry showed higher NH_3 emissions than untreated slurry, so the potential for ammonia losses is increased.
Greenhouse gases reduction induced by the anaerobic treatment cannot be guaranteed for ammonia.
Although Italy, as other European countries require that slurry tanks have surface covers (Dalgaard et al. 2011, Hoeksma et al. 2012) before it is spread on cultivated soil, the higher ammonia emission released by digested wastes spread on cultivated soils as fertilizer, could represent a not negligible environmental risk.

4. Conclusion

This preliminary study conducted in a mesophilic anaerobic plant showed an increase in ammonia emission levels after the digestion treatment. Since the trial was based on the digestion of pig slurry added with biomass (corn silage), this could affect ammonia emissions.
Further studies need to be carried out in order to deepen the dynamics of ammonia emissions from digested animal wastes. At the end, it has to be remembered that the reduction of greenhouse gases and ammonia could be obtained only if good management practices will be applied during digested manure spreading on field, using low emission spreading systems like trailing hose, trailing shoe or soil injection.

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Compostable packaging based on fibrous natural materials and bioplastics. Preliminary results.

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Keywords: bio-packaging, straw-waste, bioplastics

Summary
The aim of the research was to find a solution for the production of packaging for industrial products in different commercial sectors, in order to reduce the environmental impacts from the production and use of packaging made out of plastics.
The research took into account materials not only biodegradable but also compostable: in fact, the composite material consists solely of materials in their turn compostable according to European Standard EN 13432 "Packaging - Requirements for packaging recoverable through composting and biodegradation".
The experimental application consisted in the realization of packaging prototypes made of a composite material with straw and bioplastics. If the required composite material is compostable, the packaging at the end of its life-cycle can be dispersed in the soil as biomass. In this case, the disposal is absolutely harmless to the environment.

1. Introduction
Traditional packaging materials, including plastics, glass, metals, wood and other, can constitute the packaging for consumer goods. Currently a prominent part of the packaging is made from foamed synthetic material, which gives rise to great problems during disposal when they are not biodegradable materials. For this reason, it is important to search for substitute materials for packaging which minimize the problems due to the disposal.
According to Davis at al. (2006) careful redesign of packaging is necessary to minimize the use of materials. At the same time the new packaging has to meet functional and legislative requirements. This redesign, whenever possible, should also make primary and secondary packaging more recyclable. Composting is seen in many European countries as a cheap method of disposal and composting facilities in many European states offer attractive gate fees compared with landfill.
Biodegradable polymers broaden the range of waste management treatment options over traditional plastics. The most interesting end-of-life disposal options for these materials are domestic and municipal composting in place of landfill. Techniques for recycling of conventional polymers are generally not suitable for biodegradable polymers but the value of the materials may be recovered in the form of useful compost. Biodegradable polymers can thus make significant contributions to material recovery, reduction of landfill and utilization of renewable resources (Petersen et al., 1999; Vink, 2001; Murphy et al., 2004). In recent years, development of biodegradable packaging materials from renewable natural resources has received widespread government support in EU countries and many national and international organizations began new research in this area. Among the others, these include the European Renewable Resource Materials Association (ERRMA), the National Non-Food Crops Centre (NNFCC) in the UK, the International Biodegradable Polymers Association and Work Group (IBAW) based in Germany and the Interactive European Network for Industrial Crops Application (IENICA). The UK Government-Industry Forum has strongly recommended greater use of non-food crops, particularly for biodegradable packaging applications (DEFRA, 2002, 2004).

Worldwide there are numerous studies, which tend to identify sustainable materials to replace the expanded synthetic materials, such as polystyrene, for packaging (Severini et al., 2016; Ashworth et al., 2015).

2. Materials and Methods

Straw is an inevitable product of the cultivation of cereals. The amount of straw produced worldwide in the year 2015 is in the order of 21 billion tons (FAO, 2015). Currently the most widespread uses are in agriculture (bedding in livestock, soil improver, mulching, etc.) and in energy production (biomass, advanced biofuels, etc.). However, in most cases, the straw represents a disposal problem and it is left to decompose or burned on the field, requiring further actions and environmental and economic costs. For this, a surplus of straw exists everywhere, even if it is difficult to quantify volumes. In order to create an alternative market, valuing straw waste material for packaging, it could be very attractive in economic terms for cereal farms.

For biopolymers based on biologically derived polymer, significant technological development has been achieved to produce biodegradable materials for packaging applications with properties similar to the ones offered by the traditional oil-based plastic packaging (some examples of commercial products are: Mater-Bi, Nature Works Polylactide, Bioska, Bioplast, Solanyl, Potatopac, Greenfil, Eco-Foam, etc.). Specifically, Mater-Bi, obtained from polymers of corn starch and vegetable oils, used in the form of sheets of variable thickness (20 - 40 microns), has been tested.

The method for producing sustainable composite material can be described as specified below: a certain amount of dry straw (moisture content 6-7%), preserved and stored in accordance of good agricultural practice, is cut to obtain stems long between 50-150 mm; the cut straw is necessary for the preparation of a plurality of bundles arranged parallel to one another and each wrapped in a sheet of heat-meltable bioplastic to form elementary cylinders, which will be later able to form closed cells for containing the straw (Fig. 1).

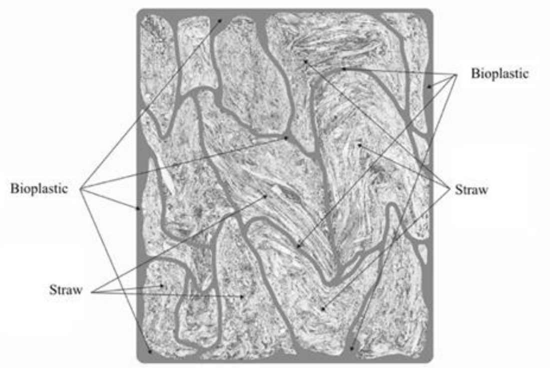

Figure 1: Arrangement diagram of composite material inside the block; the section is designed for any direction: in every direction the distribution pattern of closed cells of bioplastics and fibrous organic materials is the same.

Cylinders were arranged within a mould and compressed by means of a piston having a compression stroke perpendicular to the cylinders. In such a way, as a result of compression within the mould, fibrous of straw sets itself in all directions.

Heating the composite material in the compressive state up to melting to obtain an extensive honeycomb structure, constituted by a tri-directional lattice of bioplastic material formed by a set of closed cells connected both together and to the outer casing and adherent to the straw. The heating step was implemented by irradiation with electromagnetic radiation at high frequency in the range of 2000-4000 MHz, preferably with a power between 5.000 W and 10.000 W (Fig. 2).

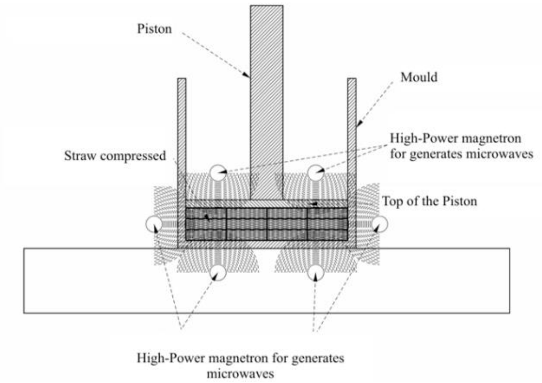

Figure 2: Production scheme characterized by straw compression and cooking

Subsequently the composite material in the compression state was cooled up to solidification of the honeycomb structure, in order to maintain a state of co-action in permanent equilibrium with the straw permanently compressed and the bioplastic material permanently tensioned.
After the production of packaging prototypes, each specimen was characterized mechanically and physically and all prototypes have shown interesting features that make them usable for packaging but also for the production of structural bearing blocks and non-structural elements (e.g. insulating panels) in the building industry.

3. Results and Discussion

The good results of preliminary tests (Fig. 3) have allowed to the Gesaaf staff, involved in this research, to present two national and international patent applications both for the material and for the production process of the invention. Both patent applications obtained a positive search reports by European Patent Office (International Publication Number WO2017/025786 A1).

Figure 3: Prototypes of bio-packaging with different shape

4. Conclusion

The design of new materials suitable for the production of packaging systems, mainly related to consumer goods, has become an issue of remarkable importance, due to the great impact that this will have on environmental protection.
Many of the currently used packaging materials, such as expanded polystyrene, corrugated cardboard, polyurethane and other foamed synthetic materials, are characterized by a life-cycle that generates high rates of pollution. Therefore, it is necessary to design innovative materials that have sustainability characteristics, in particular in the disposal stage. The aim of this research was to develop a biodegradable and compostable packaging to utilize renewable and potentially more sustainable sources of raw materials (instead of crude oil) and to facilitate integrated waste management approaches to reduce landfill.

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Effect of additives on phosphorus, copper and zinc separation from animal raw and digested slurries

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Keywords: separation, calcium hydroxide, aluminum sulfate, phosphorus, heavy metals, manure

Summary
To maintain a sustainable local and global environmental balance and secure a renewable phosphorus (P) source, it is necessary to remove and recover P from animal manure. Some concerns are also related to heavy metals contained in manure, especially copper (Cu) and zinc (Zn) that, when applied to land, can impair soil and water quality. A suitable technology to remove these elements from slurries can be solid-liquid separation. However, adequate removal efficiencies can be obtained only with the use of additives.
The objective of this study was to evaluate the effect of two additives (calcium hydroxide $Ca(OH)_2$ and aluminum sulfate $Al_2(SO_4)_3$) on the P, Cu and Zn separation efficiencies using raw slurry and co-digested slurry (before and after a physico-chemical treatment of ammonia stripping). After the addition of the chemicals, slurries were mixed and then separated using a static filter with a 0.25-mm mesh after 30 min of sedimentation. All tests were conducted in duplicate. Liquid samples were analysed for pH, dry matter content and volatile solids, which were determined using standard methods. The contents of P, Cu and Zn were obtained by ICP-MS analysis. As expected, the addition of additives effectively improved separation efficiencies of P, Cu and Zn. The maximum efficiencies obtained depended on the type of slurry and additive used. For example, the P separation efficiencies ranged from 57 to 88% using $Al_2(SO_4)_3$ and from 39 to 74% using $Ca(OH)_2$. The use of $Al_2(SO_4)_3$ had a more consistent effect on removal efficiencies of P, Cu and Zn than did $Ca(OH)_2$.

1.Introduction

Phosphorus (P) is an essential element in agriculture, being one of the nutrients necessary for the proper development of crops. Most of the P derives from rock phosphate, which is not a renewable resource and could be exhausted in 100–250 yr (Grigatti, et al. 2015). As an alternative to mining phosphate rock, P can be obtained from other sources, for example livestock slurry. A large amount of P contained in livestock manure is now spread on fields causing a P-surplus, which can be transported by runoff and subsurface flow to downstream water bodies and contribute to eutrophication. Therefore, to maintain a sustainable local and global environmental balance and secure a renewable P source, it is necessary to remove and recover P from animal manure. One possibility for recovering P from animal manure is solid-liquid separation. This treatment separates solids from slurry, obtaining two final products that can be managed separately: a dry nutrient-rich fraction and a liquid fraction. The liquid fraction is easily transported to and spread on fields (Burton, 2007).
Some concerns are also related to heavy metals contained in manure, especially copper (Cu) and zinc (Zn). These elements are essential for plant growth, but in excessive concentrations can cause soil and water pollution. Solid-liquid separation of slurry can be a suitable technology also to remove these elements (Møller et al., 2007). However, higher removal efficiencies can be reached only with the use of chemical additives.
The present study evaluated how the application of different doses of aluminum sulfate ($Al_2(SO_4)_3$) and calcium hydroxide ($Ca(OH)_2$) in solid-liquid separation treatment can affect P, Cu and Zn separation efficiencies from raw pig slurry and co-digested slurry before and after

ammonia stripping treatment. We assessed how the form of slurry, dose of additives and the physico-chemical treatment influenced the separation efficiencies of these elements.

2.Materials and Methods

For assessing P-separation efficiency and metals removal efficiency the following five forms of slurries collected in farms located in the Lombardy region were used (in brackets the short name used subsequently): liquid fraction of pig slurry ("pig slurry") from a fattening pig farm, after screw press separation; liquid fraction of co-digested pig slurry and corn silage before ("pig digestate") and after ("pig digestate stripped") a stripping process for ammonia removal; digested liquid fraction of slurry from 25,000 pigs and 1,800 dairy cattle after screw press separator and before ("mixed digestate") and after ("mixed digestate stripped") a stripping process for ammonia removal. The stripping process was conducted at laboratory scale, at the temperature of 40°C for 12 d, achieving a nitrogen removal of 80%. Each slurry was separated using three different doses: (1) null dosage, (2) an optimal dosage determined for each slurry and (3) 25% lower dosage than optimal. The $Ca(OH)_2$ was introduced into the process as "lime milk" at 200 g/L. A1 M solution of $Al_2(SO_4)_3 \cdot 18H_2O$ was prepared for each experiment and dosed at the desired concentration using a micropipette. After mixing, the suspensions were allowed to settling for 30 min (Renou et al., 2008). At the end of the settling phase, each solution was separated using a static filter with a 0.25-mm mesh. The separation efficiency was calculated as the ratio between the mass of a specific compound in the solid fraction and the mass of the same compound in the input slurry (Cocolo et al., 2016). Each slurry was characterized for Total Kjeldahl Nitrogen (TKN), electrical conductivity (EC), total ammonia nitrogen (TAN), pH, dry matter content (TS) and volatile solids (VS), determined using standard procedures. For each experiment both the raw slurry and supernatant samples after separation were characterized for P, Zn and Cu, which were quantified through the acid mineralization method using Inductively Coupled Plasma Mass Spectroscopy (ICP-MS). All tests were conducted in duplicate.

3. Results and Discussion

The physico-chemical characteristics of the five slurries are summarized in Table 3.1. The main effect of the stripping process was a reduction of TAN concentration, and consequently of TKN concentration, but EC, TS and the content of other elements were also modified. The P concentrations in raw pig slurry and digestates were comparable to those reported by Møller et al. (2007). The increase in concentrations of heavy metals and other elements after the stripping process can be explained as a consequence of water evaporation that occurs during the treatment (at 40°C). The same explanation applies for solids content: without considering evaporation, the stripping process increased the TS concentration by 17% and 21% for pig and mixed digestate, respectively. Notably, VS content (expressed as percentage of TS) decreased. Probably, in the digested slurry there were still biodegradable components that were degraded during the process.

Table3.1: Main characteristic of five slurries used for the tests.

	Pig slurry	Pig digestate	Mixed digestate	Pig digestate stripped	Mixed digestate stripped
pH	6.75 (±0.18)	8.1 (±0.08)	8.2 (±0.24)	7.6 (±0.03)	8.4 (±0.04)
EC	25.84 (±0.32)	29.7 (±1.15)	20.9 (±1.2)	15.8 (±0.13)	12.0 (±0.23)
TKN (g/kg_{TQ})	3.93	4.6	2.4	2.2	1.2
$N\text{-}NH_4^+$ (g/kg_{TQ})	2.26	3.4	1.9	0.6	0.2
TS(%)	2.5 (±0.18)	4.2 (±0.44)	2.5	5.0 (±0.23)	3.1 (±0.49)
VS (VS/TS%)	63.0 (±2.28)	58.2 (±0.89)	59.5	55.7 (±2.41)	51.1 (±8.78)
P (mg/kg_{TQ})	371 (±43.0)	1137 (±354.6)	452 (±50.6)	1509 (±30.8)	613 (±98.7)
Cu (mg/kg_{TQ})	12.9 (±1.6)	6.8 (±2.4)	5.1 (±0.5)	10 (±0.9)	6.6 (±0.5)
Zn (mg/kg_{TQ})	20.4 (±2.8)	41.5 (±12.1)	25.1 (±3.2)	61.7 (±3.9)	31.6 (±4.8)

The removal efficiencies obtained for total solids, P, Cu and Zn are reported in Figure 3.1. The addition of $Al_2(SO_4)_3$ generally improved the removal efficiencies for all elements for all the slurries tested. The efficiencies, however, varied consistently for different elements and different slurries. For example, the P removal efficiency obtained with $Al_2(SO_4)_3$ was 70–80% for the mixed digestate, both raw and after stripping. The removal efficiencies for pig digestate were lower (55–60%) but increased significantly after stripping (to~90%). None of the removal efficiencies for any elements in pig slurries were particularly high (75% for P), emphasizing that the effect of the additive was more relevant because the difference in efficiency obtained with the additive compared that with the null dose was greater than for the other slurries. The efficiencies reachable with $Ca(OH)_2$ were much lower and in many cases this additive did not increase the separation efficiency. In fact, $Ca(OH)_2$ had a clear effect only for pig slurry at the highest applied dose and for pig digestate slurry after stripping, which had higher TS content (5%). The maximum removal efficiency obtained for P was 75% for mixed digestate stripped, but this was not significantly different from that achieved with the null dose (60%). As with $Al_2(SO_4)_3$, the addition of $Ca(OH)_2$ produced greater differences in removal efficiencies compared to the null dose for pig slurry than for other slurry forms.

4. Conclusions

The maximum efficiencies achievable when removing chemical constituents from animal manure slurries depend on the type of slurry and the additive used. For example, P removal efficiency for pig slurry increased from 11% (±15%) without additives to 39% (±6%) with $Ca(OH)_2$ and to 72% (±5%) with $Al_2(SO_4)_3$. Furthermore, $Al_2(SO_4)_3$ achieves higher P, Cu and Zn separation efficiencies than $Ca(OH)_2$. The high doses of additives required to achieve acceptable separation efficiencies should be carefully evaluated due to their high cost and potential environmental impact.

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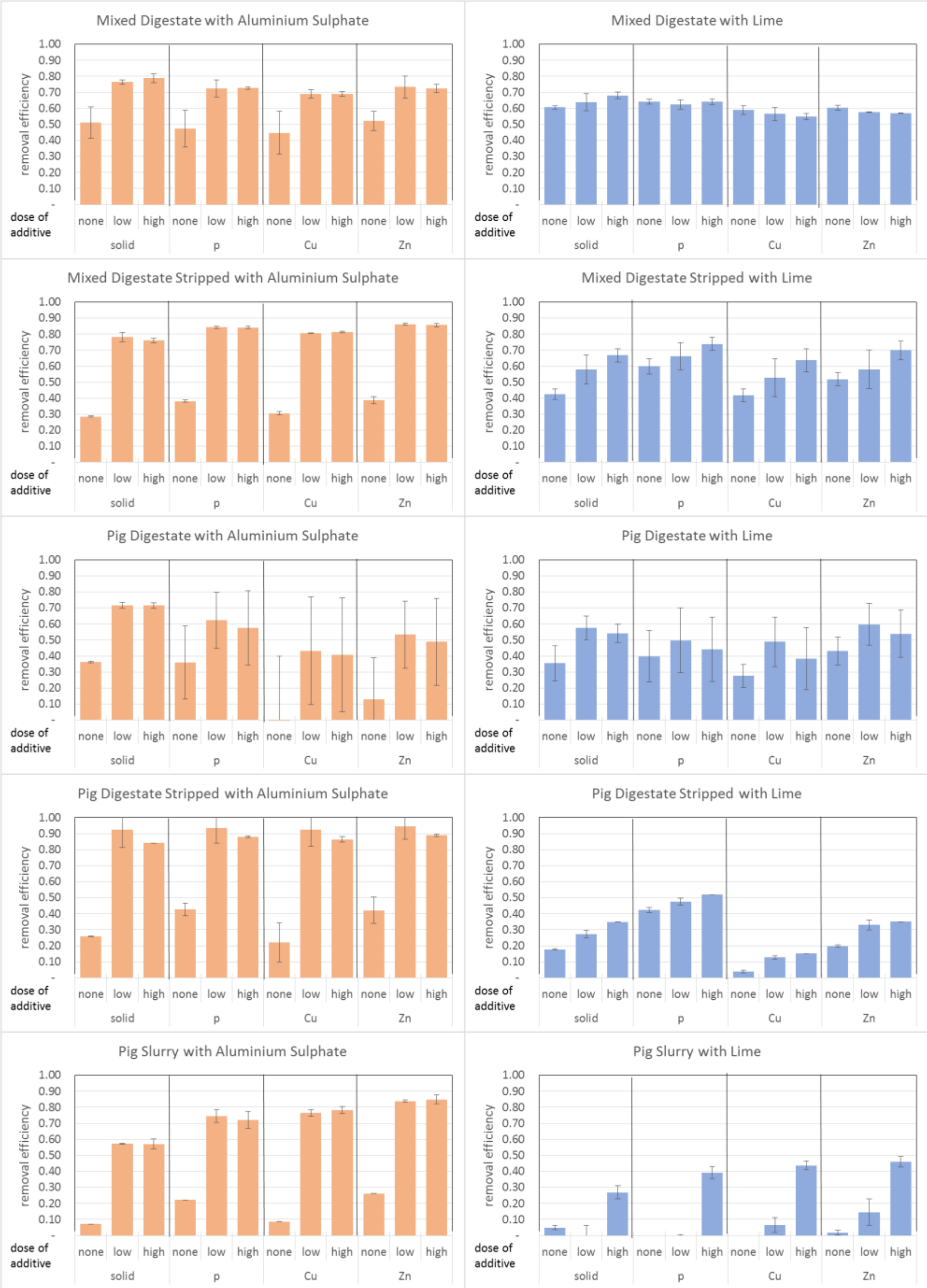

Figure 3.1: Separation efficiencies obtained for the different slurries without additives (none) and with two doses (low and high) of aluminum sulfate (left) and calcium hydroxide (right). The error bar express the standard deviation.

Valorization of Tilia sp.'s pruning waste as insulation material

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Keywords: urban forestry, sustainable construction material, by-product smart use

Summary
This paper is part of a broader research aimed at identifying valorization path for pruning waste of some of the most common tree species in urban greening and forestry.
Urban forestry often suffer for an inadequate maintenance due to economic hardship of Italian public administrations.
The identification of a possible reuse of any by-products resulting from pruning operations, could translate in better care for urban arboreal patrimony, with all the positive fallbacks that this practice would imply in terms of functionality, safety and wellbeing.

1. Introduction
Urban greening is a fundamental element in guaranteeing life quality in urban context (Day & Dickinson, 2008; Demuzere et al. 2014). In this regard, urban forestry plays a central role (Rowntree & Nowak, 1991; Dwyer et al., 1992; Nowak et al., 1996; Fazio, 2012; Hirabayashi & Nowak, 2016).
Urban Forestry is usually less diverse than many could expect (Conway & Vecht 2015). *Acer sp*. and *Tilia sp*. are among the most frequently occurring genera found in a recent study on 328 cities (Yang et al., 2015). They are also the more common two genera in 10 Nordic cities (Sjoman et al., 2012).
Tilia genus trees, especially *Tilia cordata* Mill., are the most recurrent among urban deciduous trees and are one of the most typical tree species in cities and parks of Western, Nordic, and Central Europe (Stravinskiene et al. 2015)
In Italy, urban forestry maintenance is constrained by the limited economic means of public administrations. Therefore, proper maintenance is avoided in favor of more drastic, but less frequent and very dangerous practices, such as tree topping. Such practices causes many issues that also translate in increasing economic costs in mid-term (Campanella et al., 2009), worsening the problem they were supposed to fix.
Obtaining secondary product from tree parts is not a novelty. Recently the COST Action E42: Valuable Broadleaved Trees in Europe (Hemery et al, 2008) highlighted, between various aspects, the various traditional use of linden by-products (Pennati & Ferrini, 2008) ranging from gunpowder, to artist's charcoal, from animals feeding to preparation for calming infusions.

2. Materials and Methods
For this study, we produced different types of tiles based on the residues of pruning of the linden trees (*Tilia sp.*) obtained in two different periods.
The first sample was generated from the shredding of linden's suckers cut at the end of August; the other two samples were obtained through the shredding of the residues of a proper pruning, carried out after the fall of all the leaves, to have cleaner samples.
In all cases, the wood fibers were manually mixed with PVA glue and then pressed to obtain a tile. The tile obtained with the first sample (fig. 2.1a) has a density of 333 kg/m^3. The two samples (fig. 2.1 b - 2.1c) obtained with the more refined material differ in terms of their density (202 kg/m^3 and 260 kg/m^3).

Each tile was held four days in the mold, after performing the clamping and the evacuation of all the excess water, and then transferred in the oven with the whole mold, for 48 hours by a temperature of 65 ° C.
The measurement of thermal conductivity was performed on all three materials by means of a membrane probe.

a) b) c)
Figure 2.1: samples obtained by pressing with various densities: a)333 kg/m^3; b) 202 kg/m^3; c) 260 kg/m^3

Figure 2.2: Fully assembled press

Once out of the oven, the material was allowed to cool to room temperature, within a transparent plastic bag, which was perfectly sealed. This also allows checking the presence of residual moisture, as it would show condensation formation, deposited on the walls of the bag.
As for the composition of the different types of material, a water and vinyl mixture was prepared in advance in both cases, in which the glue represented about 7.5% by weight. The biomass was previously dried for about 24 hours at a temperature of 60 ° C.
The samples were then weighed and measured to calculate their density for each type of product. The diameter of each sample was approximately 160 mm.
Subsequently, they were subjected to thermal conductivity measurement tests. This was carried out by means of a ISOMET, model 2104.
For the measurement was used as a membrane probe, which was directly placed on the surface of each specimen. Each sample was subjected to the test four times (two for each flat surface).

3. Results and Discussion

The performed tests allowed us to obtain the values of thermal conductivity (λ), specific heat (ρ).
The results are shown in table 3.1

Table 3.1: analysis results

Material	Thermal conductivity λ (10^{-2} W/m*K)	Specific heat ρ (10^5 J/m^3*K)
a)	8,37 ± 0,76	2,40 ± 0,44
b)	8,30 ± 0,54	2,26 ± 0,51
c)	8,60 ± 1,40	2,80 ± 0,65

As benchmark materials for a first comparison were selected some of the more popular wood fiberboards products on the market (λ=4 10-2 W/(mK); density 130kg/m^3).

Even though the results are incomplete, since the experimental phase of the research is still in its early stages, the first results look very promising.
The characterization of the first three materials is close enough to the benchmark values to allow foreseeing a possible use in the insulation materials' market for these products.
It could be very useful to test other mixtures of vinyl binder and wood chips and other bio-shredders, with different blades' configurations, in order to optimize the physical attributes of the material that would result in the enhancement of the thermal performances.

4. Conclusion

In nations like Italy, always struggling to find enough economic resources to ensure a proper maintenance of their arboreal patrimony, finding new ways to exploit any residues should be thoughtfully explored.
Obtaining usable by-products from street trees' maintenance can be a double-edged sword, because it could means more cutting that what is strictly functional to guarantee public safety in the city, in order to maximize the profits. So it should be carefully monitored. Still, the first results suggest that this could be a viable path, one that would open interesting, and crucial, scenarios for urban greening's care and maintenance.

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ReNuWal: a software tool to improve manure management and nutrient use efficiency

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Keywords: manure management, decision support system, nutrient use efficiency

Summary
The use of fertilizers in agriculture, in particular those of livestock origin, is one of the most significant sources of diffuse water pollution. In this context project ReNuWal, funded by Fondazione Cariplo, aims to i) identify suitable methods to optimize fertilization at farm level and ii) develop innovative techniques for nutrient processing to limit surpluses and the emissions of nutrients, improving the efficiency with which they are used. This paper describes the software tool developed. The approach used for the software tool is to compare the characteristics of the manure produced in a farm with the crop requirements, considering also distribution methods used. Thus, it is possible to evaluate if additional treatments are needed to reduce the nutrient surplus or to improve the manure use efficiency. Furthermore, an assessment of nitrogen losses to air and nitrogen and phosphorus losses to water based on the methods used to manage and spread the manure can be obtained. Using this tool, a farmer can evaluate possible improvement of nutrient use efficiency and reduce fertilization cost due to mineral fertilizers.

1. Introduction

The use of fertilizers in agriculture, in particular those of livestock origin, is one of the most significant sources of diffuse water pollution. Agricultural sources in the Po basin of Italy contribute 53% of the total nitrogen (N) and 23% of the phosphorus (P) to surface waters (ARPA, 2013).

To help improve this situation the project ReNuWal, funded by Fondazione Cariplo, aims to i) identify suitable methods to optimize fertilization at farm level and ii) develop innovative techniques for nutrient processing to limit surpluses and the emissions of nutrients, improving the efficiency with which they are used.

The project is focusing on water pollution caused by nonpoint source emissions of nutrients (N and P) from agricultural activities. Although this problem is relevant in Lombardy, it has a European (and worldwide) importance (EEA, 2012)**Specificata fonte non valida.**. In fact, although significant improvements in water quality have been achieved in Europe over the last two decades, water quality status is still below desirable levels in many locations. Diffuse pollution from agricultural landscapes remains the key cause of water quality problems in many parts of Europe due to N surplus, and, in some countries, losses of P (European Commission, 2013)**Specificata fonte non valida.**.

To prevent diffuse pollution the fundamental challenge for farmers is to know how to behave (i.e., what to do) in these rather unique production systems that are simultaneously affected by the environment and have such a dramatic effect on the environment.

One of the reasons agriculture contributes so significantly to diffuse water pollution is related to the surplus of nutrients associated with crop requirements, especially in intensive livestock areas, and the consequent low efficiency with which nutrients applied to the soil are utilized. Impacts depend on what practices are implemented and on local conditions in terms of climate and soil, but the eventual magnitude of nutrient overload in environmental compartments is the primary driver.

To fill the gap between the general guidelines on nutrient use and the practice at farm level (especially when a surplus of nutrients is produced by the livestock) adequate support to farmers

is necessary. One of the basic tools is the Nutrient Management Planning (NMP) (also called Site Specific Nutrient Management). Achieving the "right rate" (i.e., the correct quantity of a nutrient applied to a specific plant species) is no easy task for farmers that use animal manure (or other organic material) as a nutrient source.
When integrated with the appropriate timing of nutrient applications, NMP increases the potential for added nutrients to be utilised by plants, rather than lost to the environment. The assumption of NMP is that the nutrients used in the farm are balanced with crop requirements. When the nutrients contained in manure produced in the farm exceed requirements, it is necessary to reduce the amount of nutrients to be applied to the soil by using a suitable treatment so as to avoid emissions to water.
When manures are used as fertilizers there is another aspect affecting the efficiency with which the nutrients are utilized. The ratio between N and P (N:P) in manure is not the same that crops require. Thus, the use of manure as a fertilizer typically results in the over- or under-application of one nutrient. To avoid over-application of nutrients it is necessary to modify the initial N:P ratio through suitable treatment to balance the manure to a crops' requirements.

2. Materials and Methods

Three different and complementary products were developed.

- The first is a software tool to assess the farm nutrient balance and to indicate the best strategies to reduce nutrient release to water. This tool evaluates the potential surplus and the options to improve nutrient use efficiency, which will reduce emissions to water. In addition, the software guides fertilizer management during the year by taking into account the local climate and ongoing nutrient applications. This helps the farmer to determine the relative risk of releasing nutrients to the environment as a result of particular management activities. The results include an economic assessment of the different solutions.
- The second product is an innovative technology (at prototype stage) for the treatment of raw slurries or anaerobically co-digested slurries that produces three fractions that facilitate improved nutrient management. A working prototype using this technology has been designed to be modular for achieving removal efficiencies according to crop requirements, as well as for accommodating slurry quantities produced directly by livestock or by an anaerobic digestion treatment plant.
- The third product is a decision support system (DSS) to help farmers manage fertilization by updating records of past operations and defining the best strategies according to the nutrient runoff and leaching effect that a planned operation can have.

Herein we focus only on the software tool developed (Fig. 3.1).

3. Results and Discussion

The software tool can support a farmer in planning nutrient use on the farm and assessing the effect of different nutrient management strategies on emissions of nutrients to water. The software takes into account crop cultivation techniques adopted and provides guidance on the best strategies for containing nutrient emissions, giving the farmer advice on the possible technological alternatives and their relative costs and benefits. After entering data about the farm, the user obtains an estimate of the amount of manure that will be produced and its characteristics (Fig. 3.1).

Figure 3.1: Screenshot of the software report for a farm assessment

The type of management can be selected considering different alternatives. Each alternative is based on the simulation of the processes and transformations that occur in the manure during each management strategy. The evaluation performed gives the user information about the compliance of the farm with requirements and about the lack or excess of nutrients compared to crop demands (Fig. 3.2).

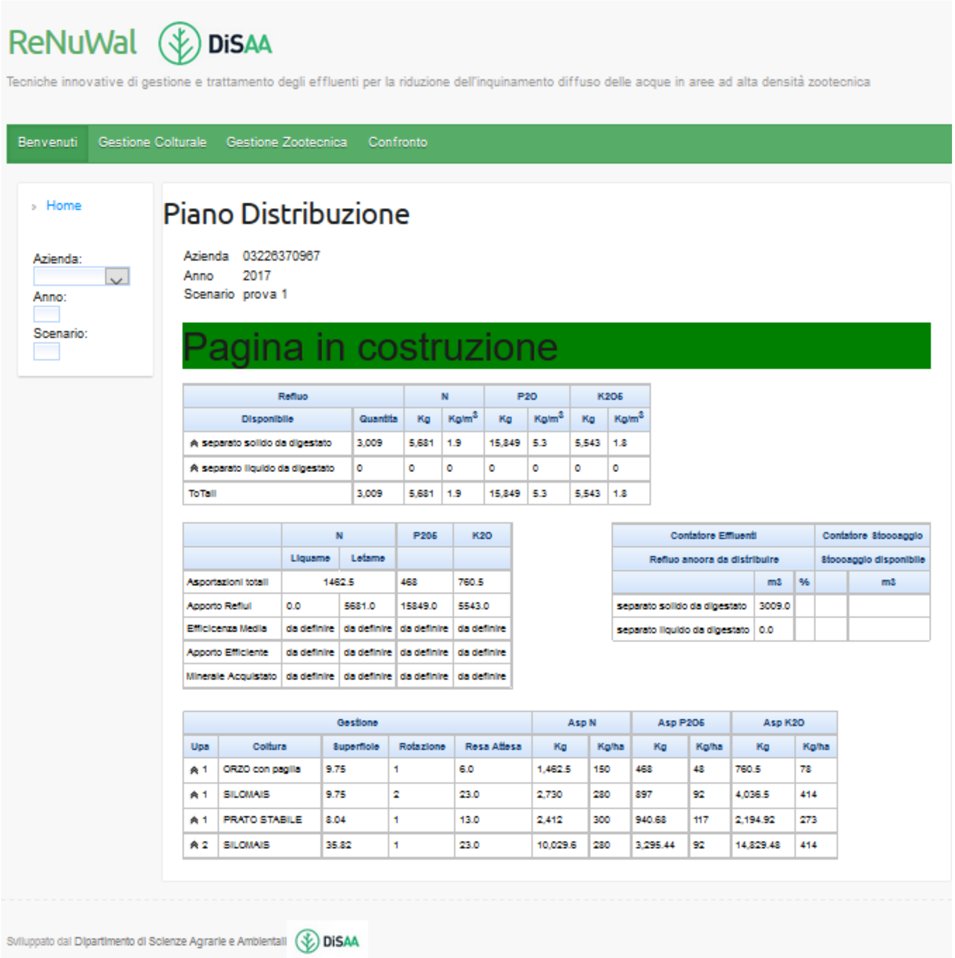

Figure 3.2: Screenshot of the software related to the spreading plan

4. Conclusions

The software tool can be used by farmers to help them highlight nutrient reductions and potential nutrient releases to environment, considering the possible introduction of available technologies. Thus, results will show the farmer the actual situation (nutrient imbalance) of the farm, the possibility for improvement and the related costs. At spreading time the support system will suggest to farmers the best strategies by which to improve nutrient use efficiency and reduce runoff and leaching of nutrients.

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Planning the energy valorization of agricultural co-products, by-products and waste in a landscape context

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Keywords: renewable energy, rural landscape, agricultural biomass, decomposition process

Summary
Within the current global trend aimed to increase energy saving and exploit renewable energies, agriculture may play a significant role, mainly when the energy valorization of agricultural by-products, co-products and waste is concerned. Agricultural biomass is a diffuse source of energy, having one of the highest potential to cover renewable energy needs for the future, but the previous restoration of organic matter in the soil should be anyway properly considered. Litter decomposition governs the soil nutrient levels and the carbon cycle, consequently influencing the physical and chemical properties of the soil, which are the key components to maintain the productivity of agro-ecosystems and the entirety of rural landscapes. In the present paper, the spatial relationships between renewable energy potentials, coming from agricultural co-products, by-products and waste, and the rural landscape, were analyzed through the implementation of a GIS over the whole territory of the Basilicata Region. This internal Southern Italian Region can be considered as a *benchmarking* case study, since it is characterized by big sources of renewable energy connected to its morphological and environmental structure, as well as to its traditional agricultural and food productions. Basing on the quantity of agricultural residues, the energy production in this study area after restoring the nutrient balance of the soil was estimated in the framework of a planning process able to preserve the rural landscape.

1. Introduction

The temporal and spatial aspects linking the biomass resource, the waste biomass, the energy conversion plant size, the transport system and the environmental impacts need to combine energy system design with spatial planning (Blaschke et al., 2013). In the recent years the attention has been focused on the energy from biomass by-products, while the exploitation of agro-industrial residues, although being products with a limited energy potential, will fit into the goals of the general energy efficient conservation and sustainable protection of the natural resources (Statuto et al., 2013). Agricultural co-products, by-products and waste, other than being considered as an important energy source, are indeed important factors for restoring the level of organic matter in the soil (fig. 1.1). Litter decomposition governs the soil nutrient levels and the carbon cycle, influencing the physical and chemical properties of the soil, which are the key components to maintain the productivity of agro-ecosystems and the entirety of rural landscapes (Endeshaw et al., 2015).

This paper focuses on the identification and quantification of biomass distribution, arising from agro-food productions in Basilicata Region. The analysis has been carried out considering main traditional cultivation - *i.e.*: cereal straw and pruning residues (olive groves and vineyards) - implementing a Geographic Information System (GIS) for calculating the energy potential of agricultural biomass, after restoring soil fertility.

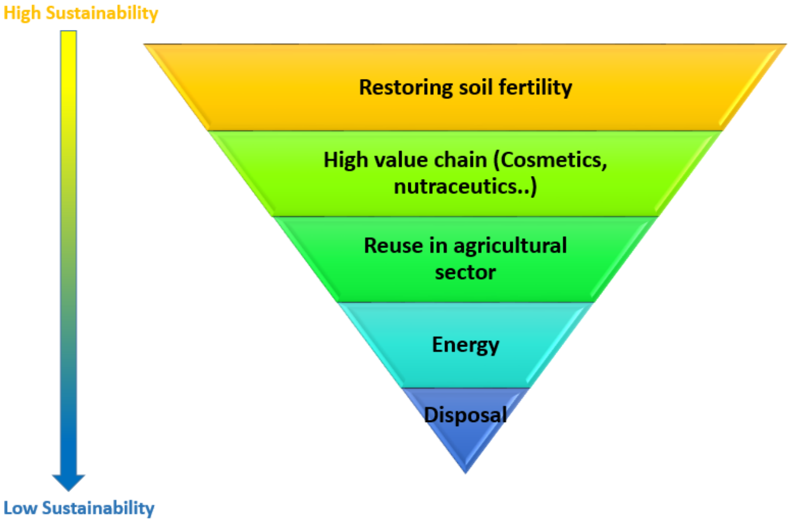

Figure 1.1: Agricultural by-product, co-product and waste management hierarchy.

2. Materials and Methods

2.1. Biomass production: Cereal crops

After harvesting cereal crops, a large quantity of straw, estimated to have a larger volume than the crop itself, is available as a waste. Several studies assumed that about 50% of straw was actually used as bioenergy feedstock; the other part is used as litter for the animals, or left on the field to promote chemical, physical and biological soil fertility. In order to evaluate the spatial variability of different crops, the data derived from agricultural census (2010) of the *Italian National Institute of Statistics* (ISTAT, 2011) at an average humidity of 14% were used. For each cereal crops it is so possible to estimate the straw amount (Tab. 2.1) generated every year over the regional territory.

Table 2.1: Estimation of dry matter from cereal straw

	Land	**Straw per hectar**	**Total of straw**	**Dry matter**
Crops	***ha***	***t·ha^{-1}***	***t·year^{-1}***	***t d.m.·year^{-1}***
Common wheat	7,545.95	2.50	18,864.88	16,223.79
Durum wheat	136,333.69	2.30	313,567.49	269,668.04
Rye	296.20	3.00	888.60	764.20
Barley	17,909.90	3.02	54,087.90	46,515.59
Oats	18,285.19	1.00	18,285.19	15,725.26
Grain maize	887.18	14.60	12,952.83	11,139.43
Other cereals	1,743.57	3.00	5,230.71	4,498.41
TOTAL			**423,877.59**	**364,534.73**

2.2. Biomass production: olive trees & vineyards

Depending on the technical criteria of olive trees pruning system, the average values obtained for dry matter after cutting in Mediterranean areas is (Velázquez-Martí et al., 2011/a) equal to 2.16 tons/ha. The available residual biomass obtained from pruning operations in vineyards depends on the type of vineyard and on the supporting structure or cropping system. Adopting the estimation conducted by Velázquez-Martí (2011/b), a production of 2.15 tons/ha of dry biomass on average was here considered (Tab. 2.2).

Table 2.2. : Estimation of dry matter (tons/year) from pruning trees

Pruning residues	ha	tons/(ha year)	tons/year
Olive grove	27,721.68	2.16	59,878.82
Vineyards	5,567.11	2.15	11,969.28

2.3. Biomass for soil fertility restoration

An increase in quality and quantity of soil organic carbon (SOC) could improve the soil productivity. Lehtinen *et al.* (2014) reviewed 50 long-term experiments in Europe and found that Soil Organic Carbon concentration increased with 7% due to straw incorporation. The sequestration potential for straw incorporation reported by several studies is 0.7 Mg C ha^{-1} $year^{-1}$ (Reiter, 2015). The situation of organic matter content of soil in Basilicata is reported in figure 2.1 arising from information concerning the *"Carta Pedologica dei Suoli"* (Basilicata Region, 2006). Ligneous pruning residues need specific treatment and water to ensure activation of the composting process, and the consequent estimation of organic matter is therefore quite difficult to be calculated.

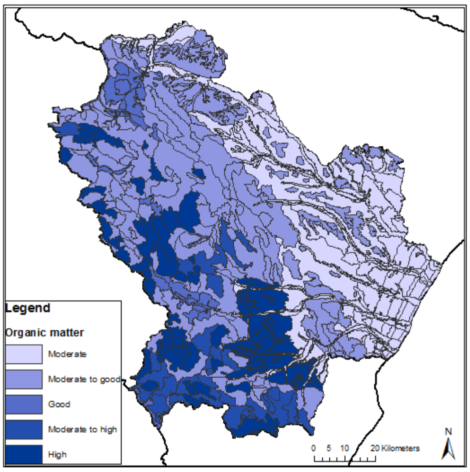

Figure 2.1: Organic matter content of different soils in Basilicata region.

3. Results and Discussion

Starting from the quantification of agricultural biomass it was so possible to evaluate the spatial distribution (fig. 3.1), in terms of tons of dry matter per year.

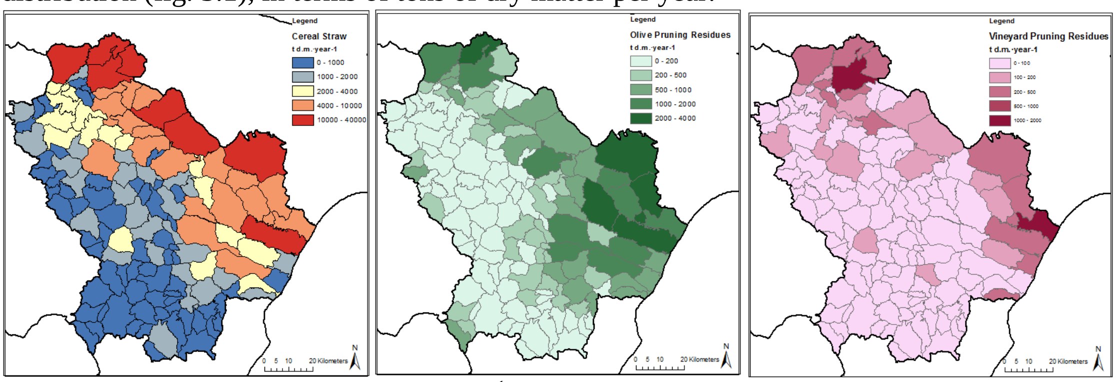

Figure 3.1: Estimation of dry matter $year^{-1}$ of cereal straw, olive and vineyard pruning residues

The biomass energy potential was therefore calculated on the total biomass potential production and the respective *Lower Heating Value (LHV)* of each biomass type. A value of 218,191 tons/year of biomass could be indeed considered all over Basilicata region for energy production, after having previously assured a proper restoration of the fertility of the same soils

in which that biomass is originated, leading to an estimated amount of 1,051 GWh/year. More added-value options could be anyway investigated for possible valorization in different production chains (cosmetic, nutraceutical, *etc.*).
Considering the spatial distribution of organic matter and the by-product distribution, it is possible to notice that in the east part of the Region, where the organic content is smaller, there is an higher availability of biomass. More analysis is therefore needed for optimizing its valorization within a more general holistic approach, able to properly consider the safeguard of the rural landscape, which is the general framework system in which all different ecosystems may evolve in a sustainable way.

4. Conclusion

The results coming from the implementation of a GIS at regional level have shown that a sound planning of co-products, by-products and waste biomass flows coming from agro-food production could reveal a very powerful tool, having an hidden economic value, when this resource is valorized according to a hierarchy. Within this specially focused approach, suitable collection station, aimed to receive agro-food biomass so as to identify it and direct towards the most convenient solution, should be realized, so as to contribute to the socio-economic growth of a region having a so high natural potential connected to its traditional agricultural and food productions.

Acknowledgements

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Evaluation of citrus pulp and olive pomace potential availability for biogas production by using a GIS-based model

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Keywords: olive pomace; citrus pulp; by-products; anaerobic digestion; biogas-biomethane; GIS; spatial analysis; Sicily.

Summary
Renewable energy sources represent a suitable alternative to conventional fossil fuels, due to the possible advantages in terms of environmental impact reduction. Anaerobic digestion of biomasses could be considered an environmental friendly way to treat and revalorise large amounts of by-products from farming industries because it ensures both pollution control and energy recovery. Therefore, the objective of this study was to evaluate the potential availability of citrus pulp and olive pomace and assess the potential biogas production from these two by-products.

1. Introduction

Among many renewable energy alternatives, which have been intensively studied and developed in the past decades, the production of biogas from biomass by anaerobic digestion has developed significantly worldwide in the last twenty years. A growing number of biogas plants have been built in Italy, especially in Northern Italy, where the biogas is produced by using dedicated energy crops which arise environmental, social and economic concerns related to the use of no-food energy crops. Therefore, in more recent years, an innovative concept to produce biogas, based on a system of sustainable intensification of crop rotation and the use of agro-industrial by-products, was developed (Dale et al., 2016). The adoption of this new system of production would reduce the environmental, economic and social impacts generated by both the cultivation of dedicated energy crops and the presence of waste generated by agro-industrial activities (Dell'Antonia et al., 2013).
To date, the development of biogas plants in Sicily is still very limited, despite the importance of the agricultural sector for the island. This situation of delay with respect to North Italy could, however, be an advantage for the biogas sector, as the development of biogas production plants still has the potential to be planned according to environmental, economic and social criteria of sustainability.
On this basis, the objective of this study was to evaluate the potential availability of two main by-products of the Sicilian agro-industrial sector, i.e., citrus pulp and olive pomace, obtained from the citrus and olive oil processing industries. Since they are suitable agricultural by-products for biogas production, their quantification and localisation in Sicily could contribute to build an information base suitable for multi-criteria analysis aimed at finding optimal locations for biogas plants in view of increasing them in number.

2. Materials and Methods

Previous research studies (Valenti et al., 2017a, 2017b, 2017c) have demonstrated how citrus and olive crops have maintained a decisive position for the regional economy of Sicily and have confirmed the Sicily's key role in the Italian production. In fact, by considering the Italian citrus production, Sicily contributes with 56% of the total, and in the Italian olive oil sector, the data analysis confirms that the South Italy, particularly Apulia, Calabria and Sicily produce 70% of the total olive production. Particularly, the computation of the index, which describes the level of availability of citrus pulp and olive pomace obtained at regional level, highlighted that the province of Catania has the highest potential production of citrus pulp and olive pomace (Figure 2.1).

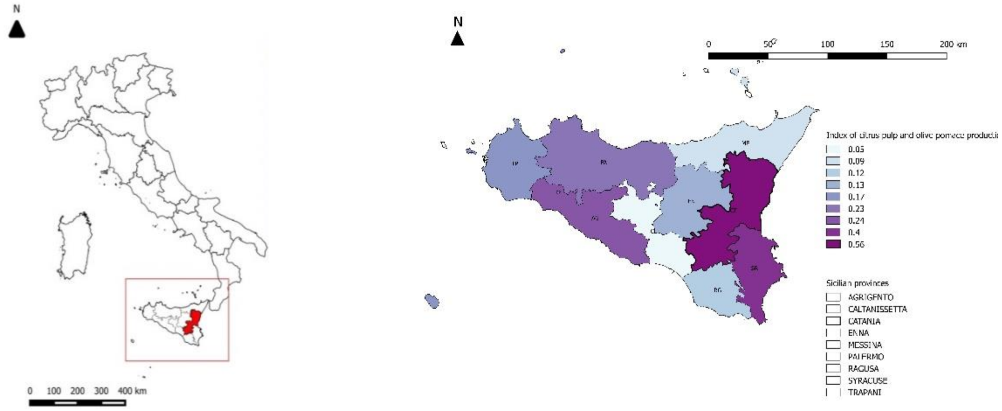

Figure 2.1: Geographic position of the study area and the index of citrus pulp and olive pomace potential production at the regional level.

The model proposed by Valenti et al. (2016), previously applied at regional level in Sicily, was used in this study to compute the level of citrus pulp and olive pomace potential production, O_{p_i} and C_{p_i}, respectively, in the province of Catania. This study area was subdivided into 58 zones, which are the municipalities composing the province of Catania. Then, the computation of the olive cultivation area (S_{olive_i}) and the citrus cultivation area (S_{citrus_i}) at municipal level was carried out in the study area by utilising the data obtained from the 6th Agricultural Census 2010 (Istat, 2010), and were used to perform GIS analyses, by using the Regional Technical Map related to the year 2008 (RTM 2008) as base map.
The average percentage of olive pomace $O_{pav\%}$ and citrus pulp $C_{pav\%}$, computed by utilising a specific questionnaire for surveying the citrus and olive processing industries located in the study area, were used to compute O_{p_i} and C_{p_i}, by applying the following relations:

$$O_{p\_i} = O_{pav\%} \times Ca_{olive} \times Y_{olive} \times S_{olive\_i} \tag{2.1}$$

$$C_{p\_i} = C_{pav\%} \times Ca_{citrus} \times Y_{citrus} \times S_{citrus_i} \tag{2.2}$$

where Ca_{citrus} and Ca_{olive} are the coefficients of availability, for citrus was fixed to 0.3 (Inea, 2014), because only 30% of the citrus production is currently allocated to the agro-industrial sector and for olive was fixed to 1 since the amount of olive production considered in this study was entirely used for olive oil production (Istat, 2013). Y_{citrus} and Y_{olive} were the yields (t/ha) of citrus and olive producing areas, respectively computed by the following equations:

$$Y_{olive} = \frac{P_{olive\_prov}}{S_{olive\_prov}} \tag{2.3}$$

$$Y_{citrus} = \frac{P_{citrus\_prov}}{S_{citrus\_prov}} \tag{2.4}$$

where P_{olive_prov} and P_{citrus_prov} are the amounts (expressed in tons) of olives and citrus produced in the province, respectively, related to year 2010 and recorded by 6th Agricultural Census 2010; and S_{olive_prov} and S_{citrus_prov} are the olive and citrus producing areas of the province, respectively, in the same time interval considered for P_{olive_prov} and P_{citrus_prov}.The last step of this study involved the evaluation of biogas potential production associated to the estimated citrus pulp C_{p_i} and olive pomace O_{p_i}. The theoretical biogas potential (Btot) was calculated by using the following relation:

$$B_{tot} = C_{p\_i} \times Y_{citrus\_pulp} + O_{p\_i} \times Y_{olive\_pomace} \tag{2.5}$$

where Y_{citrus_pulp} and Y_{olive_pomace} are the biogas potential of citrus pulp and the biogas potential of olive pomace, respectively. They were equal to 89.3 Nmc/ttq (Cerruto et al., 2016) and 131.00 Nmc/ttq (Reale et al., 2009), respectively.

3. Results and Discussion

The olive and citrus processing industries, previously identified in Valenti et al. (2017b, 2017c), respectively, were located by using their GPS coordinates in order to produce a feature class which described the distribution of citrus and olive processing industries in the province of Catania. In detail, 29 olive processing industries and 6 citrus processing industries were located and surveyed. Data elaboration made it possible to compute $O_{pav\%}$ and c $C_{pav\%}$, which amount to approximately 45% and 57.5%, respectively (Valenti et al., 2017c, 2017b). For each municipality by using the equations 2 and 3, O_{p_i} and C_{p_i} were computed and elaborated by using descriptive statistical tools. The related biogas potential production, B_{tot}, was computed by applying Equation 5 (Table 3.1).

Table 3.1: Minimum, maximum and mean values of O_{p_i}, C_{p_i} and B_{tot} obtained by elaborating the data related to 58 municipalities of the province of Catania.

	O_{p_i} (t)	C_{p_i} (t)	B_{tot} (Nm^3)
Minimum	-	-	-
Maximum	1,946.5	23,217.5	2,200,118.4
Mean	256.4	1,876.3	201,134.7
Standard deviation	381.1	4,254.5	406,293.7

(*) Elaborations of data collected through direct survey.

For the whole province of Catania, the total biogas production was estimated to be about 11.665.815 Nm^3. Therefore, the olive pomace and citrus pulp constitute a promising combination of biomass resources because of their potential utilisation for energy purposes. At the same time, they could offer a solution to reduce the national dependence on imported fossil fuels (Cherubini, 2010; Fountoulakis et al., 2008).

4. Conclusion

The application of the proposed methodology made it possible to assess the availability of citrus pulp and olive pomace in a study area highly representative of the Sicilian region with regard to the amount of the potential production of these two kind of by-products.
Based on the obtained results, the olive pomace and citrus pulp obtained from the citrus and olive growing areas could constitute a promising combination of biomass resources because of their potential utilisation for energy purposes. The results lay the basis for a future study aimed at finding a more sustainable localisation for new biogas plants.

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TOPIC 4

CHALLENGES IN WATER AND SOIL CONSERVATION AND MANAGEMENT

Effects of pruning and weed residues retention on soil hydrological properties in a sloping olive grove

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Keywords: Soil conservation, runoff, olive, organic matter, water infiltration, vegetal cover.

Summary
The hydrological effects of four soil management practices were evaluated in an olive grove over a sloping area of Southern Italy. Soil cover by pruning residues and weeds (350 g/m^2) showed the highest infiltration rate and thus the lowest runoff production, also after soil disturbance due to simulated rainfall. A higher dose of vegetal residues (1750 g/m^2) did not further increase the infiltration rate. A high correlation was detected between the infiltration rates measured by double cylinder and rain simulator.

1. Introduction

Biomass (pruning residues, weeds, etc.) retention over the soil surface together with elimination of tillage operations are considered as sustainable agricultural models. It is known that "no tillage", combined with ground cover by biomass, shields soil from raindrop impact (with a drastic reduction of the kinetic energy), avoiding soil particle detachment (splash erosion) and decreasing infiltration by sealing of the soil surface. During high intensity storms the infiltration capacity of soil surface is kept high also by the increase in surface storage by the vegetal residues, and the reduction of flow velocity by the increased hydraulic roughness overall reduces peak flows. This limits the loss of fertile soil and minimizes the transport of pollutants downslope and offsite erosion damages, such as the loss of infrastructure functionality (e.g. reservoir storage capacity). Additionally there are other positive effects, such as higher carbon storage in soil (as organic matter) and reduced CO_2 emissions. Orchards on Mediterranean areas, often in sloping areas, and subject to heavy and intense rainfalls, are particularly prone to high runoff and soil losses; thus, it is advisable to keep a proper soil cover by adequate management practices, which reduce land degradation, while maintaining an appropriate water balance of the main crop.

This study aims at evaluating the hydrological effects (water infiltration rates of surface soil and runoff volumes) of four soil management practices in a sloping olive grove of Southern Italy, where available information on this subject is very limited. The hypothesis is that the conservation agriculture system based on no tillage and biomass retention has a significant impact in increasing infiltration rate on dry and wet conditions compared to conventional management.

2. Materials and Methods

In an olive grove (at 6x6 m spacing) at the experimental site of Locri (Southern Calabria) eight plots (each of 250 m^2) were isolated and monitored from January to December 2016. Four plots were subject to the following soil management practices:

1. Standard Protection of soil by a horizontal net (mesh of 1 mm^2), 10 cm over the ground (treatment "SP", control plot) covering the whole plot;
2. Tillage in Autumn and Spring (treatment "T");
3. No Tillage and Retention of coarse vegetal residues from weed (cut periodically by a trimmer) and pruning chopping (dry matter of 350 g/m^2) (treatment "NTR-350");

4. the same management practice as point 3, with addition up to 1750 g/m^2 of biomass (treatment "NTR-1750").

For each plot the following parameters were measured:

- infiltration rate (by double cylinder infiltrometer, "DCI");
- runoff volumes produced by the Eijelkamp® rain simulator ("RS", 50 mm/h throughout 30 minutes); from runoff measurement the final infiltration rate was indirectly estimated.

One year before the experiments, infiltration rate of undisturbed surface soil was measured in 31 points (randomly selected across the 4 plots not used), which gave a value of 60±5.6 mm/h (by DCI) and 53.9±3.2 mm/h (by RS).

The same soil management practices were simulated in other four plots (identified by the acronyms as above and the index "d"); the infiltration rates and runoff volumes were measured (by the same methods as above) on the dry soil and again one hour after the simulated rainfall: this induced soil saturation and sealing, which may enhance peak flow generation. Measurements (in triplicate) were carried out in Spring.

3. Results and Discussion

Table 3.1 shows the major results. Compared to the control plot ("SP", 12.7 mm/h), the lowest final infiltration rate (11.4 mm/h) was found in plot "T" (subject to tillage). The plot "NTR-350" (covered by a dose of vegetal residues of 350 g/m^2) showed the highest infiltration rate (22.4 mm/h); this latter was higher than the value (15.6 mm/h) measured in plot "NTR-1750" (where residual biomass retained on soil was increased to 1750 g/m^2). The noticeable reduction of infiltration rates after the rainfall (on the average by 50%, with a maximum of 76.4% in plot "NTR-350") is presumably due to the soil protection against raindrop impact due to vegetal residues over soil.

Table 3.1 – Hydrological variables of experimental plots under different soil management practices.

Hydrological variable	*Plot*							
	SP	*SPd*	*T*	*Td*	*NTR-350*	*NTR-350d*	*NTR-1750*	*NTR -1750d*
Final infiltration rate (DC, mm/h)	*12,7^a*	***8,0^A***	*11,4^a*	***6,1^A***	*22,4^b*	***12,4^B***	*15,6^a*	***8,7^A***
Peak flow (mm/h)	*42,0^a*	***48,0^A***	*42,2^a*	***48,0^A***	*30,1^b*	***39,0^B***	*40,7^a*	***47,0^A***
Time to peak (minutes)	*28^a*	***24^A***	*30^a*	***24^A***	*30^a*	***24^A***	*30^a*	*28^B*
Runoff volume (mm)	*11,5^a*	***15,0^A***	*13,6^a*	***16,0^A***	*8,1^b*	***12,5^A***	*9,1^b*	***11,7^A***
Final infiltration rate (RS, mm/h)	*11,0^a*	***2,0^A***	*8,0^a*	***2,0^A***	*20,0^b*	***11,0^B***	*9,3^a*	***3,0^A***

Notes: different letters (among treatments) and bold characters (between disturbed and undisturbed plots) indicate significant differences at $p < 0.05$ of Mann-Whitney test ($n = 3$).

Several Authors (e.g. Murphy et al., 1993; Repullo et al., 2012; Bissett and O 'Leary, 2013) have shown that retention of vegetal residues on soil leads to an increase in infiltration rates by about 5 times, compared to conventional farming practices, because of soil structure modification. Compared to plot "NTR-350", the lower infiltration rate measured in the plot "NTR-1750" could be explained by the lower presence of a such dense cover of coarse vegetal residues and pruning chops, which hampers herbaceous vegetation growth, differently from what happens under plot "NTR-350" (5-fold less dense). This is also confirmed by the higher vegetation cover measured on plot "NTR-350" (on the average 22.3% of the total plot area) compared to plot "NTR-1750" (15.5%).

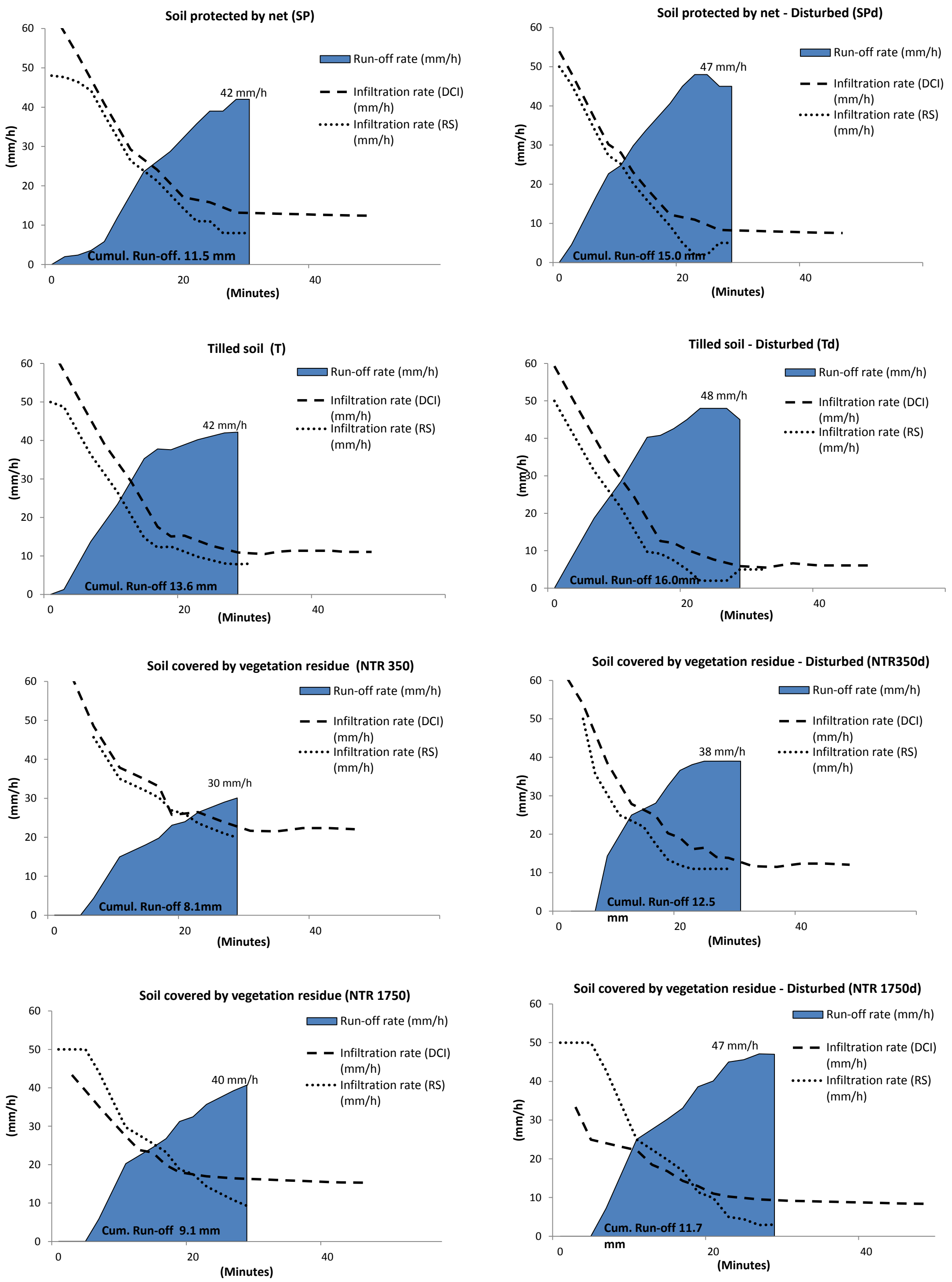

Figure 3.1: Mean values (n = 3) of infiltration/runoff rates and cumulated runoff volumes measured by double cylinder infiltrometer (DCI) and rain simulator (RS) on the experimental plots.

The lowest peak flow (30.1 mm/h) was measured in plot "NTR-350", about 29% of the other plots, which showed similar values (40.7, plot "NTR-1750", to 42.2, plot "T", mm/h). The time to peak was equal to 30 minutes in plots "T", "NTR-350" and "NTR-1750", two minutes longer than the time (28 minutes) observed in plot "SP" (Table 3.1).

Soil disturbance by the simulated rainfall: (i) reduced infiltration rates by 37.0% ("SPd") to 46.3% ("Td"); (ii) lowered peak flows by 13.7% ("Td") to 29.6% ("NTR-350"); and (iii) moved up the time to peak on the average by 15.2%, with a maximum (20%) observed for plot "NTR-350" (Figure 3.1). The soil surface sealing determined by rainfall can explain the reduction of the infiltration rate measured after soil disturbance by simulated rainfall (Helalia et al., 1988; Gomez et al., 1999).

The runoff volumes measured by RS allowed indirect estimates of the infiltration rates, which were lower by 39.1% compared to measurements by DCI. A noticeable variability (about 30%) of these estimates among the different plots was detected; however, a considerable correlation was found between the survey methods (r^2 = 0.91). Differences in absolute values between the methods were due to the specific conditions imposed (DCI tends to give higher infiltration rates compared to RS, because the water depth is higher and the large pores of soil are fully filled with water). Moreover, infiltration measures by DCI are more stable than measurements by RS, as shown by the more clear correlation (r^2 = 0.96, DCI, against 0.93, RS) between wet and dry tests.

4. Conclusion

This investigation has confirmed the positive hydrological effects played by biomass retention on soil surface without tillage operations. The highest infiltration rate was found in the plot with permanent cover of soil by pruning residues and weeds (350 g/m^2), also after soil disturbance due to simulated rainfall; a higher dose of vegetal residues (1750 g/m^2) did not further increase soil infiltration rates, because the more dense residue cover hampers vegetation growth. The consequent reduction of runoff production capability surveyed in plots with vegetal residues retention leads to the reduction of peak flow and erosion; this reduction could be also due to the increased hydraulic roughness: however, further investigations are required. Finally, a higher correlation was detected between infiltration rate measurements by double cylinder infiltrometer and rain simulator.

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Effect of irrigation and foliar application of calcium nitrate and boric acid on fruit cracking of Thomson navel orange

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Keywords: Calcium nitrate, Boric acid, Irrigation, Thomson navel orange,

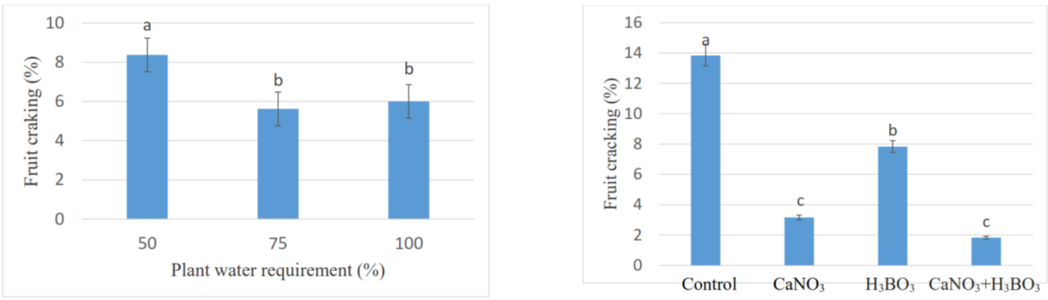
Summary
Fruit splitting is prevalent in Thomson navel orange. Irrigation and nutrient disorders play an important role in the emergence of this phenomenon. An experiment with three irrigation levels (50%, 75 % and 100% water requirement) in combination with four foliar spraying treatments (calcium nitrate, boric acid, calcium nitrate + boric acid and water as control) was conducted in a factorial based complete randomized block design. According to obtained results, Thomson navel orange fruit splitting was significantly less in 100% and 75% irrigation levels than 50% irrigation. Foliar spraying with calcium nitrite and calcium nitrite + boric acid reduced fruit cracking significantly. Foliar spraying with calcium nitrate and calcium nitrate + boric acid was effective in elevating calcium content of leaves and fruit as well as yield increase. The use of boric acid significantly increased fruit size, fruit weight with and without peel and orange fruit diameter. Based on the results of this study, prevention of severe moisture stress, along with at least three times spraying with calcium nitrate solution after fruit formation was very effective in reducing Thomson navel orange fruit cracking.

1. Introduction
Fruit splitting is an abiotic disorder which occurs in some fruits, and thereby reducing the marketability of fruits and causing huge economic losses. Varieties, environmental conditions, irrigation (Conesa et al., 2014; García-Tejero et al., 2010) and nutrient disorders play important roles in the emergence of this phenomenon. This disorder also is prevalent in some citrus varieties (Martinez-Fuentes and Mesejo 2002). Thomson navel orange (*Citrus sinensis* L.) is one of the most sensitive fruit to cracking. Water stress and some nutrient deficiencies cause fruit peel cracking of Thomson navel orange. In present study, the effects of irrigation amount and foliar application of calcium nitrate and boric acid were investigated on fruit cracking of Thomson navel orange.

2. Materials and Methods
The experiment was conducted based on factorial randomized complete block design with three irrigation levels of full irrigation (FI), which trees received 100 percent of depleted soil water, and two deficit irrigation managements of DI50 and DI75, which orange trees received 50 and 75 percent water relative to FI, in combination with four foliar spraying treatments of calcium nitrate (C), boric acid (B), calcium nitrate + boric acid (CB) and control (water) (W) with 4 replications of 3 trees in each experimental unit. At the end of experiment, traits such as percentage of fruit cracking, leaf and fruit calcium content, titratable acidity (TA), total soluble solids (TSS), and flavor index (the ratio of TSS to TA), fruit volume, fruit firmness, fruit weight with and without peel, and fruit yield were measured. Data were analyzed using SAS software and SNK post-hoc test was employed to compare treatments means.

3. Results and Discussion
According to obtain findings, the effect of irrigation on percentage of fruit cracking was statistically significant ($p \leq 0.01$) and the highest fruit cracking (8.4%) occurred in 50%

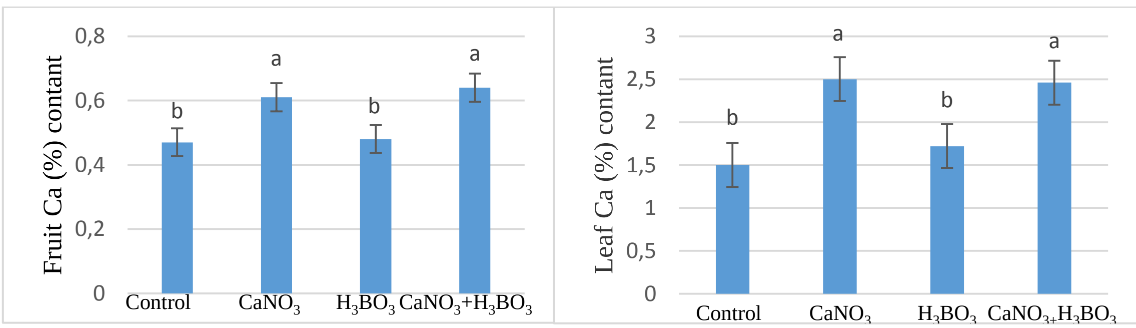
irrigation treatment (DI 50). Thomson navel orange fruit splitting was significantly less in 100% and 75% irrigation levels compared to 50% irrigation (figure 1a). It has been reported that not only water stress, but also fluctuation in water availability after rainy days could increase Thomson navel orange fruit splitting (Lima and Davies, 1984). Irrigation factor was not significant for other traits. Foliar application significantly affected most of the measured traits. Foliar spraying with calcium nitrite and calcium nitrite + boric acid reduced fruit cracking significantly (figure 1b). Fruit cracking percentage was reduced significantly in calcium nitrate treatment and in calcium nitrate in combination with boric acid treatment. Fruit cracking percentage was reduced significantly in calcium nitrate treatment and in calcium nitrate in combination with boric acid treatment. These results are in agreement with Sdoodee and Chiarawipa, (2005) findings.



(a) (b)

Figure 1: Mean orange fruit cracking (%) along different water treatments (a), and foliar spray fertlizers (b). Bars that carry the same letters are not significantly different at 5% level.

In addition to reducing fruit splitting, foliar spraying with calcium nitrate and calcium nitrate + boric acid was effective in elevating calcium content of fruit and leaves as well as yield increase. Fruit and leaf calcium contents significantly increased **by** 0.61% (figure 2a) and **2.5%** (figure 2b), respectively, by calcium nitrate treatment and by 0.64% and 2.46% by calcium nitrate + boric acid treatments, respectively. Likewise, yield significantly increased in calcium nitrate treatment (data are not shown). The use of boric acid significantly increased fruit size, fruit weight with and without peel and orange fruit diameter (data are not shown). With the use of boric acid, fruit dry weight also significantly increased. Regarding increasing fruit dry weight, means comparison showed that calcium nitrate and boric acid treatments were in a group and did not differ statistically (data are not shown). Also, the use of calcium nitrate increased soluble solids and fruit firmness (data are not shown).



(a) (b)

Figure 2: Mean fruit Ca (%) along different foliar spray fertilizer treatments (a), and leaf Ca (%) along different foliar spray fertilizer treatments (b). Bars that carry the same letters are not significantly different at 5% level.

4. Conclusion

In general, based on the results of this study, prevention of severe moisture stress, along with at least three times spraying with calcium nitrate solution after fruit formation was very effective in reducing Thomson navel orange fruit cracking. Therefore, several foliar applications of calcium nitrate in two week intervals after fruit formation in mid June and also having irrigation at 75% to 100% levels was effective in reducing Thomson navel orange fruit cracking.

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Effects of shading and irrigation cycles on yield, quality and water use efficiency of bell pepper

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Keywords: Shading, Irrigation cycle, Bell pepper, Sub-humid climate

Summary
Bell pepper is a hot season crop and sensitive to high light intensity and drought. Present study was conducted to investigate the effect of shading and irrigation timing on yield and some quality characteristics of bell pepper fruit. This study was a factorial based completely randomized design experiment with three levels, 0, 30% and 50% of shading in combination with three irrigation timings, every 2, 3 or 4 day intervals. According to obtained results, among different treatments, significant differences were observed for yield, vitamin C, fruit antioxidant capacity, fruit anthocyanin. Data mean comparison showed that, the highest yield belonged to 30% shading with every 2- day irrigation. The highest vitamin C was observed in 30% and 50% of shading with every 4- day irrigation and the lowest vitamin C was observed in no shading with every 2- day irrigation. In 30% shading with every 4- day irrigation, the highest antioxidant capacity and in 50% shading with every 2- day irrigation, the highest anthocyanin were obtained. In conclusion, the results of present study show that the use of shading, probably because of heat stress reduction, would increase yield and quality of bell pepper fruit crop.

1. Introduction

Bell pepper (*Capsicum annum* L.) is a hot season crop and sensitive to high light intensity and drought. Summer production of bell pepper in open fields is challenging in Mazandran provence, in Caspian Sea region of Iran, due to high ambient temperatures and humidity. The use of shade or shading nets is not common for vegetable production in Iran,. Shading could prevent light stress (Dı´az-Pe´rez, 2013; Möller M. and Assouline, 2007) and increase water use efficiency (Möller and Assouline, 2008; Silber et al., 2003). There are reports that the use of shading nets for bell pepper production in Brazil (Padron et al., 2015) and Israel (Shahak Y., 2008) increased yield. In addition, the shaded pepper plants require less water (Padron et al., 2015) and shading would increase water use efficiency in bell pepper production. Likewise, efficient irrigation scheduling is a vital component for successful vegetable production and through water saving would be possible to cover more area under cultivation. Present study was conducted to investigate the effect of shading and irrigation timing on yield and some quality characteristics of bell pepper fruit in Sari region of Iran wich has hot summers with little rainfall.

2. Materials and Methods

This resreach was done at Sari Agricultural Sciences and Natural Resources University, Sari, Iran. Sari is located in Caspian Sea region of Iran. Sari has hot summers by average daily maximun temperature above 30^{oC} (figure1) and the amount of average rainfall and rainy days are little during summer months in this region (figure 2).

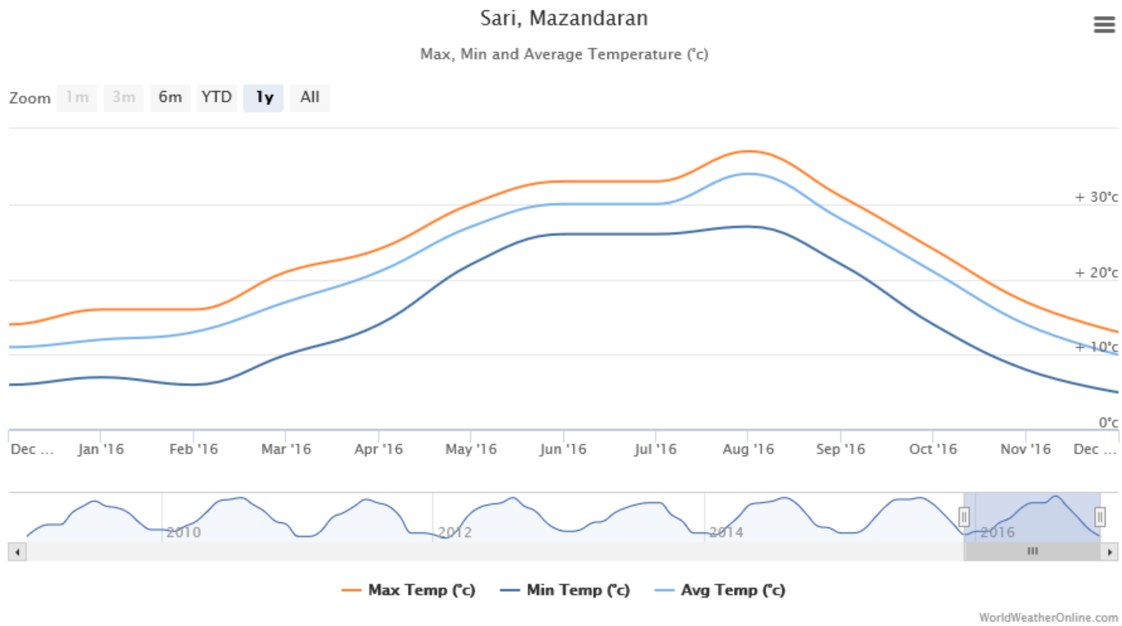

Figure 1: Daily temperature of Sari in Mazandaran province of Iran. (https://www.worldweatheronline.com/sari-weather-averages/mazandaran/ir.aspx)

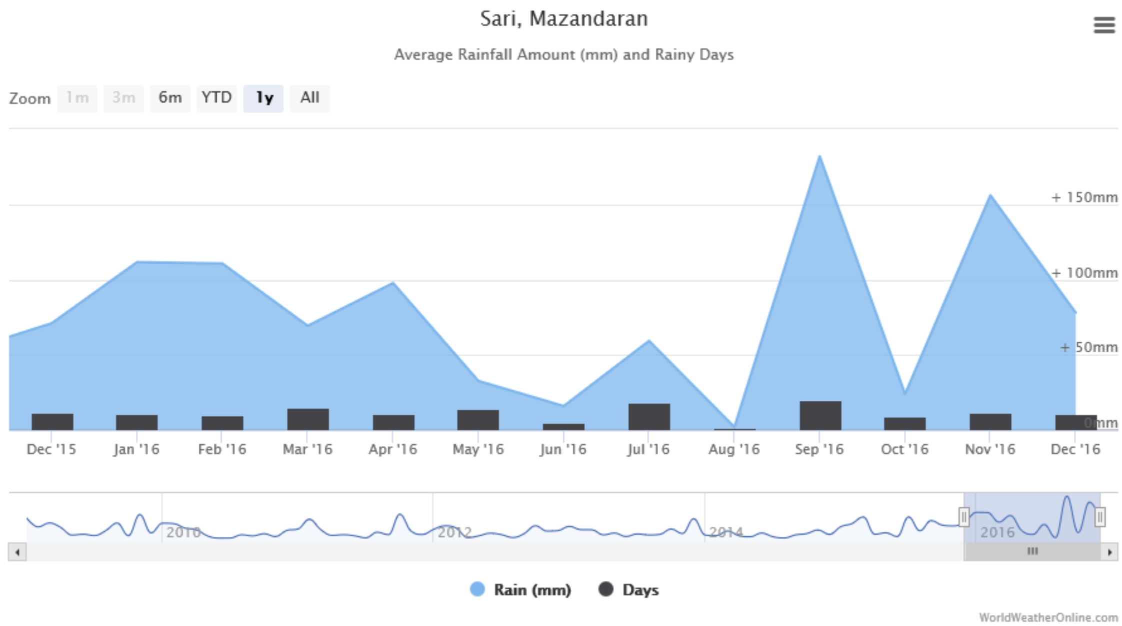

Figure 2: Average rainfall amount and rainy days of Sari in Mazandaran province of Iran. (https://www.worldweatheronline.com/sari-weather-averages/mazandaran/ir.aspx)

This study conducted in a factorial based on completely randomized design experiment with three shading levels of 0, 30% (with 70% of sunlight passes through) and 50% (with 50% of sunlight passes through), in combination with three irrigation timings, every 2, 3 or 4 day intervals up to field capacity. Shading was provided by using green plastic shade cloth. The experiment had 10 replications for yield, 6 replications for growth charactrestics and 4 replications for quality charactristics. At the end of experiment, charactrestics such as plant water use, fruit length and diameter, soluble solid, fruit firmness, titratable acidity (TA), pH, fruit wall thickness, water use efficiency, leaf area, yield, relative water content, fresh and dry weight (root, shoot and leaf), ion leakage percentage, vitamin C, leaf chrolophil, fruit chrolophil, antioxcidant capacity, anthocyanin, crown diameter, shoot diameter, number of shoot per plant, number of buds in main shoot, plant length and root length and volume were evaluated. Data was analyzed using the general linear models procedure of SAS, (version 9.1; SAS Institute, Cary, N.C.). Differences among means were tested by least significant difference (LSD) ($p \leq 0.05$).

3. Results and Discussion

Obtained results showed that shading and irrigation timing interactions were not statistically significant. Therefore their simple effects were as follow. The highest yield (762.9 g plant^{-1}) obtained in 30% shading treatment (Table 1). The highest average fruit length (73.8 mm) and (70.7 mm) was produced in shading treatments of 50% and 30% shadings, respectively. The highest average fruit diameter (71.5 mm) and 70.1 mm) were produced in 50% and 30% shading treatments, respectively (data are not shown). It seems that 30% shading was able to protect bell pepper plants from negative effects of high light intensity, while providing enough light for plant growth and development.

*Table 1. Mean yield, anothocynin and vitamin C values of bell pepper along different shading treatments**

Shading	Yield (g plant^{-1})	Anothocynin (mg per 100 fresh weight)	Vitamin C (mg per 100 fresh weight)
No shade	578.4^{b}	0.01^{b}	66.4^{b}
30% shading	762.9^{a}	0.01^{b}	79.6^{a}
50% shading	694.1^{ab}	0.02^{a}	87.7^{a}

**Means carrying the same letter in each column are not significantly different at 5% level*

Obtained yield for every 2 and 3 day irrigation cycles were 748.8 and 743.1 g plant^{-1}, respectively, which were significantly different in compare to 4 day irrigation cycle (Table 2). Since 2 and 3 day irrigation intervals did not differ statistically, every 3 day irrigation cycle could beneficial to save water.

*Table 2. Mean yield, anothocynin and vitamin C values of bell pepper along different irrigation cycle treatments**

Irrigation Cycle (days)	Yield (g plant^{-1})	Anothocynin (mg per 100 fresh weight)	Vitamin C (mg per 100 fresh weight)
2	748.8^{a}	0.02^{a}	62.6^{b}
3	743.2^{a}	0.01^{b}	76.7^{a}
4	543.5^{b}	0.02^{b}	87.4^{a}

**Means carrying the same letter in each column are not significantly different at 5% level.*

The higest titratable acidity (1.2%) and (1.1%) was observed in every 3 and 4 day of irrigation, respectively. The higest fruit soluble solid (94.5%) was observed in both 4 and 3 day of irrigation intervals (data are not shown). The highest amount of fruit antioxidant (8.4%) was obtained in 4 day watering interval.
The highest total fruit anthocyanin (0.02 mg per 100 fresh weight) and fruit vitamin C (87.7 mg per 100 fresh weight) were produced in 50% shading treatment (Table 1). The highest water use efficiency was observed in 3 and 2 day irrigation cycles, respectively and in open air treatment.

4. Conclusion

To our best knowledge, this is the first report about the effect of shading and irrigation timing on yield and quality characteristics of bell pepper fruit in Iran. Because of heat stress reduction, the use of shading would increase yield and quality of bell pepper fruit crop. Shade-grown peppers are less stressed and require less irrigation. Therefore, shade cloth can be adapted to make summer production of bell pepper more successful.

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Hydraulic modeling for the management of irrigation canals: application to the Canale Emiliano Romagnolo (CER)

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Keywords: Irrigation canal, hydraulic modeling, water management

Summary
The sustainable management of irrigation canals represents an essential aspect to avoid overflows and satisfy water demands. This work presents the hydraulic modelling of a pilot segment of the Canale Emiliano Romagnolo (CER). The calibrated and validated model is an example of the adaption of a well-known and quite simple simulation software (HEC-RAS) to a complex operational and geometric configuration without direct flow measurements.

1. Introduction

In Mediterranean countries, as Italy, the largest water uses are for agricultural production, while industrial and civil consumption are less than the EU average (EEA, 2009). In a context of climate changes and water scarcity, policies to reduce water consumption are considered as key components of sustainable development (European Commission, 2012). Among the causes of inefficient water uses in agriculture, Litrico et al. (2005) have identified the poor management of the water conveyance systems. Therefore, any improvement in agricultural water management, from conveyance to distribution, will positively affect the overall water efficiency and productivity, minimising non-productive water losses. The present study is aimed at optimising the hydraulic modelling of a segment of an agricultural waterwork, the artificial open-canal CER. A pilot segment of the CER canal has been chosen for these modelling studies; a wide geometric and functional data collection was put in place to overcome the lack of observed data and actualised information about the infrastructure geometry. The tool implemented is quite simple, but requires calibration and validation of a set of assumptions and algorithms, developed with the aim to propose modelling solutions of a complex system based on reasonable simplifications of the reality. This approach will allow to extend the model to the whole CER canal and related systems.

2. Materials and Methods

The Emiliano- Romagnolo canal (CER) is an artificial waterwork lined with concrete. The CER has a total length of 133 km and a flow rate ranging from 60 to 6 m^3/s. It is the major infrastructure for irrigation water supply in the Emilia-Romagna Region. The CER can be represented as a one-dimensional system made of a sequence of pseudo-independent segments, without water entries from surface runoff or water discharges, and with several water withdrawals suppling the territories served by 5 irrigation Consortia. The following data were collected in order to set the simulation model: infrastructure geometric data (sections, slopes, elevations, roughness) as for the original design, positions of culverts crossing roads or streams, of water withdrawals and of water-gauges. In parallel, daily water levels (2012-2015) measured at the inflow and outflow cross-section of culverts critical for the water management and monthly cumulated water withdrawn volumes (2001-2015) per each of the diversion along the CER canal, have been organised in a dataset and audited. Climate data of the district of CER have been made available by the local Agro-meteorological service (ARPAER) for the period 2001-2015. A pilot segment has been chosen to test the methodology developed for the hydraulic modelling of the CER. For the purposes of the present paper, a segment is defined as a

portion of CER starting and ending with culverts equipped with automatic water-gauges. The pilot segment chosen is 7 km long, starting and ending with culverts under passing rivers. Six diversions serving large, not-pressurized, irrigation districts are present: three of them are diverting 71% of the total withdrawn water of the pilot segment, the remaining quota is diverted by the smaller diversions. Since the flow in the canal can be considered mono-dimensional, the software HEC-RAS is used. The simulations are performed under steady conditions. Daily values of flow and measured water levels at the two ends of the pilot segment are used to calibrate and validate the model. The full exercise of CER is during the irrigation period (June-August). The four years studied, from 2012 to 2015, involve enough climate variability to be representative of the multiannual average as well as of the extreme conditions: rainy (2014), dry (2012) and average seasons (2013, 2015). The CER flow is subcritical, so the perturbations propagate from the downstream to the upstream. Aiming to reconstructing unmeasured data (flows entering at the upstream, flows exiting from each withdrawal and from the downstream) the following approach has been applied. At the downstream, the rating curve is determined. At the upstream the flow is calculated by adding the flows of every diversion to the flow at the downstream. The great uncertainty is caused by the lack of verified diversions flows. The resulting water levels (outputs) at the in and outflow of the pilot segment were then compared to the water-gauge measured values. This procedure allows to calibrate and validate the model.
Downstream, the analytical relation between flow (Q_u) and water level (h_u) is determined by the calibration and the validation of the parameters a and b of the monomial equation:

$$Q_u = a * h_u^b \tag{2.1}$$

The rating curve has been calibrated on 23 days of 2015. Validation has been carried out using the measured water level values of the remaining 22 days.
Upstream, the daily flow (Q_i) results from the expression:

$$Q_i = Q_u + q_r * 1 + q_r * k_1 + q_r * k_2 + q_r * k_3 + q_r * k_4 + q_r * k_5 \tag{2.2}$$

Where: Q_u=flow at the downstream (m^3/s); q_r=flow exiting from the withdrawal of reference (m^3/s); k_i=weight of every withdrawal compared to the withdrawal of reference (i=1,..,5).

The reference withdrawal for the identified segment is chosen every year. It is the most significant withdrawal in terms of monthly cumulated volumes. Two methods are proposed to the estimation of k_i and q_r. The first considers the monthly declared cumulated volumes. The second averages the monthly declared cumulated volumes with decadal calculated volumes. The decadal calculated volumes consider the efficiency of the system of distribution (open canal networks) and the classes of crops (j=1,..,n). For the j-th crop the following data are used: area, optimal crop water requirement (CWR), irrigation intensity and efficiency of the irrigation method. The CWR is provided by IRRIFRAME (www.irriframe.it) based on daily water balance of soil-plant-atmosphere system (Mannini P. et al., 2013). The model in HEC-RAS is calibrated and validated. Daily values of water levels as output of the model, are compared to measured water levels at the segment in and outflow. 23 days were simulated for each year (2015-2012).

3. Results and Discussion

Downstream, the validated rating curve equation is as follow:

$$Q_u = 1.54 * 10^9 * h_u^{8.4} \tag{3.1}$$

The linear regression is statistically highly significant, with a coefficient of determination R^2 of 0.999.

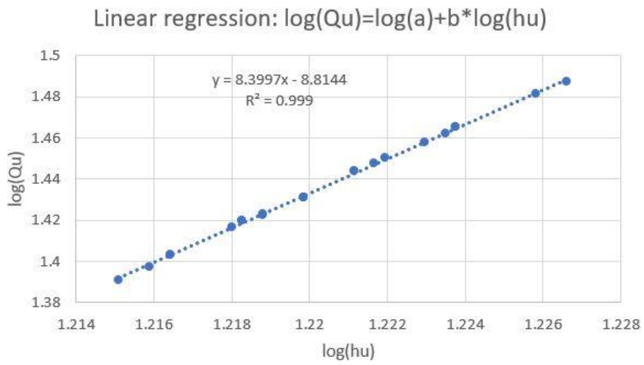

Figure 3.1: The regression line for the calibration of parameters a and b

The estimated flow values are obtained with the equation (2.2) and are used for implementing simulations in HEC-RAS. Up and downstream, measured water levels (h_{obs}) are compared with those simulated (h_{sim}). For the pilot segment, the two proposed methods of weighing produce similar results in term of water levels. To test what is the most suitable, an extension to other segments must be done. The Weibull plotting position formula is an effective measure of the exceedance probability of h_{obs} and h_{sim}. The values of specific probability estimators (minimum, maximum, median, first-quartile, third-quartile) are evaluated. At the downstream, the differences (h_{obs}-h_{sim}) are positive or negative. On average the values, over the four years, are ±0.05 m. At the downstream, all differences are negative and on average the difference is -0.13 m.

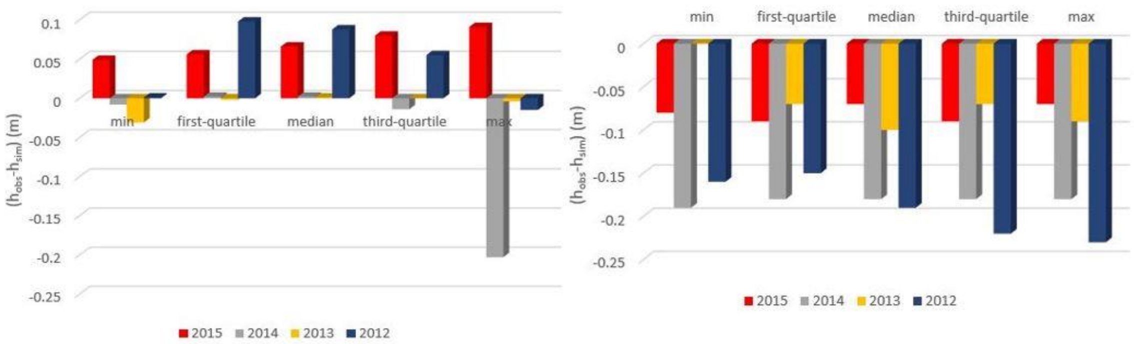

Figure 3.2: Values of differences (h_{obs}-h_{sim}) for the specific probability estimators

It is useful to relate the mean difference (positive or negative) over the four years with the yearly maximum fluctuations of water level. In this way, the difference is expressed as a rate of the fluctuation.

Table 3.1: Mean differences as rates of yearly maximum fluctuations

	$MD: MF_i = x: 100$ Where: *MD=mean (h_{obs}-h_{sim}) positive or negative (m); MF_i=maximum fluctuation of water level for the i-th year (m)*		
	Downstream		**Upstream**
	M>C	M<C	M<C
2015	10.54	-	-29.43
2014	9.44	-8.24	-26.43
2013	6.47	-5.65	-24.43
2012	9.85	-8.60	-34.08

In both cases (downstream, upstream) the rates are satisfying. Having regard to the many uncertainties, at the upstream the values are major but they represent a good result. The uncertainties affect flows but also geometric data. In fact, the configuration of the original design could be modified in terms of: elevation, slope and roughness. The model represents an effective tool for the hydraulic description of the pilot segment. It contains reasonable simplifications of the real system. Considering the analysis of the different components of the mean squared deviation MSD (Kabayashi K. et al., 2000), it emerges that the bias of the simulation from the measurement is the major source of error.

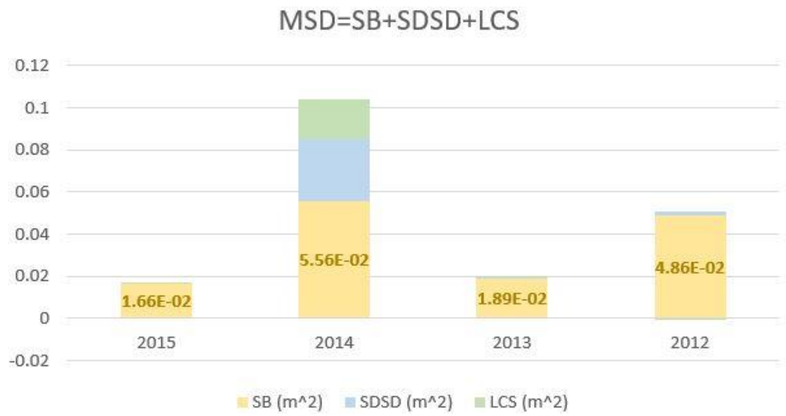

Figure 3.3: Values of the 3 components of MSD: SB=bias of the simulation from the measurement; SDSD=failure of the model to simulate the magnitude of fluctuation among the measurements; LCS=failure of the model to simulate the pattern of the fluctuation across the measurements.

4. Conclusion

The paper proposes a methodology for the hydraulic modelling of the CER. It can be represented as a mono-dimensional system formed by pseudo-independent segments related each other by boundary conditions. A methodology for the construction of the hydraulic model is proposed on a pilot segment 7 km long. The simulations using HEC-RAS consider the irrigation period (June-August) of four years (2012-2015) under steady conditions. To estimate the unmeasured flows exiting from the withdrawals two methods are proposed. In the hydraulic model the values of flow are entered while the water levels are the output. At the downstream end, the means of differences (measured water level-simulated water level) over the four years are ±0.05 m. At the upstream end, the means are only negative of -0.13 m. Relating the mean differences with the yearly maximum fluctuations of water level, satisfying results are obtained. They are expressed as rates of the yearly maximum fluctuations. The rates are: +9.07% and -7.50% at the downstream and -28.59% at the upstream. Considering the uncertainties, the results indicate an accurate prediction of the hydraulic behaviour. The model will be tested for the simulation of other segments of CER, including also a qualitative module.

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Constructed wetland for treatment and reuse for irrigation of winery wastewater

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Summary
This paper reports the performance of a multistage constructed wetland (CW) for treatment of winery wastewater and its suitability for irrigation reuse. The CW is located in Southern Italy (Sicily) and treat a portion of wastewater produced by a small winery. Chemical-physical and microbiological characteristics of wastewater were analysed on samples collected at the inlet and outlet of each stage of the treatment system. CW removal efficiency was evaluated both in terms of water quality improvement (removal percentage) and achievement of the Italian wastewater discharge and irrigation reuse limits. The experimental CW during the monitoring period, has shown an effluent average quality compatible with the limits required by the Italian law for wastewater discharge in water bodies and for wastewater reuse. The irrigation reuse of winery wastewater, treated with natural systems, may represent a valid option for wastewater disposal by farmers.

1. Introduction
Wastewaters generated from wine production are characterized by high contaminant load, large volumes and seasonal variability, which make it difficult to treat them. Several treatment approaches have been adopted for wineries wastewater treatment (i.e. activated sludge, sequencing batch reactors, anaerobic digesters, etc.), but the development of alternative treatments is necessary in order to maximize the efficiency and flexibility and decrease the investment/operational costs. In this context the natural wastewater systems, such as constructed wetlands (CWs), are in many cases, an effective solution to fulfil legal obligations with low O&M costs. Despite several studies demonstrated the efficiency of CWs for the treatment of agro-industrial wastewater (Masi et al., 2015) only few applications for the reuse of the treated wineries wastewater are known.
In this paper the results of experimental activity carried out in a multistage CW sited in Sicily (Italy) are presented. The treatment performances and effluent concentrations were monitored at each treatment step. The aims of this study was to increase the knowledge on the performance of CWs for treatment of winery wastewater and explore their potential for irrigation reuse.

2. Materials and Methods
The research activity was carried out in a multistage pilot-scale CW, treating part of winery wastewater produced by the Marabino farm (i.e. production capacity of about 1,500 hL wine year^{-1}) located in South East Sicily. At the farm, winery wastewater is treated by a Imhoff tank and effluents are generally disposed on the soil by a sub-irrigation system. From October 2013, the treatment system was integrated with a preliminary treatment, which consists in a coarse screening, and about 3 m^3 day^{-1}of Imhoff effluent where diverted into a equalization tank (5 m^3) and treated with a multistage CW. This CW (Figure 1) consists of 3 beds in series with a total surface area of about 230 m^2: 1) vertical subsurface flow (VF) (about 140 m^2); 2) horizontal subsurface flow (HF) (about 60 m^2); 3) free water (FW) system (about 30 m^2). The end of the FW section operates as a subsurface flow and it was vegetated with *Iris pseudacorus*. The CW system was planted with *Phragmites australis* (VF), *Cyperus Papirus var. Siculus* and *Canna indica* (HF), *Nymphaea alba* and *Scirpus lacustris* (FW). The CW effluent is used for irrigation of a green area close to the experimental plant.

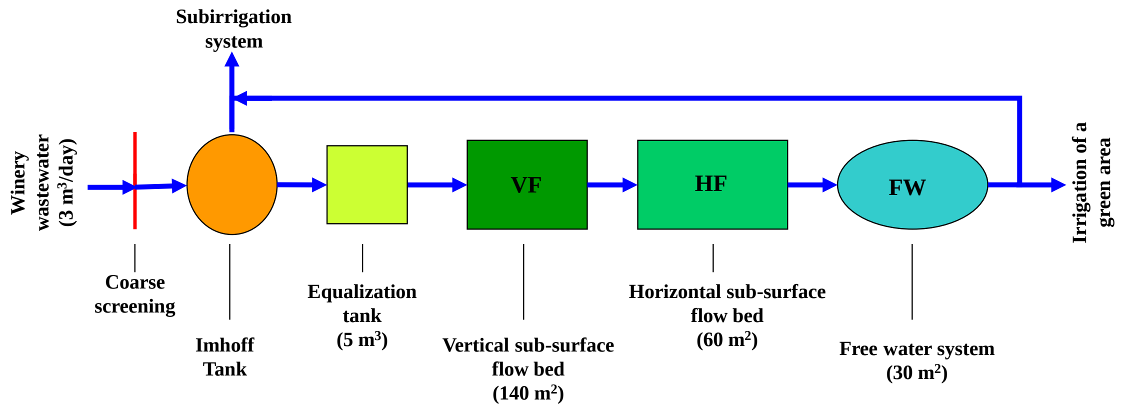

Figure 2.1: Layout of constructed wetland pilot plant located in Marabino farm (Sicily-Italy)

The wastewater quality parameters have been monitored, about a monthly frequency, from March 2014 to April 2017. The wastewater samples (about #100) were collected at the inlet and outlet of each stage of the treatment system. The following physicochemical parameters were evaluated according to standard methods (APHA, 1998): pH, Electrical Conductivity (EC), TSS at 105°C, BOD_5, COD, Total Nitrogen (TN), Ammonia Nitrogen (NH_4-N) and Orthophosphates (PO_4-P).
The percent removal (removal efficiency) was calculated as follows:

$$\text{Removal efficiency } (\%\ R) = (C_{in} - C_{out})/C_{in} \times 100 \qquad (1)$$

where C_{in} and C_{out} inflow and outflow concentrations (mg L^{-1}), respectively.
The effluent quality of the CW system was also evaluated in terms of its achievement of Italian wastewater discharge and irrigation reuse limits.

3. Results and Discussion

The pH of the CW influent during the monitoring period ranged from 4.7 to 11.1 with the lower values observed in the vintage periods (mean value about 7.1) and the maxima during the washing operations carried out with caustic cleaning agents (sodium hydroxide). After the passage through the different treatment stages we have observed a reduction of the range variation of pH with standard deviation values that are passed from 1.3 (inlet of the first stage) to 0.4 (outlet of the last stage). Similar results were found by Masi et al. (2015), that report pH values of CW's effluent near to the neutrality also when the winery wastewater was acid, in particular during vintage.
The electrical conductivity of the influent wastewater varied widely from 561 to 2,930 µS cm^{-1}, the average value of 1,047 µS cm^{-1} was slightly reduced, of about 20%, after passage through CW.

The CW exhibits a strong buffer capacity that was able to mitigate the wide fluctuations of influent TSS, COD and BOD_5 concentrations highlighting a mean removal efficiencies of about 67%, 78% and 75%, respectively (Table 2.1). As expected, the maximum pollutants influent values were detected during the various washing operations of fermentation tanks, barrels and the equipment used for the crushing and pressing of grapes. The mean removal efficiency of nutrients was lower due to the small concentrations detected in the influent. The lower removal efficiency of chemical-physical parameters showed by FW was probably due to the low influent concentrations associated with the algal bloom.
During the observation period the *E. coli* concentration in the CW influent showed an average value of about 4.3 Ulog CFU 100 mL^{-1} with a decrease of about 1.0 log unit in each treatment stage.

Table 2.1: Wastewater quality at the inlet and outlet of each CW stage and mean pollutant removal efficiencies

	Minimum	Average	Maximum	Standard Deviation	Removal (%) Each stage	Removal (%) All CW
TSS (mg L^{-1})						
Inlet VF	8	88	630	142		
Outlet VF	5	34	180	43	43	
Outlet HF	3	20	80	23	31	
Outlet FW	2	10	33	7	23	67
BOD_5 (mg L^{-1})						
Inlet VF	4	218	1,580	381		
Outlet VF	2	117	1,265	280	40	
Outlet HF	2	29	245	55	43	
Outlet FW	2	11	38	13	26	75
COD (mg L^{-1})						
Inlet VF	6	418	2,940	705		
Outlet VF	5	206	2,245	498	40	
Outlet HF	4	48	396	91	48	
Outlet FW	3	20	155	35	35	78
NH_4-N (mg L^{-1})						
Inlet VF	0.5	3.1	15.2	3.9		
Outlet VF	0.5	2.0	10.5	2.7	24	
Outlet HF	0.5	0.8	1.6	0.3	27	
Outlet FW	0.4	0.7	1.6	0.3	11	51
TN (mg L^{-1})						
Inlet VF	2.7	14.6	132.7	28.0		
Outlet VF	2.1	8.4	60.0	12.6	29	
Outlet HF	1.7	3.5	10.3	1.7	32	
Outlet FW	1.5	3.0	7.2	1.2	12	55
PO_4-P (mg L^{-1})						
Inlet VF	1.7	5.0	12.5	3.4		
Outlet VF	1.5	3.4	7.6	1.6	23	
Outlet HF	1.3	2.9	5.9	1.2	11	
Outlet FW	1.2	2.6	4.1	0.9	11	38
***E.coli* (Ulog CFU 100 mL^{-1})**						
Inlet VF	3.5	4.3	4.8	1.0		
Outlet VF	2.0	3.2	3.9	0.9	1.1*	
Outlet HF	1.5	2.3	2.9	0.3	0.9*	
Outlet FW	0.3	1.3	2.3	0.5	1.1*	3.0*

* removal values in Ulog

The concentrations of chemical-physical and microbiological parameters were always below the limits imposed by the Italian regulation for discharge into surface waters and, for COD, nutrient and *E.coli*, also for wastewater reuse (Table 2.2). Only 33% and 14% wastewater samples collected at the CW's outlet exceeded, respectively, the TSS and BOD_5 limits fixed by Ministerial Decree 185/2003. This could be explained by the algal bloom occurring in the FW only partially removed by the filtering operated by the sub-surface terminal section.

Table 2.2: Percentage of each CW stage effluent samples under WW Italian law limits to discharge into surface waters and for agriculture reuse

	WW Italian law limits to discharge in surface water bodies(1)	**% samples under discharge limits**	**WW Italian law limits for agricultural reuse**	**% samples under reuse limits**
TSS	80 mg L^{-1}		10 mg L^{-1}	
Inlet VF		71		19
Outlet FW		100		67
BOD_5	40 mg L^{-1}		20 mg L^{-1}	
Inlet VF		48		29
Outlet FW		100		86
COD	160 mg L^{-1}		100 mg L^{-1}	
Inlet VF		57		57
Outlet FW		100		100
NH_4-N	15 mg L^{-1}		2 mg L^{-1}	
Inlet VF		95		62
Outlet FW		100		100
E.coli	5.000 CFU 100 mL^{-1}		50(2) - 200(3) CFU 100 mL^{-1}	
Inlet VF		20		0 - 0
Outlet FW		100		80 - 100

(1) for industrial wastewater – (2) for 80% of samples – (3) maximum value

4. Conclusion

The results show that the CW effluents achieve the limits imposed by the Italian law for the wastewater discharge in water bodies and for wastewater reuse. However, the algae growth occurring in the final FW stage has determined, for TSS and BOD_5 parameters, an exceeding of the wastewater reuse law limit in some samples taken at the CW's output. A further reduction of the TSS and BOD_5, therefore, the complete match to law limits could be achieved by adopting, in the terminal sub-surface section of FW, a gravel material with a diameter less than of 80-100 mm and increasing the filtering surface.
In conclusion, the results confirm the high potential of CWs for the wastewater winery treatment in small wineries also aimed to the use of reclaimed water, especially in arid and semi-arid areas.

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Improvement of citrus water productivity using partial root zone drying irrigation along with shading nets

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Summary
Climate change and ever-increasing water use, along with water scarcity, reduces crop production. Thus, efficient water management, such as deficit irrigation and shading could resolve some of these shortcomings. Therefore, the aims of this research were to evaluate the effects of partial root zone drying (PRD) along with shading screens on yield, water use efficiency and stomatal conductance of citrus trees in a humid area with hot and relatively dry air during summer time. The experiment was conducted in the Citrus and Subtropical Fruits Research Center of Ramsar, close to Caspian Sea, IRAN. The following treatments were employed on citrus trees (*Citrus chinesis* L), cultivar Valencia, (1) full irrigation (FI), which trees received 100 percent of soil field capacity (FC), 2) two PRD treatments, where trees receiving 50 (PRD50) and 75% (PRD75) of FI, and 3) two PRD treatments of PRD50 and PRD75 were treated with shading nets (SHPRD50 and SHPRD75, respectively). Tukey post-hoc test was used to compare treatment's means. The results show that g_s and rwc were higher in FI, PRD75 and SHPRD75 relative to stressed treatments of PRD50 and SHPRD50. The same trend was registered for $\Psi_{st,}$ and the lowest values were achieved by treatments receiving 50% water of FI. Leaf temperatures in some measurement intervals were significantly higher in stressed treatments of PRD50 and SHPRD50. Water deficiency significantly reduced yield in stressed treatments of PRD50, while reversely affected fruit soluble solids in PRD50 and PRD75. Shading on PRD treatments increased fruit size and yield, although this improvement was significant only for fruit diameter of SHPRD75 in comparison with PRD50.

1. Introduction
Climate change and ever-increasing water use, along with water scarcity, reduces crop production. Thus, efficient water management, such as partial root zone drying irrigation (PRD) and shading could resolve some of these shortcomings. In deficit irrigation with PRD, half of the root zone is irrigated and the other half is left unirrigated. Therefore, it could benefit crop water use efficiency. Conducted experiments on orange orchards with PRD irrigation strategy showed that this method significantly increased water use efficiency and reduced water consumption (Shahabian et al., 2011; Romero-Conde et al., 2013).
Meanwhile in orchards during dry and warm weather conditions high irradiance might load an extra stress on trees and increase transpiration. Shading screens could help to reduce irradiance loads. Shading orange trees by reducing radiation load increased water use efficiency (Jifon and Syvertsen, 2003; Nicolas et al., 2008).

Therefore, the aims of this research are to evaluate the effects of PRD along with shading screens on yield, water use efficiency and stomatal conductance of citrus trees in a humid area with hot and relatively dry air during summer time.

2. Materials and Methods
The experiment was conducted in the Citrus and Subtropical Fruits Research Center of Ramsar, close to Caspian Sea, IRAN on 2014. The station located at 50°39'19" east longitude and 36°54'30" north latitude with average 6 m above sea level. The orange orchard soil is sandy-

loam. The site has a humid climate with little rain during summer time. Mean annual precipitation and air temperature are 1166 mm and 16.8°C, respectively.
The following treatments were employed on citrus trees (*Citrus chinesis* L), cultivar Valencia, (1) full irrigation (FI), which trees received 100 percent of soil field capacity (FC), 2) two PRD treatments, which trees receiving 50 (PRD50) and 75% (PRD75) of FI, and 3) two PRD treatments of PRD50 and PRD75 were treated with shading nets (SHPRD50 and SHPRD75, respectively). Tukey post-hoc test was used to compare treatment's means of stomatal conductance (g_s), leaf relative water content (rwc), stem water potential (Ψ_{st}), and leaf temperature (T_l). Moreover, Regression analysis was done between the above factors and leaf to air vapor pressure difference.

3. Results and Discussion

The results of the experiment show that water management treatments along with shading screen had significantly influenced stomatal conductance (gs), stem water potential (Ψ_{st}), leaf relative water content (RWC) and leaf temperature (T_l) (Table 1). Stomatal conductance after irrigation relative to pre-irrigation significantly increased and the highest g_s occurred in trees in treatments of FI, PRD75 or SHPRD75 (Table 1). Stomatal conductance is highly sensitive to soil water content and leaf surrounding environment (Raeini-Sarjaz and Chalavi, 2008). Within a crop canopy transpiration rate is directly correlated to g_s, while vapor pressure difference (VPD) between leaf and surounding leaf air is a major governing factor (Raeini-Sarjaz, 1997). In this experiment highly significant,but negative correlations were registered between g_s and VPD (r = -0.61 to -0.82) and by increasing soil water content the relation was negatively higher, which is in agreements with Pérez-Pérez et al. (2012) findings.
Water management significantly affects stem water potential (Ψ_{st}) before and after watering. The highest Ψ_{st} before watering occurred on PRD75 with shading (SHPRD75), and after watering the lowest occurred on PRD50 (Table 1). It could be speculated that by shading radiation load reduction decreased transpiration, therefore Ψ_{st} stayed higher than that of corresponding treatments. Between Ψ_{st} and VPD highly significant, but negative correlations (r = -0.59 to -0.82), along different water treatments, were found. Our results of relation between stem water potential and VPD were in agreement with those of Ortuno et al. (2006).
Relative leaf water content (RWC) and leaf temperatures of different water treatments were significantly different only before watering (Table 1), and the less RWC and T_l occurred for PRD50, which received the less water during the trial, but by water and enough water for transpiration leaf temperatures of all treatments were almost equal (Table 1)

Table 1. stomatal conductance (g_s), stem water potential (Ψ), leaf relative water content (RWC) and leaf temperature (T_l) before (Ptr-) and after (Post-) irrigation along different water management treatments.*

treatments	g_s (µmol $m^{-2}s^{-1}$)		Ψ_{st} (bar)		RWC %		T_l (°C)	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
FI	71.1	111.2^a	-22.2^b	-14.6^{ab}	70^a	80	32.0^b	30.3
PRD75	59.1	92.4^{ab}	-19.0^b	-12.0^a	67.2^{ab}	77.4	32.2^{ab}	29.9
PRD50	45.7	62.4^b	-26.1^b	-16.0^b	68.9^{ab}	73.3	33.1^a	29.8
SHPRD75	81.1	140.1^a	-16.0^a	-12.1^a	70.1^a	79.2	33.0^{ab}	29.9
SHPRD50	45.1	63.2^b	-26.1^b	-16.0^b	64.1^b	74.1	32.7^{ab}	29.8
Mean	60.4	93.8	-21.9	-14.1	68.1	77.6	32.6	29.9

** in each column treatments that catty different letters are significantly at 5% level.*

4. Conclusion

In conclusion, mild PRD along with shading screen could improve citrus plant water potential and adjust stomatal conductance.

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Sugar beet production using partial root zone drying irrigation as a management tool to combat water shortage in a sub-humid region

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Keywords: water scarcity, PRD, WUE, Iran

Summary
Water scarcity nowadays is becoming one of the common features of arid and semi-arid regions of the world, due to population growth, water allocations, low water productivity, climate change, and water mismanagements. Therefore, the aim of this paper is to employ a recently developed water management procedure, partial root zone drying irrigation system (PRD), to increase crop water-use efficiency (WUE). Sugar beet (*Beta vulgaris* L.), Toucan cultivar, was grown in 2014 summer growing season in a clay-loam soil at the Agricultural Research Station of Shahr-e-Kord, a temperate semi-humid region with cold winters and dry summers, with 319 mm annual precipitation. The experiment was conducted in a complete block design using five water treatments of (1) full irrigation (FI), as control, where plants received 100 percent of soil water field capacity (FC), (2) two conventional deficit irrigations with 80 (DI80) and 60 (DI60) percent water relative to FI, where water was applied to whole root system, and (3) two PRD treatments of fixed PRD (FPRD), where plants received their corresponding water in one side, and an alternate PRD (APRD), where one side of root system was irrigated and irrigation was switched to the dry part at the next irrigation schedule. Plants were irrigated using a drip irrigation system and water volumes were established using a time domain reflectometer (TDR). Data were analyzed using SAS software and SNK post-hoc test was employed to compare treatment means. The percentage of saved water during whole sugar beet growth and development period relative to FI were 18, 44, 33 and 45 percent for DI80, DI60, APRD and FPRD, respectively. Soil water content significantly ($p \leq 0.05$) affected root yield, sugar content, sugar yield, and root and sugar yield water use efficiencies (WUE_{ry} and WUE_{sy}).

1. Introduction

Population growth and climate change are the two major constraints in food shortage in future. Due to FAO report (FAO, 2003) world population would increase by 35 percent by 2030, while due to the U.N. Environmental Programme prediction air temperature might increase to 3.5^{o}C by 2035. This increase of global temperature could be translated to more water demand for crop production due to increase of evapotranspiration and shift of nonlocal invasive plants. Therefore, thoughtful strategies should be managed to reach the new goals, such as adaptation to new conditions and improvement of new crop verities which could provide enough food within the new climate thresholds.

Climate change might have more influence on water shortage in arid and semi-arid regions of the world. Iran located in sub-tropical high pressure system belt, where mainly arid and semi-arid climates are prevailed, therefore, water availability is vital for livelihood and crop production. In these regions water shortage and water scarcity are the most common environmental stresses in crop production, and these phenomana are regular features of the nature. Therefore, a great deal of emphasis is on crop physiology and crop water management to use water efficiently (Stikic et al., 2003).

Partial root-zone drying (PRD) irrigation, as a further development in deficit irrigation (DI) method, based on crop physiology and crop water management, nowadays is gaining a lot of attention for reducing crop water consumption and increasing water use efficiency (Sepaskhoh and Khajehabdollahi, 2005). The partial root-zone drying irrigation (PRD) relative to conventional deficit irrigation (DI) is more beneficial, where plant root system gets alternate

irrigation on both sides. Water stress mainly reduces stomatal conductance, where transpiration rate reduction is more inhibited relative to CO_2 gain, therefore, in general WUE increases by water stress (Raeini-Sarjaz et al., 1998). Meanwhile, in PRD strategy the dry part of the plant root system in response to water deficit generates abscisic acid hormone (ABA), which regulates stomatal pores to control transpiration (Liu et al., 2003; Liu et al., 2005), by which plant WUE enhances. The PRD is commonly consider as a DI method, because it does not receive more than 50-70 percent of water relative to full irrigation (Marsal et al., 2008).
The objective of this study was to evaluate the effect of partial root-zone drying, along with conventional water deficit irrigation strategy, on sugar beet root and sugar yields and thier water use efficiencies (WUE) relative to full irrigation strategy in a sub-humid climate with low rain during late spring and summer time.

2. Materials and Methods

The experiment was conducted on a clay-loam soil during 2014 summer growing season at the Agricultural Research Station of Shahr-e-Kord, Iran, a temperate semi-humid region with cold winters and dry summers, with 319 mm annual precipitation. The site is located at 48°31' east longitude and 31°18' north latitude with average altitude of 2073 m above sea level. Sugar beet (*Beta vulgaris* L.), Toucan cultivar, was grown in a complete block design using five water treatments of (1) full irrigation (FI), as control, where plants received 100 percent of soil water field capacity (FC), (2) two conventional deficit irrigations with 80 (DI80) and 60 (DI60) percent water relative to FI, where water was applied to the whole root system, and (3) two partial root drying irrigation system (PRD) treatments of fixed PRD (FPRD), where plants received their corresponding water in one side, and an alternate PRD (APRD), where one side of root system was irrigated and irrigation was switched to the dry part at the next irrigation schedule. Plants were irrigated using a drip irrigation system and water volumes were established using a time domain reflectometer (TDR). Before cultivation soil received 200 kg/ha superphosphate triple and 200 kg/ha potassium sulphate, while 250 kg/ha urea fertilizer was divided to 5 portions and used as a side dressing fertilizer during growing season. Each experimental unit was consisted of a plot with hill rows of 10 m long and 60 cm wide. During the growing season consumed water was measured and at the harvest time sugar beet roots were collected and corresponding factors were measured. The data were analyzed using SAS software (9.1 version, SAS Inc.) and SNK post-hoc test was employed to compare treatments means.

3. Results and Discussion

Water consumption along different water management treatments reduced relative to full irrigation treatment (FI) (Table 1). Water management treatments significantly affected root and sugar yields and root and sugar water-use efficiencies. Water deficit treatment of DI80, which received 80% water relative to FI consumed 20% less water, while root and sugar productions were reduced by 6.6 and 13.8 percent relative to FI. It means that crops under water stress condition may use water efficiently. This trend could not be the same when crop is under severe water stress. Water deficit treatment of DI60, which received 60% water relative to FI consumed 52% less water, while its root and sugar productions relative to FI reduced by 82 and 92 percent, respectively. Water use efficiency of DI80 significantly was higher than FI and DI60, while surprisingly WUEs of DI60 were less than those of FI (Table 1). Based on Raeini-Sarjaz and Barthakur (1998) when crop decouples from its surrounding environment or there is not enough soil water to adjust loaded net radiation, stomatal conductance could not be regulated well to increase the ratio of photosynthesis to transpiration. In agreement with our findings Fabrio et al. (2003) reported that deficit irrigation reduced sugar beet yield while significantly increased WUE.

Table 1. The influence of soil water management treatments on mean consumed water, root and sugar yields and water use efficiency.*

Treatments	Consumed water (m^3/ha)	Root yield (tone/ha)	Sugar yield (tone/ha)	Root WUE (kg/m^3)	Sugar WUE (kg/m^3)
FI	7473	71.39^a	14.50^a	9.55^c	1.94^b
DI80	6192	66.94^c	12.74^b	11.19^b	2.13^a
DI60	4910	38.33^e	7.36^e	8.55^d	1.64^c
APRD	5014	61.39^c	11.47^c	11.86^a	2.21^a
FPRD	4140	45.55^d	9.09^d	10.80^b	2.15^a

** In each column means that carry different letters are significantly different at 5% level.*

Water consumption of alternative and fixed PRD water management treatments relative to full irrigation treatment reduced by 49 and 80 percent, respectively, root and sugar productions reduced by 16.2 and 23.6 percent for APRD and by 56.7 and 59.5 percent for fixed PRD, respectively. Both root and sugar WUEs of APRD and FPRD were significantly higher than those of FI treatment (Table 1), while not different from DI80. Ustun et al, (2014) found an increase of 34.9% in WUE for PRD relative to FI strategy in sugar beet. Based on our findings root WUE of APRD was significantly highr than that of DI80, while between their sugar WUE no difference was found (Table 1).

4. Conclusion

In conclusion, although full irrigation provided 15 and 20 percent more root and sugar yields, respectively, relative to alternate PRD, the latter consumed 33 percent less water and had higher water-use efficiency. Therefore, in regions with water scarcity APRD could be recommended as an appropriate water management tool to combat water shortage and increase water productivity.

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Analysis of current performance in water delivery systems of Calabria (Southern Italy)

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Keywords: water delivery system; performance indicators; collective irrigation.

Summary
Water delivery performances were evaluated throughout four seasons in three collective systems of Calabria, Southern Italy. Adequacy, efficiency, dependability and equity of water delivery (compared to net irrigation requirement, estimated by CROPWAT) were measured through the indicators of Molden and Gates (1990) at the monthly scale for each crop. Delivered water was lower than required (low system adequacy), but used without waste (high efficiency). Water delivery was not timely matching to requirement (low dependability), although it was fairly equitable among users. User satisfaction towards irrigation was low, while the available water was fully exploited, as shown by the new User Satisfaction and Water Exploitation Indices proposed in this study.

1. Introduction
In the 11 Water Users Associations of Calabria (Southern Italy) the performance of the collective irrigation service is generally poor, because of inadequate water delivery, with low farmer satisfaction (Zema et al., 2015). In these cases, the assessment of water delivery performance represents a point of departure for future improvements. The literature shows that quantitative indicators such as efficiency, adequacy, equity and dependability of water delivery are the most important to assess the performance of a Water Delivery System (WDS).
This study evaluates adequacy, efficiency, dependability and equity of water delivery performance (evaluated by the corresponding indicators proposed by Molden and Gates, 1990) in three collective irrigation systems of Calabria throughout four irrigation seasons. Two new indicators to quantify user satisfaction and water exploitation in collective irrigation are proposed.

2. Materials and Methods
The three investigated WDS ("Angitola 3DMF", irrigated area of 117 ha, "Angitola 6DMF", 86 ha, and "Savuto", 411 ha) fall within the Water Users Association "Tirreno Catanzarese" (Calabria) (Figure 1). The main crops are olives (6%), citrus (36%) and other fruits (3%), vegetables (52%, mainly tomatoes, aubergines and onions), gardens (1%), forage (1%), maize (1%), and are mainly irrigated with sprinkler systems. The irrigation water, supplied from surface water bodies, is transported by gravity, delivered in pressurized pipelines (about 75% of the network total length) or canals (25%) and distributed to farmers on demand. The three WDS were designed by probabilistic criteria and currently are not able to allocate water simultaneously to the whole area.
The net irrigation requirement of each crop (in addition to precipitation) was estimated using the software CROPWAT 8.0 (Clarke et al., 1998; FAO, 2009). The water balance was performed daily for each crop over four irrigation seasons (from April to September). The daily meteorological data required by CROPWAT were measured at a station (Lamezia Terme) inside the Water Users Association. The crop data for estimating evapo-transpiration (by Penman-Monteith model) were derived from FAO guidelines; the farm cultivation practices were identified by interviewing farmers. Soil hydrological parameters were estimated using the Pedo Transfer Function of Saxton et al. (1986) on the basis of the sandy loam texture (65% sand, 22% silt and 13% clay) from the Soil Map of the Calabria Region, ARSSA, 2003). The total irrigation requirement of each crop ("water required") was calculated from the net value considering farm irrigation efficiencies of 0.70 for sprinklers, 0.85 for sprayers and 0.95 for drippers, accordingly to FAO guidelines. The water volumes delivered to users ("water delivered") were measured by the automated system "Acquacard®" at farm hydrants. Data were classified per WDS, year (irrigation season), month and crop.

For the month "j" of each irrigation season and farm outlet "i", the water delivered and required per unit area (WD_{ij} and WR_{ij}, [m^3 ha^{-1} $month^{-1}$]) were quantified as above. Then, the indicators of Molden and Gates (1990) - whose paper reports more details together with calculation methods and equations - of adequacy (AD), efficiency (EF), dependability (DE) and equity (EQ) were evaluated at annual scale. The values reported by Molden and Gates (1990) were adopted as reference limits: (i) AD good if ≥ 0.90, fair in the range 0.80 – 0.89 and poor if < 0.80; (ii) EF good if ≥ 0.85, fair in the range 0.70 – 0.84 and poor if < 0.70; (iii) DE good if ≤ 0.10, fair in the range 0.11 – 0.20 and poor if > 0.20; (iv) EQ good if ≤ 0.10, fair in the range 0.11 – 0.25 and poor if > 0.25.

As regards the two new indicators suggested, for the irrigation system "R" and throughout the irrigation season "T" a "User Satisfaction Index" (USI, [%]) and a "Water Exploitation Index" (WEI, [%]) of the water delivery can be defined as follows:

$$USI_{R,T} = \frac{1}{m\ n}\sum_{j=1}^{n}\sum_{i=1}^{m} p_{ij} \times 100 \tag{2.1}$$

$$WEI_{R,T} = \frac{1}{m\ n}\sum_{j=1}^{n}\sum_{i=1}^{m} q_{ij} \times 100 \tag{2.2}$$

where $p_{ij} = 1$, if $WD_{ij}/WR_{ij} = 1$, otherwise $p_{ij} = 0$, in (2.1), while $q_{ij} = 1$, if $WR_{ij}/WD_{ij} = 1$, otherwise $q_{ij} = 0$, in (2.2). Of course, the sum of $USI_{R,T}$ and $WEI_{R,T}$ is equal to 100.

$USI_{R,T}$ accounts throughout all the time periods of an irrigation season the number of farmers which receive the adequate water volume for crop irrigation (thus the incidence of the periods in which a share of the irrigation system users is globally satisfied for the adequate water delivery).

$WEI_{R,T}$ accounts throughout all the time periods of an irrigation season the number of farmers which irrigate crops using the entire water delivered by the system (thus the incidence of those situations for which irrigation water is fully exploited throughout the irrigation season and on the total number of farmers).

3. Results and Discussion

Poor adequacy (mean AD = 0.57) and dependability (mean DE = 0.43), but good efficiency (mean EF = 0.92), water exploitation level (mean WEI = 74%) and equity (mean = 0.09) were detected in the WDS "Angitola 3DMF". Globally, user satisfaction was very low, as shown by the average USI of 26% (Figures 3.1 and 3.2). In the WDS "Angitola 6DMF", mean adequacy (0.55), dependability (0.49) and equity (0.33) of the irrigation service were far from the acceptance limits (0.80, 0.20 and 0.25, respectively), while the efficiency in water resource exploitation (0.82) was generally fair (WEI = 68.7%). User satisfaction (measured by USI), even though again low (31%), was the highest among the studied WDS (Figures 3.1 and 3.2). In the WDS "Savuto", the analysis of the performance indicators showed: (i) very poor adequacy (0.44) and dependability (0.62); (ii) good efficiency (EF = 0.90) and water exploitation (WEI = 82.3%); (iii) fair equity (0.13) (Figure 3c). The users are little satisfied with the irrigation service performance, the mean USI being equal to 18% (Figures 3.1 and 3.2).

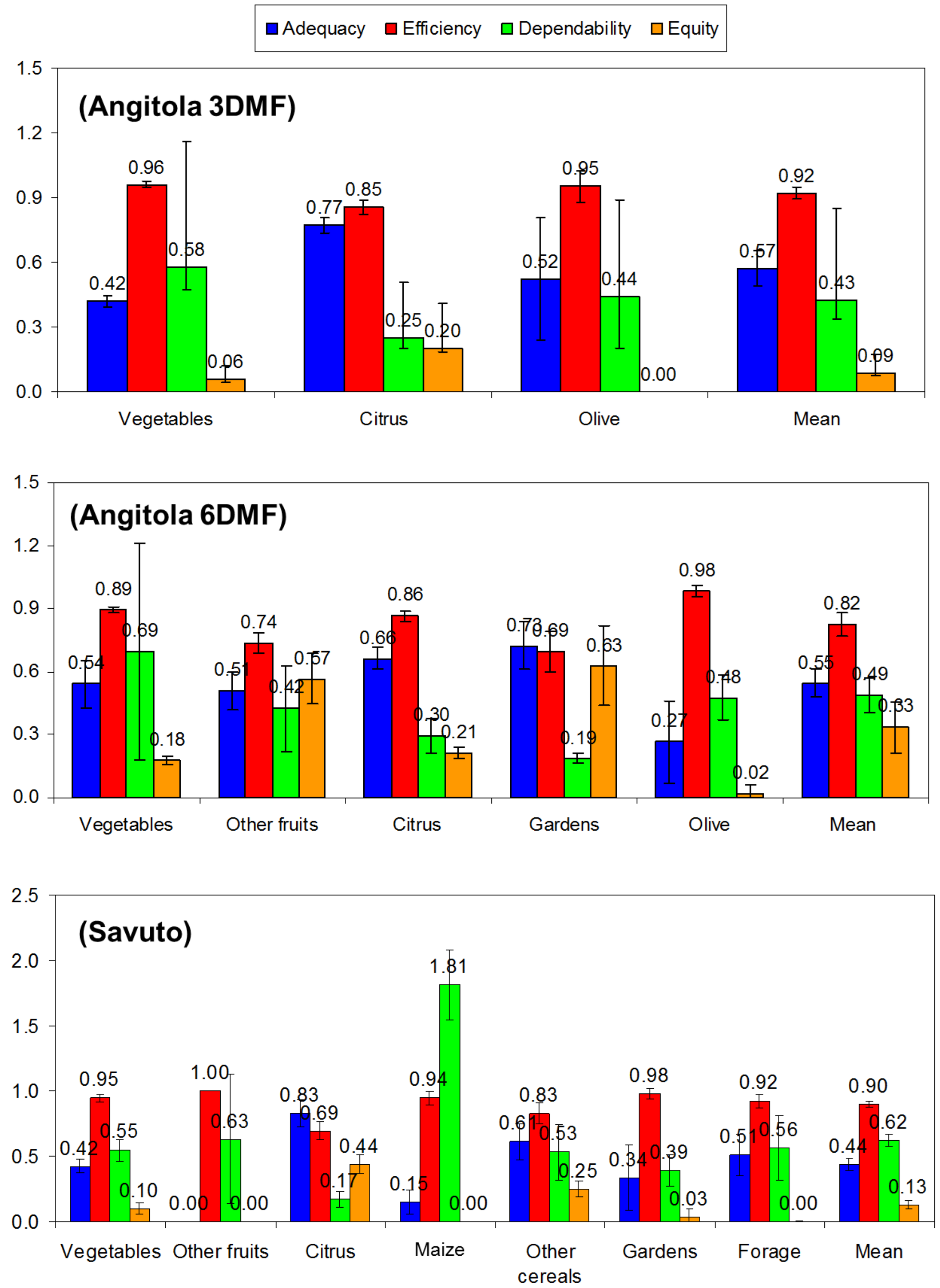

Figure 3.1 – Performance indicators (mean and std. dev.) in the analysed WDS.

The low adequacy of WDS is due to the generally insufficient capacity of the hydraulic infrastructure to allocate water simultaneously to the whole area in an equitable measure. Moreover, the individual irrigation programs of the farmers do not appear suitable for the management of the WDS. Since the users do not report a reduction in crop yield, it may be deduced that farmers irrigate crops with additional resources, such as groundwater and/or potable water, often without authorization. However, the fair value of the indicator of efficiency and water exploitation indicates that the available water volume delivered to the crops is properly used for irrigation. As shown by the poor dependability, the systems are not able to deliver water at the desired time, and thus the irrigation service is not uniform over time. This may be attributable to a farmers' lack of knowledge about times of supplying irrigation water to crops.

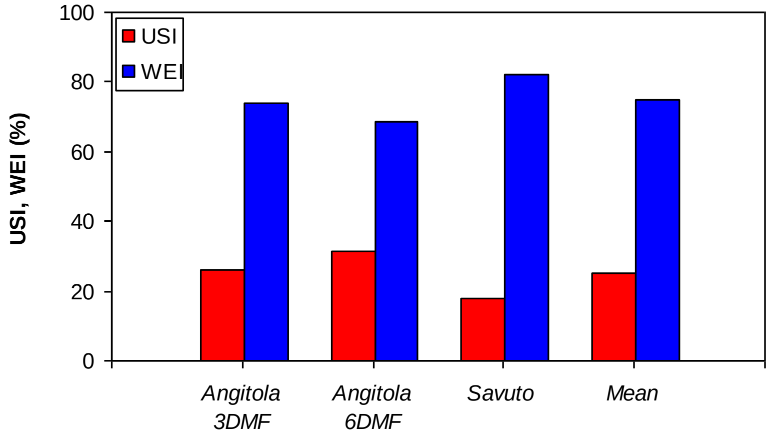

Figure 3.2 - USI and WEI indices in the analysed WDS.

4. Conclusion

This study suggests to service managers and users the need for substantial changes in the system infrastructure and management procedures. For example, the replacement of farm sprinkler irrigation with micro-irrigation may increase water delivery adequacy; the introduction of an arranged demand method (in replacement of the current on-demand) and of an irrigation advisory service (based on the water balance of crops) could improve system dependability. The effects on the WDS of the above mentioned scenarios - or of the combination of them - may be easily evaluated by the six performance indicators above, thus exploiting this performance evaluation method as design tool for collective irrigation improvement.

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Evaluating economic sustainability of the first automatic system for paddy irrigation in Europe

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Keywords: Gravity-fed surface irrigation systems; rice field irrigation management; automatic and remote controlled gate.

Summary
Italy is the leading rice producer in Europe, accounting for more than half of the total high-quality production of this crop. Rice is traditionally grown in fields that remain flooded starting with crop establishment until close to harvest, and this traditional irrigation technique (i.e., continuous submergence) is recognised as an important water resource sink (almost 40% of the irrigation water available worldwide is used for paddy areas). Meanwhile, the water management in rice areas requires a high level of labour because it is based on maintaining a predetermined water height in paddy fields and because the regulation of input and output flow is typically operated manually by the farmer. This study aims to evaluate the economical sustainability of adopting automatic and remote-controlled systems for irrigation of paddy fields. The results show that the investment is affordable for Italian farmers, it amount on average at about 650 € hectare^{-1} and it is repaid in about 15 year.

1. Introduction

Rice is a staple crop for more than half the world's population. Approximately 90% of world rice production is grown in Asia, while the quantities produced in Europe are relatively limited (approximately 2 million tons). Italy, with more than half of the total European rice production, is the first producer of the old continent, while Spain, Greece, Portugal and France appear in the top five producers providing about 30%, 10%, 5% and 3% of the total European rice production, respectively (EUROSTAT 2013, ISTAT 2009). The most important rice-growing area in Italy is a portion of the Padana plain located to the east of Ticino river, straddling the regions of Lombardy and Piedmont in northern Italy (more than 200.000 hectares, 92% of the Italian rice surface). Although the main objective of the rice farms is productive, areas in which the prevailing crop is rice create a peculiar agro-ecosystem characterized by the presence of water in the fields for several months each year (Masseroni et al. 2017b). The prolonged presence and circulation of water, due to continuous flooding of fields from wet-sowing until close to harvest, represents a distinguishing feature of these rice areas, some of which have also been included in the European ecological network NATURA 2000 and on the official list of the European Special Protected Areas (Habitat Directive, 92/43/EEC). However, the traditional irrigation technique, based on continuous flooding during the growing season, still dominates in most areas (for example, in 85% of the northern Italy rice area) and is characterized by very low irrigation efficiencies and a high level labor requirement performed by workers (named in Italian "acquaioli"), which combine rich hands-on experience and local traditional knowledge. Although there are no accurate literature measurements related to the time that farmers spend for irrigation management of their fields, it may be estimated that a significant fraction of the working day during the agricultural season is dedicated to the manual control and adjustment of the gates to maintain the correct levels of water inside the paddy fields. This fraction of the day can vary considerably depending on the extension of the cultivated area, the growing period and the fragmentation of the rice-growing property. Consequently, these features affect the fixed costs of individual companies, primarily for the assumption of seasonal workers' time that is dedicated full-time or part-time to irrigation management. The implementation of reliable

automatic irrigation systems which support the manual operations of these workers is strictly encouraged especially by farmers in order to ensure a more rational allocation of water in the fields according crop conditions.
The purpose of this study concerns the evaluation economic sustainability of the first automatic and remote controlled gate prototype (already described in its hardware and software components in Masseroni et al. (2017a)) originally designed for furrow, basin or border irrigations and rearranged for a traditional rice irrigation in Europe and tested with a pilot project in Italy.

2. Materials and Methods

The pilot project was carried out in the agricultural season 2016 (from April to September) in a paddy field of the Cerino farm (45° 08' 00.00'' N; 8° 44' 42.15'' E) located in Semiana (PV). The system was composed by one BayDrive® gate of 70cm width for automatic and remote-controlled flow regulation, one FlumeMeter® box for inlet flow measurements, one FloodTech® sensor for the real-time monitoring of water level in the field, and lastly one FarmConnect Gateway® as a connection device to the cellular network. All devices were designed by Rubicon Water industry involved in the project together with Civil Engineering department of University of Melbourne.
The assessment of the economical performance is performed analyzing the improvements achieved by the automated irrigation system with respect to traditional rice irrigation management features. In particular, traditional rice irrigation management practices were extrapolated from questionnaires distributed by the National Rice Center technicians to 45 farmers homogenously spread over a rice area of about 1500 km^2 located between the Ticino and Sesia rivers. The 13 questions listed in the interview are the following and the answer referring to the agricultural season 2016: (i) Municipality where the farm is located. (ii) Utilized Agricultural Area (UAA) for rice cultivation within the farm. (iii) Type of seeding method, surface devoted to each method, and irrigation management. In particular: (iiia) Dry seeding and delayed FLooding (DFL); (iiib) Water seeding and continuous FLooding (WFL); (iiic) Dry seeding and intermittent IRrigation (DIR). (iv) Number of diversion canals used for the farm irrigation supply. (v) Methodology of water delivering to the farm (i.e. continuous or rotational). (vi) Level of farm fragmentation (i.e. time the farmer spends to reach the farthest rice field). (vii) Type of irrigation: (viia) Gravity irrigation; (viib) Tractor with water pomp (pumped irrigation). (viii) Irrigation management (i.e. manually or based on automatic systems). (ix) Number of times per day that the inlet gate to a generic rice field needs to be maneuvered/adjusted. (x) Man-hours a day required for farm irrigation. (xi) Number of workers involved in the irrigation procedures. (xii) Number of times the irrigation system requires maintenance in an year. (xiii) Annual average cost for the irrigation network maintenance (e.g. gate replacement, canal relining etc.).
Starting from questionnaire responses, a cost-benefit analysis of the economic impact of automation on farmer's income is performed through Net Present Value (NPV) methodology (Khan 1993).

3. Results and Discussion

The average cost for a complete automated irrigation system inferred by Rubicon quotations and composed by one BayDrive® gate, one FloodTech® sensor, transmission antenna, communication and actuation protocols, power supply, and FarmConnect® software is about 7,704 € (subdivided in 1,540 € for the gate, 700 € for the rubber insert, 1,806 € for the water level sensor, 3,224 € for the antenna, communication protocols, 245 € for installation and finally 189 € for FarmConnect® software and commissioning). The gate cost can vary considerably in function of the BayDrive® width, however, in this study we chose the price of a generic gate of about 70cm width according the dimension used in the pilot project. In addition to this cost, an annual maintenance fee for automation of about 21 € $gate^{-1}$ $year^{-1}$ and $FloodTech^{-1}$ $year^{-1}$ is required, which include software upgrade services, gates maintenance and data storages. An annual SIM card recharge service of about 315 € $year^{-1}$ has to be included.

The cost of the initial investment for the surveyed farms is on average 43,474€. This cost was obtained by multiplying the fixed costs for the automation system (i.e. 1,540 € for gate, 700 € for rubber insert 1,806 € for the water level sensor, 378 € for software and commissioning) for the mean number of fields per farm (supposing one field - one gate). The mean number of fields per farm is about 9, the latter calculated as the ratio between the mean UAA for the surveyed farms (about 63 hectares) and the mean size of a rice field (about 7 hectares). Furthermore, to the previous costs, 3,224 € plus 245 € respectively for central gateway transmission device and for installation (both costs are independent by the number of fields) are summed.
The life-time of the whole automatic system is supposed to be 20 years, after which all the devices should be replaced with new equipment.
Regarding the management costs of a traditional rice irrigation system, the overall hours invested in a day for the farm irrigation were multiplied for (i) the hourly cost of a non-specialized agricultural worker (13.73 € hour^{-1} by ISTAT information), (ii) the days of an irrigation season (about 90 days) and, lastly, (iii) the number of workers involved in irrigation procedures. The irrigation management cost amounts to 3,400 € year^{-1} as well as 2,300 € year^{-1} for the irrigation network maintenance.
The NPV methodology was applied to quantify the profitability of the automation adoption and separately the manual option, by subtracting the actual value of cash outflows (including initial cost) from the actual value of cash inflows over the life time of devices (20 year). A discount rate of 5% is supposed.
The cash outflows for the automation solution are: (i) the initial investment (43,474€) at the first year; (ii) the annual fee for automation and SIM card recharge service (688 € year^{-1}); (iii) the cost for farm canals maintenance (about 460 € year^{-1}) supposed to be 20% of the total cost of the irrigation network maintenance;(iv) the cost for the gates tele-control (supposed about 15 min day^{-1}) of about 309 € year^{-1} (i.e. 13.73 € hour^{-1} x 15 min day^{-1} x 90 days year^{-1} x 60^{-1} hour min^{-1}). While the cash outflow for the manual solution are: (i) the labor cost for traditional rice irrigation (3,400 € year^{-1}); (ii) the cost of irrigation network maintenance (2,300 € year^{-1}).
The results show that the NPV at the end of the 20th year is positive (about 9,400 €) for the automation solution and therefore the investment can be accepted and can be selected over the manual option (Fig. 1). The investment is fully repaid at the end of the 14th year, with a total capital cost of ranging from 638 to 689 € hectare^{-1} the former in the case where Gateway® and installation costs are amortized across 12 properties as usually performed in the Australian installations.

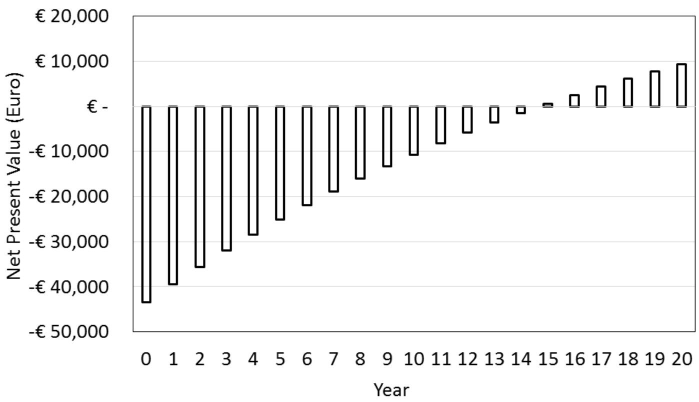

Fig. 1. Cost-benefit analysis over 20 years of the automatic irrigation system life time.

4. Conclusion

The current costs for the automation appear affordable for the Italian rice farmers since the NPV of the automatic solution is positive. Moreover, many externalities connected with an automatic and remote controlled management of irrigation should be taken into account if the performances of these systems are evaluated on a wider spatial scale (i.e. irrigation district or basin scales). In these cases, the maintaining of the ecological, landscape and environmental functions of the gravity-fed irrigation systems and the continuous monitoring of the binominal crop water requirements - water availability, give to the irrigation water managers the possibility to plan the water allocation and to regulate water distribution in function of farmer requirements. This overall improvement of the management performance could provide a profitable growth in revenue of irrigation consortia, in particular reducing the time spending for gates maneuvering especially in the context of Padana plain where the length of the irrigation network exceeds the 40,000 km. Lastly, the combination of flow regulation and measurements provided by the automatic irrigation system, can be a valuable support for the regional water authorities in order to evaluate the actual water consumptions according to the national law and European Union recommendations. This might provide an overview on irrigation efficiencies over the territories allow a more rational planning of irrigation resources.

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Agricultural water scarcity assessment in northern Italy by means of the Transpiration Deficit Index (TDI)

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Keywords: Water scarcity, Index, Hydrological model, Transpiration Deficit, Agricultural drought

Summary
The Mediterranean is the most vulnerable European region to both short-term and long-term water imbalance. Since irrigated agriculture accounts for a considerable share of water abstractions, the development and adoption of spatially distributed indicators able to recognize and predict water shortage and water scarcity situations are crucial to manage their effects. This work shows the suitability of the newly developed Transpiration Deficit Index (TDI) to monitor water scarcity in a pilot study area of the Padana Plain (northern Italy) characterized by limited water availability by surface diversions. Preliminary results of its validation through a comparison with a Landsat-derived time-series of proxy for crop yield is also presented along with the potentials of the proposed approach.

1. Introduction
The Mediterranean is considered the most vulnerable European region to short-term (water shortage) or long-term (water scarcity) water imbalances (i.e. abstractions exceeding resource availability; Spinoni et al. 2016), and it is forecasted that the situation will worsen in the coming decades, with southern Europe as a hotspot for drought (Forzieri et al. 2014).
Meteorological drought indices, like the well-known Standardized Precipitation Index (*SPI*; McKee et al. 1993), provide a standardized indication of rain water availability over a geographical area. However, in many areas of the world, irrigation is used to compensate for drought impacts, and meteorological index such as *SPI* cannot provide information on the effective water availability with respect to the agricultural land water needs. As a matter of fact, irrigated agriculture, accounting for a considerable share of water abstractions, is a key sector for water management in many regions. With reference to Italy, more than 55% of the area equipped for irrigation in this country is located in the Po River basin, and 84% of the area equipped for irrigation in Lombardy is actually irrigated (ISTAT 2014).
In the framework of irrigated agriculture, the development and adoption of spatially distributed indicators able to recognize and predict water shortage/scarcity situations are crucial to manage their effects, also in view of an adaptation to the climate change. In this context, this work, supported by Fondazione Cariplo (grant n° 2015-0220), aims to: (1) present the newly developed Transpiration Deficit Index (*TDI*), (2) illustrate its application to a pilot study area within the Po River Plain (northern Italy) characterized by irrigated land with a limited water availability from surface sources, and (3) provide a first measure of its consistency with both *SPI* and a crop yield indicator, to assess its suitability to predict the effect of water shortages.

2. Materials and Methods
TDI is an agricultural drought and water scarcity index based on the crop transpiration deficit (potential minus actual transpiration), calculated on a fixed time step (e.g. 10 days) over a long reference time period (e.g. 50 years). In particular, *TDI* is expressed, for each time step, as values of a standard normal distribution (e.g. -3 indicates an extreme drought while +3 and extremely wet period), thanks to a transformation of the probability distribution (Borghi 2017).
TDI calculation is implemented within the IdrAgra model (Facchi et al. 2004; Vassena et al. 2012; Gandolfi et al. 2014), a spatially distributed hydrological model which allows the simulation of water conveyance and distribution over irrigated territories, and the computation

of the hydrological balance on a daily basis for the unit volumes in which the agricultural land is divided. *TDI* can be respectively calculated as: (1) an agricultural drought (*D-TDI*) index, where rainfall is supposed to be the only water input to the system; and (2) a water scarcity (*WS-TDI*) index, where the simulation takes into account the irrigation supply.

In this study, both the indicators are calculated over time steps of 10 days (*D-TDI*$_{10}$ and *WS-TDI*$_{10}$). The results are visually compared, and a cross-correlation analysis is conducted to evaluate the response of both *D-TDI* and *WS-TDI* with respect to *SPI*$_{10}$ (accumulated over 10 days; Mishra et al. 2015). The *SPI*$_{6m}$ (6 months) is also computed to analyse the trend of dry and wet seasons over the simulation period.

Finally, an evaluation of the water shortage effects on crop productivity is performed by comparing *WS-TDI* maps to an earth observation (EO) product, the yearly Absorbed Photosynthetically Active Radiation (*APARy*), representing a proxy of the crop yield (Rembold et al. 2013; Running et al. 2000) obtained by using Landsat imagery. An ensemble correlation analysis between *WS-TDI*$_{10}$ and *APARy* is conducted to evaluate whether *TDI* could help in identifying areas associated with crop yield losses.

The pilot study area considered for the application is located in the northern part of the Irrigation District Media Pianura Bergamasca (IDMPB; Figure 2.1), it extends for 64 km^2 and it is characterized by scarce water availability for irrigation.

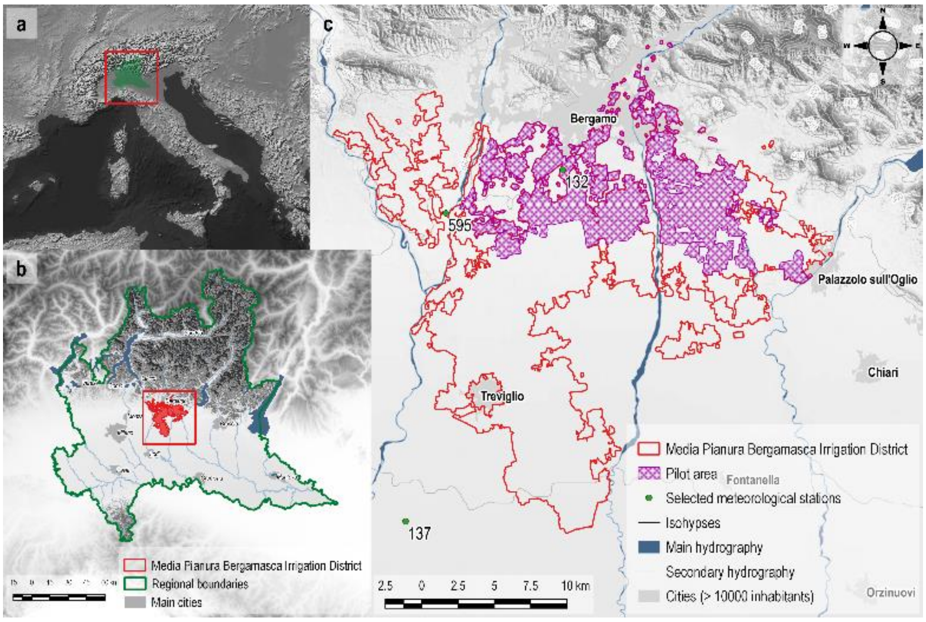

Figure 2.1: Overview of the pilot study area (north of the Bergamo province, northern Italy)

TDI maps with a spatial resolution of 250 m where produced considering a time series of 22 years (1993-2014) of meteorological and land use data. To avoid cross-sensor calibration (Vogelmann et al. 2016), the Landsat dataset was limited to the last 6 years (2009-2014). The produced *APARy* maps were masked to consider only maize pixels.

3. Results and Discussion

The *SPI*$_{6m}$ time series for the period 1993-2014 shows spring-summer 2014 to be the absolute wettest season, and summer 2009 the third driest growing season over the 22 years data series. Cross-correlation between *D-TDI* and *SPI* at lag 0 is 0.3 on average, and it is generally positive up to 40 days showing, as expected, a dependence of *D-TDI* from *SPI*. Deseasonalized series of *SPI* and *D-TDI* still show a positive cross-correlation especially in soils with lower soil available water content (AWC).

The visual comparison between *D-TDI* and *WS-TDI* maps shows that dry spell effects can be mitigated by irrigation, according to water availability and soil hydrological characteristics of each unit volume. As an example, Figure 3.1 shows a situation in which irrigation was not sufficient to compensate the effects of drought during the decade 20-29 June 2009 in many areas. Indeed, while in some pixels negative *TDI* values disappear (gray color indicates that over the reference period the transpiration deficit was always null) or become less negative, the situation does not improve in areas characterized by low water availability for irrigation and/or low soil AWC.

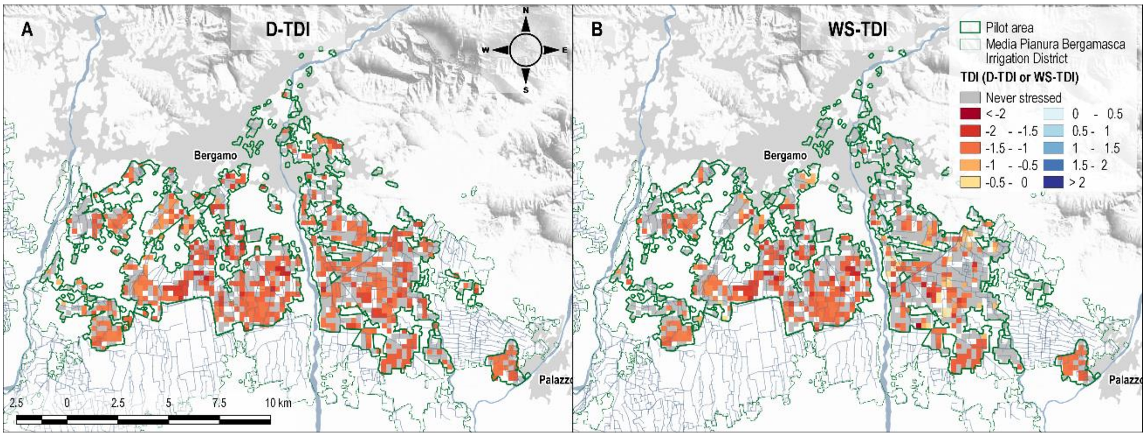

Figure 3.1: Comparison of D-TDI$_{10}$ and WS-TDI$_{10}$ maps for the period 20/06/2009-29/06/2009

APARy values of the maize cells confirmed, as expected from the SPI$_{6m}$ time series, that 2009 had a lower productivity (1967±456 MJ·m^2) than 2014 (2533±677 MJ·m^2). However, $WS\text{-}TDI_{10}$ series of each specific decade do not show a significant correlation with the annual crop productivity data. This may be mainly due to the noisy behaviour of the $WS\text{-}TDI_{10}$ series that, being influenced by rotational irrigations, shows a negative autocorrelation. However, even if not significant, 65% of the $WS\text{-}TDI_{10}\text{-}APARy$ comparisons show a positive correlation. This fact has a very low probability to occur in case the considered variables are effectively uncorrelated (p=0.003 considering a binomial distribution). Therefore, a positive correlation can be assumed between *WS-TDI* and *APARy* (i.e. lower productivity in case of water stress). However, since the correlation analysis between *WS-TDI* and *APARy* conducted so far is preliminary, in the next steps of the research a more accurate method for such analysis will be developed, to allow a better use of EO yield data for the *WS-TDI* validation.

4. Conclusion

Results of this study show that $WS\text{-}TDI$ could be used as an operational indicator for the periodic production of maps that could support irrigation district managers and farmers to cope with water shortages and scarcity. In particular, if real time data could be available, $WS\text{-}TDI$ maps could be adopted by competent authorities responsible for the monitoring of the state of agriculture, to set up an early warning system with respect to water scarcity phenomena. Additionally, *WS-TDI* may be adopted in water planning activities (e.g. decisions on water resources allocation, action plans to reduce water consumption in specific portions of the territory), also in a contest of climate change adaptation.

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Role of topographic gradient on water use performance in a paddy area

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Keywords: Topography, Water use efficiency, Water balance, Paddy field, Water reuse, Seepage, Percolation, Slope

Summary
Flooding irrigation management in paddy areas requires copious volumes of water, which are highly variable mainly according to soil features, groundwater table depth and climate conditions. Irrigation efficiencies ranging between 20% and 60% are commonly reported for field-scale studies. Despite researches investigating the water use efficiency (WUE) of paddy areas at larger spatial scales are scarce, there is evidence that water performance indicators may increase with increasing spatial scale because of water reuse. In paddy areas, topography is one of the factors activating water exchanges and reuse between rice fields. In particular, lower paddies may receive seepage and runoff from paddies located upslope. Very few studies in the literature addressed this topic so far. This study investigated the water balance terms and the water use performance of a group of four rice fields located in Lombardy and characterized by different elevations (A ≈ B > C > D) during two years (2015-2016). The main outcomes of the study are: *i)* paddy fields on a slope have interdependent WUE, with lower values at the top than at the bottom of the toposequence (WUE even greater than one may be observed for downslope fields); (b) WUE of none of the fields in a toposequence can be considered representative of the whole area: thus, to quantify the WUE of a series of paddies on a slope, the monitoring scale must be enlarged to include all the fields in the toposequence; (c) when groundwater is shallow, WUE is strongly dependent on the groundwater level both at the field-scale and at the slope-scale: significant variations in water fluxes and WUE may be observed from one year to the next as a consequence of fluctuations in the groundwater table depth.

1. Introduction

Italy is the largest rice producer in Europe, with the main production concentrated in Lombardy and Piedmont regions. Due to the high water requirements of paddy rice cultivation, irrigation efficiencies in rice areas range between 20% and 60% (Tuong and Bhuiyan, 1999). However, water performance indicators may increase with increasing spatial scale because of water reuse (Hafeez et al., 2007). In paddy areas, topography is one of the factors that may activate water exchanges and reuse between paddies. In particular, lower paddies may receive seepage and runoff from paddies located upslope, and may benefit form a higher groundwater level that plays an important role in reducing the percolation (Tsubo et al., 2006; Schmitter et al., 2015). These phenomena are described in some studies but, to the authors' knowledge, no experiments in the literature led to their quantification, at least for European rice areas. The study presented in this paper, developed in the context of the WATPAD project funded by Fondazione Cariplo (grant n° 2014-1260), aimed at quantifying the water balance terms and the water use performance of a group of adjacent rice paddies on a slope, with a focus on both the single fields and the group of rice paddies.

2. Materials and Methods

A two-year monitoring activity (2015-2016) was conducted in a rice farm located in Semiana (PV, Northern Italy). Four rice fields (A, B, C, D; for a total of 26 ha), were instrumented with sensors and devices to measure, at a hourly time step, the following water fluxes and storages: irrigation inflows (Q_{in}), irrigation outflows (Q_{out}), water levels within the fields (S_w), soil moisture (S_s) at four depth (from to 10 to 70 cm) and groundwater levels (Figure 2.1). All sensors and devices were connected to dataloggers following Chiaradia et al. (2015). Crop parameters (LAI, crop height) were measured in periodic campaigns along the season and used, together with agro-meteorological variables registered by a nearby meteo station, for computing potential evapotranspiration (ET) with the FAO Penman-Monteith single crop coefficient method; Kc values were derived from a previous experiment conducted in a nearby area (Cesari de Maria et al., 2017; Chiaradia et al., 2015). During spring 2015, a geophysical survey with an EMI device (GSSI Profiler-EMP400) and a traditional soil survey based on 38 hand auger soil observations and sampling at three depths (followed by laboratory textural analysis) were carried out to obtain a soil zonation of the study area. During fall 2015, six profiles (one for each soil type identified in the previous surveys) were opened and undisturbed soil samples were collected for the laboratory determination of retention curves of the different soil horizons, and saturated hydraulic conductivity (*Ks*) of hardpan layers.
Only fields A, C and D were adjacent, while B was separated by a deep drainage channel. Elevations were in the order A ≈ B > C > D. Groundwater depths at the site were within 1 m from the soil surface during the flooding period of both years.

Figure 2.1: Monitored fields at the Cerino farm, including the location of measuring devices and of the soil profiles opened during the soil survey

Water balances for the four fields were computed at a daily time step from seeding till harvest. The sum of seepage (*S*) and percolation (*P*) fluxes was obtained for each field as the residual term of the water balance equation (*SP*). *SP* fluxes were then separated into *S* and *P* by adopting an approach involving the following steps: (a) estimation of vertical percolation fluxes based on the Darcy's law (P_D), considering lab-measured *Ks*, field-observed thickness of hardpan layers, and dynamic values of water levels within the field and groundwater table depth (ten Berge et al., 1992). For fields characterized by different soil zones, total percolation was obtained by weighing percolation fluxes by the surface areas of the zones. The reliability of the obtained P_D fluxes was verified in the case of the upslope fields A and B, where *SP* can be assumed equal to the vertical flux *P* since *S* fluxes are negligible; (b) comparison of *SP* - P_D data series of adjacent fields, in order to find periods with corresponding anomalies (namely, volumes outgoing from an upslope field and entering into a downslope field); (c) double-check of the resulting *S* fluxes considering all the available information collected during the experimental activity (e.g., observed rodent holes in field bunds and drainage ditches, piezometric levels).

Water use efficiency (WUE) was calculated for the four fields and for the ACD block of fields as WUE = ET/(Net irr. + Rain), where Net irr. is defined as Q_{in}-Q_{out}.

3. Results and Discussion

During the season 2015, higher net irrigation amounts were required by the upslope fields A and B, whereas irrigation inputs to C were much smaller, and nearly absent in the case of D (Table 3.1). Lateral fluxes (*S*) identified in 2015 involved only fields C and D, and corresponded to: (i) a break in the bund between C and D; (ii) a moderate seepage flux at the end of the season from C to D; (iii) a relevant income of groundwater supply to D (confirmed by piezometer levels); (iv) a seepage flux from D to the southern bounding ditch at the very end of the season. Therefore, the percolation in A increased the groundwater level thus reducing the percolation in C (in synergy with the low *Ks* of its hardpan) and providing excess water input to D (bringing its WUE to a value higher than 100%). Consequently, the block of fields ACD showed low irrigation requirements and a quite high WUE thanks to the water recycling provided by the seepage fluxes promoted by the topography. Conversely, the percolation water lost from B was collected only by ditches surrounding the field and it may be reused downstream, eventually increasing the WUE at the district scale, but not at the slope scale considered in the study. Table 3.1 shows the water balance terms and WUE of fields A, B, C, D and ACD for the year 2015.

Table 3.1: Seasonal (2015) water balance terms (mm) and water use efficiency (WUE, %)

Field	Rain	Q_{in}	Q_{out}	Net irr.	ΔS_s	ΔS_w	ET	SP	WUE
A	273	2716	6	2710	10	0	630	-2327	21
B	273	2067	17	2050	13	0	635	-1660	28
C	198	899	261	638	6	0	575	-277	66
D	198	504	501	3	19	0	575	387	275
ACD	273	1544	230	1315	6	0	611	-972	39

The dataset for the season 2016 is still under analysis, but preliminary results, compared to 2015, show that: (a) the overall behavior of the four fields in terms of water exchanges and internal recycling was confirmed; (b) vertical percolation was higher with respect to 2015 in all the four study fields, and consequently the WUE value decreased; this was justified by the highest water level maintained in the fields by the farmer throughout the whole season (5-10 cm higher than 2015) and by a lower groundwater level especially in A and C (20-40 cm lower than in 2015); (c) the validity of the approach used to estimate the vertical flux (Darcy's law) still held: in fields A and B, despite the increase in the water pressure gradient between the top and the bottom of the hardpan, the estimated P_D value overlapped accurately with *P* (= *SP*) obtained through the computation of the residual term in the soil water balance equation for the two fields.

4. Conclusion

This study focused on the quantification of water balance terms and water use efficiency of four rice paddies located in the main Italian rice basin (Lomellina region) and characterized by different elevations (A ≅ B > C > D) over two years (2015-2016). Irrigation amounts of 2-3,000 mm were required by A and B, whereas inputs to C were less than 1,000 mm and very low water irrigation amounts were required in D. The lower values of C and D were not only due to less permeable soils, but also to the contribution given by surface and subsurface lateral fluxes, which provided extra water inputs to C and D not measured by the irrigation inflow meters. The Darcy's law, applied taking into account lab-measured *Ks* and field-observed thickness of hardpan layers, as well as dynamic values of pressure heads at the top and bottom of the same layers, showed to be a valuable tool for the estimation of vertical percolations in flooding conditions. Percolation fluxes increased in 2016 with respect to 2015 due to a simultaneous increase in water level within the fields and decrease in groundwater table levels. Average WUE over the two years was around 0.20-0.30 in A and B, around 0.6 in C, and D showed a WUE ≥

1. Considering fields A, C and D as a group, the overall efficiency increased with respect to the value found for the upslope fields, due to lateral exchanges promoted by the topographic gradient. As a general consideration, it can be affirmed that none of the fields in a toposequence can be considered representative of the overall slope scale water use condition: for quantifying the WUE of a series of paddies on a slope, the monitoring scale must be enlarged to include all the fields in the toposequence.

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Wastewater reuse in agriculture: Technical and economic feasibility for Puglia, Southern Italy

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Keywords: Wastewater reuse, cost-benefit analysis, scale effect, irrigation

Summary
This research aims to improve the economic evaluation of directly treated wastewater reuse. We follow a methodological framework for the application of cost-benefit analysis (CBA) to wastewater project plants and investigate a hypothetical scenario for the irrigation usage of reclaimed wastewater as a complementary source to current irrigation groundwater resource. The direct value and the option use value of preserving the groundwater water quality (i.e. salinity) for irrigation are estimated according to tested hypotheses. These estimated benefits were aggregated over the population of the relevant farms and weighed against the costs of providing the reclaimed water at the plant gate. The treatment costs were analyzed in relation to the incoming effluent quality standard. The economically and technically feasible reclaimed wastewater volume for direct irrigation use was assessed.

1. Introduction

Although technological progress ensures that recycling is safe, the total volume of treated wastewater reuse in Europe is a tiny percentage of the treated effluent. Water reuse projects may fail for various reasons. One is the lack of popular support, because the perceived risk of poor water quality leads to problems with acceptance. However, the main driver of the implementation of wastewater reuse is the economic feasibility of treatments. To ensure long-term economic, environmental, and social sustainability, a comprehensive economic analysis of the associated costs and benefits derived from wastewater treatment is a pre-condition. This research aims to improve the economic evaluation of directly treated wastewater reuse. A case study is carried out in the Puglia region (Southeastern Italy), where two thirds of irrigation water comes from groundwater. In fact, the regional government policy aims at reducing groundwater exploitation by increasing direct wastewater reuse (PTA, 2009; PTA, 2015). The economically and technically feasible reclaimed wastewater volume for direct irrigation use is assessed.

2. Materials and Methods

A state-of-the-art study in Puglia is reported in the Water Protection Plan (PTA, 2015), which provides an updated census of all wastewater treatment plants for which effluent reuse in agriculture could be implemented immediately (all plant upgrading works have already been carried out) or in a short time (minimal plant upgrading is required). Based on these data, we estimated, at the regional scale, the volume of reclaimed water potentially available at the plant gate through existing facilities ("current scenario") and the expected volume available after the upgrading of a number of plants ("future scenario").
For the cost-benefit analysis of wastewater reuse in agriculture, the methodological framework as implemented by Arborea et al., (2017) in Puglia region, was used. The reclaimed wastewater was supposed as a complementary source to irrigation groundwater resource, therefore the direct value and the option use value of improving the groundwater water quality (i.e., salinity) for irrigation was considered. As consequence, in this research, only the real economic benefits of reclaimed wastewater as a productive factor for irrigation were taken into account. These

estimated benefits were aggregated over the population of the relevant farms and weighed against the costs of providing the reclaimed water at the plant gate. The treatment costs were analysed in relation to the incoming effluent quality standard (Italian laws - D.L. 152/06 and D.M.185/2003, establish the effluent standard quality requirements for surface water discharge (T1), ground surface discharge (T2)), in addition to the temperature of primary sedimentation at 15 C° and 20 C°.
Finally, a cost–benefit comparison was carried out in order to take into account the scale effect of plant size. The population equivalent (PE) is the unit applied to wastewater to describe the size of package sewage treatment plants. The average cost per m^3 of reclaimed wastewater decreases as the PE increases. The break-even point is where the costs equal the benefits. This point was used as the PE threshold from which a given plant upgrading starts to become economically feasible (Table 2.1).

Table 2.1: Economic feasibility of wastewater reuse as complementary to current groundwater sources

	Effluent quality	Temperature (°C)	Feasibility threshold (PE)
Preserving (1.7–2.2 dS/m)	T1	20	>= 100,000
	T2	15	>= 5000

Source: adapted from Arborea et al., (2017)
Finally, summing up technically and economically feasible wastewater reuse for irrigation, the total volume in Puglia was assessed.

3. Results and Discussion
According to the latest reuse of treated wastewater data, referring to the year 2015 (PTA, 2015), the number of plants for wastewater treatment at *a)* operating state (already works), *b)* working (ready to work), *c)* existing to upgrade and *d)* proposed, wastewater plants in Apulia region is reported in Table 3.1. As a whole, half of treatment plants for wastewater reuse are to be build. Province of Bari and Lecce are those where Regional Government should pay greater attention.

Table 3.1: Number of plants for wastewater treatment in Puglia (2015)

Province	N° of operating, working and existing to upgrade plants	N° of proposed plants	Total
BA	8	13	21
BAT	5	0	5
BR	10	4	14
FG	8	3	11
LE	8	18	26
TA	9	7	16
Total	48	45	93

Source: Draft PTA (2015)

With reference to the available data, volumes recoverable through the reuse of purified wastewater are shown in table 3.2: we have estimated at the regional scale the volume of reclaimed water, potentially available at plant gate through existing facilities (shown as "current scenario") as well as the expected volume available after the upgrading of a number of plants ("future scenario").

Table 3.2: Technically feasible reclaimed wastewater volume in Puglia (2015)

Province	Current scenario (m^3/year)	Future scenario (m^3/year)	Increase (m^3/year)
FG	24 094 030	26 855 795	2 761 765
BA & BAT	68 645 497	107 000 229	38 354 731
TA	23 332 680	35 948 745	12 616 064
BR	15 569 700	20 092 462	4 522 762
LE	15 295 459	40 415 337	25 119 878
Total	146 937 367	230 312 568	83 375 201

We have estimated at the regional scale the volume of reclaimed water of plants for which there is the economic convenience of reuse.
Following the current state of upgrading of existing treatment plants we assumed for the purpose of our analysis, that all plants that release T1 quality wastewater are provided with a nitrification treatment line and also that all plants that produce T2 quality wastewater are provided with filtration treatment line. Therefore, we have considered only the case of plant that complies with T1 and provides primary sedimentation at T = 20 °C (Table 3.3) and the case of plant that complies with T2 and provides primary sedimentation at T = 15 °C (Table 3.4), either accounting for UV disinfection, uses reagents at high dosage and filtration. Therefore, we estimated at the regional scale the volume of reclaimed water of plants for which there is the economic convenience of reuse. To this purpose, accounting for the technical cost and the practical infeasibility of intra-annual water storage, we considered "available" for reuse in irrigation only the volume of water produced during the irrigation period, approximately assumed equal to 6-month per year. A notable environmental benefit would be obtained if treated wastewater could be used for a direct recharge of groundwater storage, but this practice is today forbidden by law. Nevertheless, in such a case some terms of our cost-benefit analysis should be revised accordingly.

Table 3.3: Economically feasible reclaimed wastewater volume in Puglia (2015). Volume available from plants discharging at T1 and providing primary sedimentation at 20 °C

<table>
<tr><th>PE</th><th>Province</th><th>Plant</th><th>Overall annual volume (m^3/year)</th><th>Volume available for irrigation (m^3/year)</th></tr>
<tr><td rowspan="7">>= 100,000</td><td rowspan="2">BA</td><td>Bari est</td><td>31 755 000</td><td>15 877 000</td></tr>
<tr><td>Bari ovest</td><td>23 579 003</td><td>19 600 000</td></tr>
<tr><td>FG</td><td>Foggia 1</td><td>11 005 556</td><td>5 503 000</td></tr>
<tr><td>LE</td><td>Lecce</td><td>5 953 156</td><td>2 977 000</td></tr>
<tr><td rowspan="2">TA</td><td>Taranto 1 Gennarini</td><td>13 638 356</td><td>11 370 000</td></tr>
<tr><td>Taranto 2 Bellavista</td><td>3 755 859</td><td>3 100 000</td></tr>
<tr><td colspan="3">Total</td><td>34 352 927</td><td>22 950 000</td></tr>
</table>

Table 3.4: Economically feasible reclaimed wastewater volume in Puglia (2015). Volume available from plants discharging at T2 and providing primary sedimentation at 15 °C

PE	Province	Plant	Overall annual volume (m^3/year)	Volume available for irrigation (m^3/year)
>= 5000	BA	Acquaviva delle Fonti	1 824 997	912 000
		Castellana Grotte	967 253	480 000
		Noci Nuovo	896 192	448 000
		Ruvo di Puglia	3 734 169	1 867 000
	BAT	Andria 1	5 045 646	2 523 000
	BR	Francavilla Fontana	2 956 500	3 652 000
		Latiano	1 095 000	
		Ceglie Messapica	1 580 830	
		Mesagne	1 671 338	
		San Donaci	524 663	262 000
		San Pancrazio Salentino	766 500	383 000
		San Pietro Vernotico	1 953 918	977 000
	FG	San Severo	4 832 428	2 420 000
		San Giovanni Rotondo	1 655 789	828 000
	LE	Casarano Nuovo	2 908 320	1 455 000
		Corsano	475 361	240 000
		Carpignano Salentino	396 022	198 000
		Tricase	1 392 840	700 000
		Zollino	201 480	100 000
	TA	Avetrana	438 000	219 000
		Maruggio	328 500	165 000
		Castellaneta 1	1 222 747	611 000
		Crispiano	840 960	420 000
		Lizzano	1 022 003	511 000
		Massafra	1 867 255	934 000
		Montemesola	219 000	109 000
	Total		34 879 245	17 445 000

As a whole, the volume of wastewater reuse for irrigation in Puglia amounts to 40,395,000 m^3/year. With respect to the potential estimates of 146,937,36, the actual economically feasible volume is around 27%. Almost a half of that volume would be available from large cities, involving only 6 plants out of 32.

4. Conclusion

Following the methodological framework for the application of cost-benefit analysis to wastewater project plants by Arborea et al. (2017), the technically and economically feasible wastewater volume in Puglia has been assessed. The up-to-date data arising from studies of PTA (2015) were used. While the applied methodology has the advantage of providing a global perspective at the regional scale, the methodology is susceptible of application at any local scale and such deeper investigation is strongly suggested in order to reach the accuracy required for operational purpose of investments planning.

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Historical review on Water Harvesting in Jordan

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Keywords: Water harvesting, Jordan, Water scarcity

Summary

Water harvesting, defined as the collection and storage of rainwater with productive purposes, has been progressively considered as an effective as well as sustainable solution to problems related with the increasing water scarcity. Various forms of water harvesting have been traditionally used throughout the centuries, especially in the Middle East. There, some of the earliest agriculture examples were based on techniques such as diversion of "wadi" flow (spate flow from normally dry water courses) onto agricultural fields. For example, in Jordan, the Jawa and Umm El-Jimal water harvesting schemes were established 6000 and 2000 years ago, respectively. Moreover, they are considered as the most ancient water harvesting schemes, as well as the engineering design and techniques used in those schemes are unique.

Thus, standing the great and fundamental Jordan technical heritage, this study has the main objective of providing an historical review of the water harvesting structures present in Jordan. Furthermore, the adaptation of the engineering techniques used in the ancient schemes to the newly established structures, could provide a mean to deal with the increasing water scarcity in the area, as well as water supply for the most populated regions invested by fluxes of refugee people.

FAO (2016) realised an assessment of water harvesting techniques in Jordan focusing mainly on dams, pools and ponds. The aim of the present review is to extend the research in order to set the ground for a complete database.

1. Introduction

Jordan is one of the most water scarce countries in the world, where around the 90% of the area receives less than 100 mm of rainfall per year (Al-adamat et al., 2012). Furthermore, due to its erratic nature, rainfall is mostly lost in evaporation and runoff (which is one of the main causes of erosion), determining frequent dry periods during the growing season. Moreover, difficulties are increasing in sustain crops, pasture and livestock (FAO, 2016). Jordan is also suffering for a high evaporation rate up to a maximum value higher than 3800 mm per year (Al-Qaisi, 2010). In addition to the climatic factors affecting the country, water security is severely threatened by the increasing demand, given by the growing population and by the fluxes of incoming refugees escaping from the conflict of the surrounding areas. The capita per person is projected to fall from less than 160 m^3 per capita per year at present to about 90 m^3 per capita per year by 2025 (Al-adamat et al., 2012).

In addition to this, Jordan is considered the cradle of many of the Middle Eastern civilizations as well as the source of many water harvesting systems (Al-Ansari et al., 2013). Therefore, water harvesting has been practiced in Jordan for thousands of years and many of the structures are still functioning, after being restored. FAO (2016) realised an assessment of water harvesting techniques in Jordan, focusing mainly on surface water harvesting structures like dams, pools and ponds. The aim of the present review is to extend the research in order to set the ground for a complete database.

The study reviews recent literature on water harvesting systems and their potentiality in Jordan, providing a first assessment of the status of water harvesting interventions in the country, considering also historical structures and recent experimentations.

2. Materials and Methods

A literature review on water harvesting interventions realized in Jordan has been carried out, checking by using Scopus and Google scholar database. "W*ater harvesting"*, "*Jordan", "water scarcity"* have been used as keywords for the query. Then, a table was created to collect the main characteristics of some identified water harvesting structures.

3. Results and Discussion

The analysis carried out on the water harvesting techniques commonly used in Jordan provided valuable information. Table 3.1 shows a summary of water harvesting systems present in Jordan, ordered according to the year in which the study referring to each technique was carried on.

Firstly, the analysis revealed studies realised on Mahafir (Agnew, 1995), ancient water harvesting systems that could be considered for recovering and pilot testing by local population. Additionally, rooftop systems are widely adopted in urban areas (FAO, 2016; Al-houri et al., 2014) as well as micro catchment techniques, such as contour ridges and runoff strips are adopted in hilly areas (Alshawahneh et al., 2010; Al-shamiri & Ziadat, 2012).

The review will be useful for the implementation of new projects, providing information on the main techniques realized in the country, sites and related parameters, as well as it can be used as a reference for setting new water harvesting interventions in Jordan.

4. Conclusions

Starting from the will to expand the FAO study on the Assessment of the water harvesting sector in Jordan also to ancient techniques and, in general, to all kinds of water harvesting structures present in the Kingdom, this paper provides a first effort to collect information about water harvesting techniques in Jordan. Further studies could be carried out through the use of GIS and remote sensing, analysing the changes in rainfall, temperature, and other climate conditions, in order to monitor the evolution of the use of water harvesting systems around the Kingdom.

Table 3.1: Water Harvesting Systems in Jordan ordered according to the year of the study

Technique	Reference	Location	Water use
Mahafir	Agnew et al. (1995)	Eastern Jordan (Badia) desert	Unknown
Sand ditches	Abu-Zrega (2000)	Northern Jordan	Agriculture and Irrigation
Dams, canals and underground reservoirs fed by runoff (Umm El-Jimal)	Alkhaddar (2000)	Badia region	Agriculture
Double Furrows	Gammoh (2011)	test made in University of Jordan	Research
Micro catchment (contour ridges)	Alshawahneh (2010)	Jordan Badia, SE of Amman (Mharib village)	Agriculture
Roof top	Zain M. Al-Houri (2014) FAO (2016)	Amman city	Only 3% of the collected water is used for drinking water
Cisterns	Assayed (2013)	Jordan	Agriculture
Dams for collecting runoff	Al-Khawaldeh (2011)	Amman-Zarqa	Irrigation and livestock
Dams (more than 200,000 m^3)	AlAyyash (2012)	Northern Badia	Pastures
Dams (more than 200,000 m^3)	FAO (2016)	All governatorates apart from Jarash and Aqaba	Agriculture
Ponds - Hafirs (50,000–200,000 m^3)	FAO (2016)	All governatorates apart from Irbid, Jarash, Balqa and Madaba	Irrigation
Pools (less than 50,000 m3)	FAO (2016)	All governatorates apart from Zarqa, Tafiela, Aqaba	Irrigation
House tanks	FAO (2016)	North of Jordan (Zarqa, Amman)	Irrigation and human consumption
Contour ridge and runoff strips; Dams, ponds and runoff strips	Al Al-Shamiri (2012) Ziadat (2012)	Jordan	Agriculture

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Effect of surface characteristics of soil surface on interrill soil erosion dynamics

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Keywords: Roughness, runoff, sediment concentration, rainfall simulation, SfM surveys

Summary
In the paper the dynamic of the random roughness along a sequence of simulated rainfalls occurring on a ploughed soil has been studied. The relations between this dynamic and that of the runoff and the concentration have also been discussed. The experiments were performed in a replicated 1m x 1m square plot, located in a 16% slope in a silt-clay-loam soil and equipped with a nozzle-type rainfall simulator. Each experiment started from a just ploughed surface and included a sequence of 3 simulated rainfall carried out in the range of few days. The independent variable along the three subsequent simulations of each sequence is the initial soil surface condition, that is progressively modified by the rainfall runoff process.

1. Introduction

The roughness of the soil surface is the result of human-induced actions and natural processes such as agricultural operations, compacting, soil erosion and re-deposition processes, structural degradation of the surface due to the impact of raindrops and the phenomena of slacking and sealing. The roughness of the soil surface is very important in the application of predictive modeling of erosion. The roughness influences, in fact, the hydrological response and erosion, through the existing relationships with the hydraulic resistance to runoff (Gilley and Finkner, 1991) and the storage in surface depressions (Onstad, 1984; Linden et al., 1988). It also acts on the effectiveness of detachment of soil particles from the impact of raindrops on the surface. A high surface roughness increases infiltration and decreases the degree of soil sealing due to the impact of the drops (Sumner and Stewart, 1992). Conversely, a finely-grounded soil will be subject to rapid sealing and, consequently, to low infiltration rates, resulting in a rapid runoff occurrence. The roughness depends mainly on the type of soil ploughing and soil characteristics. Soil roughness is commonly measured in the field or in the laboratory by using contact profilometers, laser scanner (Vinci et al. 2015) and photogrammetry (Vinci et al, 2017) as in the present paper. In the paper the dynamic of the random roughness (Cavalli et al., 2008) along a sequence of simulated rainfalls occurring on a ploughed soil, have been studied. The relations between this dynamic and that of the runoff and the concentration have also been discussed.

2. Materials and Methods

The experiment was performed in a replicated 1m x 1m square plot, located in a 16% slope in a silt-clay-loam soil and equipped with a nozzle-type rainfall simulator. Each experiment started from a just ploughed surface and included a sequence of 3 simulated rainfall carried out in the range of few days (I, II and III events in the experiment number 1 and IV, V and VI events in the experiment number 2). Each event included two phases: a wetting phase of typically 30 min with intensity of about 40 mm h^{-1} (nozzle 14 FFWSQ) followed by a rainfall event with intensity of about 65 mm^{-1} (nozzle 30 FFWSQ) having a duration between 60 (experiment 1) and 75 min (experiment 2), characterized by a rainfall kinetic energy rate of 9.6 and 13.2 J m^{-2} mm^{-1} respectively. The wetting phase ensures almost constant initial event soil moisture (mean=31%, CV=5%) and initial event bulk density (mean=1.3 g cm^{-3}, CV=3%). The total runoff, the runoff dynamic and the sediment dynamic were measured at a 5 min time step. The particle size distribution was determined. The measured soil loss could be considered as being due to interrill erosion only. The independent variable along the three subsequent simulations of each sequence is the initial soil surface condition, that is progressively modified by the rainfall-runoff process. The soil surface pre-wetting, event-initial and event-final micro-topography were monitored using Structure from Motion (SfM) photogrammetric surveys. The distributed roughness index, Roughness Index-Elevation r_i (Cavalli et al., 2008), was calculated on the 0.002 m DEMs within a moving window of 29 cells (about 0.06 m). The empirical cumulative distributions of r_i related to different trials have been compared and an objective quantification of their differences was obtained by calculating the Kolmogorov-Smirnov statistic Dn:

$$\mathrm{Dn} = \max\left|\boldsymbol{F}_i(\boldsymbol{x}) - \boldsymbol{F}_j(\boldsymbol{x})\right| \tag{2.1}$$

where $F_i(x)$ and $F_j(x)$ are the cumulative distribution of two samples *i* e *j* compared.

3. Results

The mean values of r_i (mm) related to different events and phases are given in table 1, which also shows the difference in roughness between the initial and final step of each event and the corresponding value of the Dn statistic.

Table.1 Mean values of the roughness index r_i (mm) related to different events and phases. Each experiments starts with a just-ploughed soil surface (seedbed).

	Experiment 1			Experiment 2		
	Event I	Event II	Event III	Event IV	Event V	Event VI
Initial	2.41	2.43	2.04	2.82	2.46	1.77
Final	2.14	1.97	1.78	2.10	1.93	1.46
Final-Initial	-0.27	-0.46	-0.27	-0.71	-0.53	-0.31
Dn	0.13	0.24	0.23	0.40	0.26	0.20

As expected, the roughness decreases during each event, with differences (final-initial) ranging between -0.13 and -0.40 mm. The roughness decrease can be also observed during the experiment, particularly when the final values are considered. In some cases it has been observed a roughness increment between the initial phase of an event and the final phase of the previous event. The reason of this unexpected behavior is not clear, however this situation only occurs among phases characaterized by relevant variations of the soil water content. In fact, after the end of each event, the soil dries out and then it is wetted again before the roughness survey (initial). An increase in surface roughness after the first application interval in a moist treatment was also observed by other authors such as Fohrer et al. (1999). Fig. 1a e 1b show respectively the dynamics of the runoff vs the cumulated rainfall and of the sediment concentration vs the runoff. From Fig.1a it is possible to observe that: 1) during the events of the same experiment, the runoff increases with similar rates, but the runoff amount increases progressively along the sequences; 2) being equal the distance from ploughing, both the increment rate and the initial values of the runoff in experiment 2 (empty indicators in Fig. 1) are usually higher than those of experiment 1 (filled indicators in Fig. 1); 3) each experiment seems to tend to a stable runoff amount of about 5 mm (in 5 minutes).

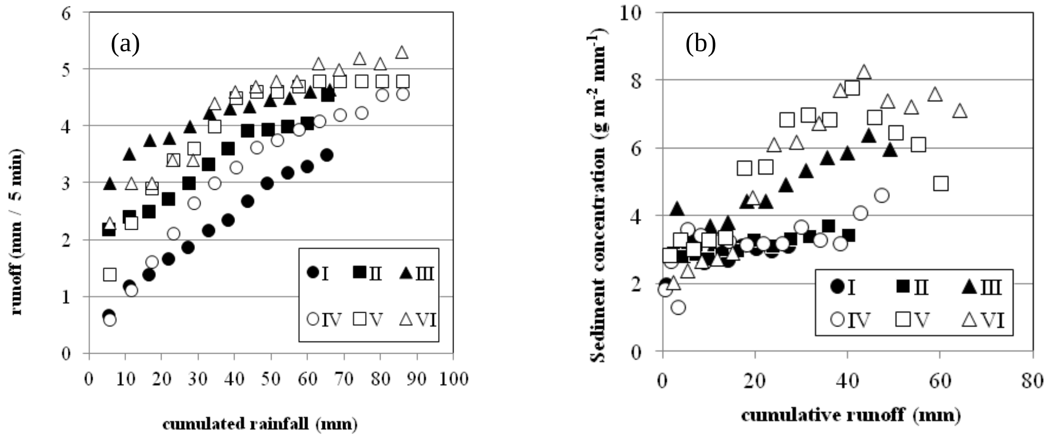

Fig. 5 Runoff and cumulative rainfall a), sediment concentration in runoff versus cumulative rainfall b), for the two experiments and the six trials.

Insight into the dynamics of soil erosion during the sequence of rainfall events, is provided through the changes of sediment concentration in the runoff during each sequence (Fig. 1b). For the post ploughing events (I for the esperiment 1 and IV for the experiment 2) the main trend of the dynamics of sediment concentration was similar in the two experiments; the mean concentration presents a sharp but very short increase toward a stable value that represents the whole simulated rainfall event. The sediment concentration stabilizing quite rapidly after runoff begun. On the contrary, the dynamics of sediment concentration for the events farther from ploughing, III, IV and V, increased mildly to a maximum value, around 8 g m^{-2} mm^{-1}, after 60mm of rainfall, and then decreased slightly as the rainfall goes on. This decrease is more pronounced for the longer V and VI events. Moreover, the maximum value is very similar in the two experiments even if slightly higher in the experiment 2. The last event of experiment 1 (event III), has a very similar behavior with a bell shape but with a lower maximum value, about 6 g m^{-2} mm^{-1}. Thus, the sediment concentration dynamics of events III, V and VI can be assimilated. Likewise, the sediment concentration dynamics related to events I, II and IV can be assimilated and distinguished from that of events III, V, VI. The existence of a clear distinction between trials III, V, VI and trials I, II, IV has also been confirmed by applying a hierarchical cluster analysis based on the Ward's criterion and on the Euclidean distance. The technique, applied to the concentration values found in the different events, clearly identifies the two above-mentioned groups. The granulometric analysis of the sediment clearly shows the increase of the concentration of the fine components (clay and fine silt) in the first minutes of the simulated rainfalls. This is clearly due to the dominant splash effect in the initial stages of runoff formation.

4. Discussion and Conclusion

The linear regression coefficients between the sediment concentration and $r_i(t)$ for assigned runoff range were calculated. For Q > 4 l/5min, the two variables become inversely proportional. The relationship of inverse proportionality between roughness and concentration is not only significant, but also very clear with a regression coefficient that increases in absolute value as the flow increases. As the runoff increases its transport capacity increases and, as a consequence, the concentration increases too up to a maximum value (since there is plenty of material detached from the splash process that, until then, dominated). Then the runoff detachment and transport capacity increases and the concentration tends to the final stable value (slightly lower than the maximum value reached previously). Therefore to the lower roughness, due to the reduced hydraulic resistance, an appreciable increase in runoff and concentration corresponds. This behavior only characterizes events in which the runoff has reached and exceeds the value of 4 l/5 min, therefore only the events III, V and VI.

For $Q < 1.5$ l/5 min, the relationship between roughness and concentration is not significant, while for medium-low runoff, Q, (roughly $1.5 < Q < 4$ l/5 min), roughness and concentration are directly proportional (positive regression coefficient values). In this range the runoff is not able to detach a lot of material and the transport limited process is dominant. Thus, after a rapid initial increase in concentration, due to the presence of splash-detached material, the concentration value remains stable or even decreases slightly (as the material produced by the splash has been depleted). This behavior almost exclusively characterizes the events I, II and IV where the runoff is typically lower than 4 l/5 min.
In conclusion for high runoff value, the smoother is the soil surface the higher is the sediment concentration because the process transport limited. For low runoff to a decreasing roughness a decrease in concentration corresponds, because the dominant process are the splash and detachment limited process. Furtheremore the stable concentration value is the higher for higher roughness, since in this case the splash effect is more effective in detaching material (Torri and Poesen, 1992).

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Irrigation Water Requirements of "Sinistra Ofanto" district from open satellite data and meteorological data

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Abstract: This study shows how to estimate the seasonal water balance and the Irrigation Water Requirements (IWR), for the irrigation district "Sinistra Ofanto" (Apulia Region - Southern Italy). The input data were meteorological measurements ("Capitanata" irrigation Consortium), and crop parameters (e.g. Leaf Area Index) estimated from open Landsat 8 Operational Land Imager Surface Reflectance (OLISR) data and MCD15A3H products. The estimation of the evapotranspiration was carried out using the standard single crop coefficient (Kc) approach proposed by the Food and Agriculture Organization (FAO). Lastly, the retrieved IWR was compared with the water volumes provided during the irrigation season for each district.
Keywords: Irrigation Water Requirements, Leaf Area Index, evapotranspiration, Landsat-8, MODIS

1. Introduction

Rational and sustainable agricultural water resources management can be achieved through Water Balance (WB) estimation. WB estimation is a tool to support decision-making in irrigation systems both on management strategies (e.g. water pricing policies) and on the implementation of infrastructural actions (OECD, 2015). The evaluation of the WB allows to estimate the Irrigation Water Requirements (IWR – Eq. 1), that is defined as the quantity of water needed in addition to the effective rainfall (Pe) for crop growth:

$$IWR = CWR - Pe = ETc - Pe \tag{1.1}$$

in which CWR is the Crop Water Requirement, represented by the actual evapotranspiration (ETc). The agricultural WB and the evapotranspiration term retrieval from Earth observation data have been an active research topic in the last three decades. In this sense, a general review of the remote sensing based evapotranspiration estimation methods has been recently proposed by Ke Zhang (Zhang et al., 2016).

Focusing on the "Sinistra Ofanto" irrigation district, the present study performs WB and IWR evaluations for the 2013 irrigation season, using open satellite data and publicly available agrometeorological data. The estimate of the IWR was carried out by comparing, for each irrigation district, the retrieved value with the data of supplied water, for all the sub district (by the irrigation Consortium), during all the irrigation season.

2. Study area and data

The study area (Fig. 1) falls within the irrigation district identified as "Sinistra Ofanto" (Apulian Region – Italy, 55.000 ha) and is delimited by the Ofanto river. The district, organized in 21 sub-districts, features a typical semi-arid Mediterranean climate. Landscapes are heterogeneous and the irrigation season starts the 20th April and finishes the 30th November of every year.

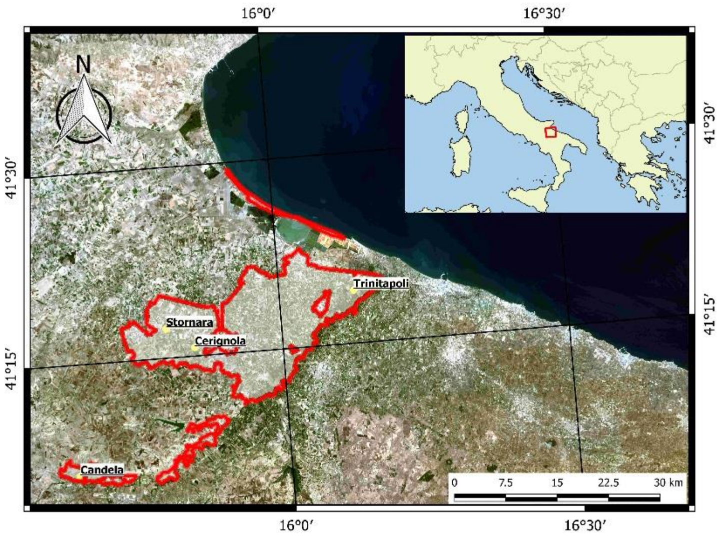

Fig. 2.1. Study area limits (in red).

For this study were used eleven Landsat 8 OLISR data acquired during the 2013 crop year downloadable for free (https://earthexplorer.usgs.gov/). Particularly, OLISIR data specification can be found in (Vermote et al., 2016). The processing of satellite data, the complete scene list, and the LAI retrieval method are reported in Peschechera et al. (Peschechera et al., (in press)). The agrometeorological data were taken from four climate stations managed by the Consortium and are publicly provided at daily scale (http://consorzio.fg.it/). The Thiessen Polygon Method was used to define climate stations area of influence.

3. Method

The IWR was firstly estimated at the daily scale as showed in Eq. 1 and then aggregated at the seasonal scale, summing the daily values of IWR. For this purpose, it was necessary: (I) to locate irrigated areas (spatial domains of the WB), (II) to estimate the Crop Evapotranspiration (ETc), and (III) the effective rainfall (Pe).

Irrigated areas were identified according to the following procedure. First of all, specific thresholds of the mean seasonal Normalized Difference Vegetation Index (NDVI) were used to separate annual (seasonal) and perennial crops from bare soil. Secondly the irrigated areas were retrieved on the basis of Kc and NDVI values (Tab. 3.1). Kc thresholds were chosen according to FAO values for the principal crop types in the area (Allen et al., 1998) whereas NDVI thresholds values followed the assumption that high NDVI values are associated to irrigation.

Tab. 3.1: Thresholding criteria for the identification of irrigated areas (in green).

	Mean seasonal NDVI	Irrigated areas (single scene)	
No crops	< 0.15	NDVI	KC
Annual crops	< 0.4 and > 0.15	> 0.4	> 0.40
Perennial crops	> 0.4	> 0.7	> 0.80

The ETc was evaluated with the single crop coefficient (Kc) approach proposed by the FAO (Allen et al., 1998) that requires the knowledge of the *crop height* (h_c), the *albedo* (α) of the crop-soil surface, the canopy resistance and the evaporation from the soil. Kc was estimated with the Analytical Approach (D'Urso and Menenti, 1995). This method allows to retrieve Kc maps, for each surface reflectance acquisition, by exploiting satellite-derived vegetation parameters (LAI, h_c, and α) and agrometeorological data measured *in situ.* Pixel Kc values, for the entire crop season, were retrieved by linear interpolation of the crop coefficient maps.

LAI was derived using the CLAIR model (Clevers, 1988) and MODIS LAI (MCD15A3H) product (Peschechera et al., (in press)). The crop height (h_c) was fixed to 0.50 meters, due to the lack of land cover classification datasets (D'Urso, 2006), whereas the albedo (α) was calculated under the hypothesis of Lambertian surfaces (Menenti et al., 1989) and using the approach proposed by (Silva et al., 2016). Lastly, the effective rainfall (P_e) was calculated by subtracting 4 mm to each registered rainfall height. Indeed, the scarce rate of precipitations and the low soil humidity, during the crops season, make feasible the assumption that almost all the rainfall is available for crops.

4. Results and Conclusions

The estimated IWR, for each sub-district, and the comparison with the volumes of Irrigation Water provided by the Consortium (IWC) are reported in the Table 4.1.

Table 4.1: Comparison at sub-district scale between the estimated IWR and the irrigation water provided by the Consortium (IWC) for the crop year 2013.

Sub-District	IWR [m³/yr]	IWC [m³/yr]	IWR / IWC	District extension [ha]	Mean IWR [m³/ha/yr]	Mean IWC [m³/ha/yr]	Mean Difference [m³/ha/yr]
3	323.542	284.135	1.14	397.4	815.1	714.9	100.2
3/B	901.475	537.374	1.68	732.9	1235.2	733.2	501.9
4	6925.717	4181.531	1.66	3441.0	2017.5	1215.2	802.3
5	7872.516	5871.392	1.34	5066.6	1553.9	1158.8	395.1
6	6376.526	5401.549	1.18	4014.1	1589.5	1345.6	243.9
7	2543.911	1745.709	1.46	1805.1	1409.5	967.1	442.4
8	4811.269	3439.874	1.40	2891.6	1667.2	1189.6	477.6
8/B	973.733	275.535	3.53	540.6	1801.2	509.7	1291.5
9	4605.215	3723.018	1.24	3308.2	1392.2	1125.4	266.8
10	3733.930	2129.800	1.75	1975.5	1890.6	1078.1	812.5
11	6279.721	4020.830	1.56	5268.7	1192.1	763.2	429.0
12	3555.344	2004.586	1.77	2115.7	1682.3	947.5	734.8
13	3217.069	1767.919	1.82	2173.1	1480.6	813.5	667.1
14	3250.249	1735.242	1.87	3222.1	1008.9	538.5	470.4
15	545.704	265.181	2.06	420.3	1299.6	630.9	668.7
16	1422.114	668.723	2.13	814.9	1753.4	820.6	932.8
17	1220.954	831.320	1.47	927.5	1319.1	896.3	422.7
	58558.988	**38883.718**	**1.51**	Max	2017.5	1345.6	1291.5
Effective rainfall [m³/yr]	**18165.468**			Mean	1476.9	908.7	568.2
CWR [m³/yr]	**76724.456**			Min	815.1	509.7	100.2

The estimated IWR for the 2013 crop year amounts to 58.6 Mm^3 and 38.9 Mm^3 were supplied by the Consortium. It could be then assumed that an additional water supply resource is used for the other fraction (19.3 Mm^3). Although the estimated seasonal IWR range (2017 - 815 m^3/ha) is in line with the maximum volume that could be provided by the Consortium (2050 m^3/ha), the actual supplied water ranges only between 1345 and 510 m^3/ha. Going further into details, the 8/B sub-district has an estimated IWR three times greater than the irrigation water volume supplied by the Consortium. Indeed, it was activated in 2012, thus the existence of alternative solutions (as direct withdrawal from the groundwater) can be easily hypothesized. However, the trends provided by the Consortium, show that both 8/B and 3/B sub-districts are gradually switching to the Consortium irrigation system (Regione Puglia, 2015).
Further improvements in the IWR assessment could be achieved with a detailed crop type classification, which is necessary to improve vegetation parameters estimation (especially h_c

and the stomatal resistance) and to better identify the irrigated crops. This last factor plays a key role for the IWR assessment since it defines the spatial domain for the water balance. Moreover, higher IWR accuracies can be achieved by using satellite data with improved spatial and temporal resolution (e.g. the Sentinel 2 A-B dataset not yet available for the crop year considerate in this study). Lastly, higher reflectance surface temporal resolutions could be achieved by composing different datasets in order to solve the problems related to cloud covered images during the crop year.

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Testing a single USLE-MM model to predict high soil losses in central and south Italy

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Keywords: Plot soil loss, Event temporal scale, USLE-MM

Summary
The USLE-MM, usable to estimate event soil loss from bare plots, has been calibrated at particular experimental sites so far and only a few attempts have been carried out to establish if a generally usable USLE-MM model can be developed. Following the USLE scheme, a model has characteristics of generality if the exponent of the erosivity term does not vary with the site whereas the soil erodibility factor is site-dependent. With reference to three experimental sites in Calabria (Bagnara), Sicily (Sparacia) and Umbria (Masse), the objective of this investigation was to check the usability of a site-independent exponent of the erosivity term especially for high soil losses prediction. The locally calibrated models performed satisfactorily at all sites, supporting the validity of the USLE-MM to predict soil loss at the event temporal scale. The general worsening of the performances of the single model was expected but it was not substantial. Moreover, the single model performed better than the locally calibrated models for high values of the normalized soil loss ($A_{e,N}$ > 1 and 10 Mg ha^{-1}). In conclusion, developing a model of the USLE-MM type having an applicability that is not limited to a few experimental sites appears to be a practical possibility.

1. Introduction
Predicting plot soil loss, A_e (Mg ha^{-1}), at the event temporal scale has great practical importance since a large proportion of total soil erosion over a long time period is due to a few large storms (Larson et al., 1997) and conservation strategies should account for these large storms rather than average weather conditions (Di Stefano and Ferro, 2016). The so-called USLE-MM can be used on bare plots to predict event soil loss (Bagarello et al., 2010, 2015):

$$A_{e,N} = \frac{A_e}{LS} = \left(Q_R EI_{30}\right)^{b_1} K \qquad (1)$$

where $A_{e,N}$ (Mg ha^{-1}) is the normalized soil loss for the event, L and S are the dimensionless plot length and steepness factors, calculated according to Renard et al. (1997) and Nearing (1997), respectively, Q_R (-) is the runoff coefficient, EI_{30} (MJ mm ha^{-1}h^{-1}) is the single storm erosion index (Wischmeier and Smith, 1978), b_1 is an exponent greater than one and K (Mg ha^{-1} per unit erosivity index) is the soil erodibility factor. So far, calibration of the model has been performed locally, i.e. at particular experimental sites, and only a few attempts have been carried out to check if a single model of more general use can be developed (Bagarello et al., 2013). Following the USLE scheme, a model has characteristics of generality if b_1 does not vary with the site whereas the soil erodibility factor is site-dependent.
With reference to three experimental sites located in Calabria (Bagnara), Sicily (Sparacia) and Umbria (Masse), the objective of this investigation was to establish if using a site-independent

exponent of the erosivity term is possible from a practical point of view, especially to predict high soil loss values.

2. Materials and Methods

Initially, the USLE-MM was calibrated at each site using a large dataset of normalized soil loss values, $A_{e,N}$ (sample size, N = 90, 532 and 570 for Bagnara, Masse and Sparacia, respectively), collected on bare plots. Then, a single dataset was developed by pooling all ($A_{e,N}$, $Q_R EI_{30}$) data pairs together and a common estimate of the b_1 coefficient, b_{1c}, was obtained by using regression analysis procedures. With an alternative approach, b_{1c} was also obtained as the exponent that minimizes the Nash and Sutcliffe efficiency index, *NSEI*, within a wide range of b_{1c} values. Subsequently, the soil erodibility factor was calculated for each station according to Foster et al. (1981). Finally, a comparison between the measured and the predicted $A_{e,N}$ values was carried out with reference to the two considered scenarios, i.e. locally calibrated models and single model. Taking into account that the events of most practical interest are those determining high soil losses, the soundness of a calibration of the USLE-MM by only considering high soil loss values, i.e. $A_{e,N} > 1$ Mg ha^{-1} (N = 496 data pairs) and $A_{e,N} > 10$ Mg ha^{-1} (N = 139), was also checked. The error, Er, associated to an experimental soil loss value, $A_{e,N}$, was calculated by the following relationship:

$$Er = \frac{\max\left(A_{e,N}, A_{e,Nest}\right)}{\min\left(A_{e,N}, A_{e,Nest}\right)} \tag{2}$$

where $A_{e,Nest}$ is the predicted soil loss.

3. Results and Discussion

The USLE-MM was successfully fitted to the ($A_{e,N}$, $Q_R EI_{30}$) data pairs obtained at the three experimental stations (Table 1). On the basis of the calculated b_1 values and their 95% confidence intervals, the USLE-MM representation of the erosion process (i.e., with $b_1 > 1$), was clearer at Sparacia and Bagnara than at Masse.

Table 1: Sample size (N), fitted exponents of eq.(1) (b_1 or b_{1c}) and associated coefficients of determination (R^2)

Parameter	Bagnara	Masse	Sparacia	All stations
N	90	532	570	1192
b_1 or b_{1c}	1.3298	1.0479	1.4361	1.1761
95% confidence interval of b_1 or b_{1c}	1.071-1.588	0.993-1.103	1.357-1.516	1.129-1.223
R^2	0.5433	0.7283	0.6896	0.6694

Fitting simultaneously eq.(1) to the ($A_{e,N}$, $Q_R EI_{30}$) data pairs collected at the three sites yielded a coefficient of determination, R^2, close to those obtained by local calibration of the model (Table 1) but larger prediction errors (Table 2), and a lower global NSEI value than that obtained with the locally calibrated models (0.5799 against 0.6962), as expected. However, the comparison between the predicted and the experimental $A_{e,N}$ values did not reveal enormous differences between the two tested approaches (Fig.1), suggesting that considering a single dataset for calibrating the model was a more statistically based way to proceed. With reference to the high normalized soil losses, i.e. $A_{e,N} > 1$ and 10 Mg ha^{-1}, the single model performed better than the locally calibrated models (Table 2). This result is important in practice since these soil erosion events have a large to very large impact on total soil loss of a given area.

Table 2: Summary of the prediction errors of the normalized soil loss

Dataset	Statistic	Local models	Single model	
			b_{1c} by regression	Optimized b_{1c}
All data (N = 1192)	max	93.4	196.1	160.4
	mean	4.20	6.04	5.51
	median	2.26	2.49	2.54
$A_{e,N}$ > 1 Mg ha^{-1} (N = 496)	max	93.4	48.1	84.8
	mean	4.19	3.06	3.71
	median	2.11	1.97	2.07
$A_{e,N}$ > 10 Mg ha^{-1} (N = 139)	max	93.4	31.2	40.9
	mean	5.14	2.75	3.11
	median	2.37	1.72	1.89

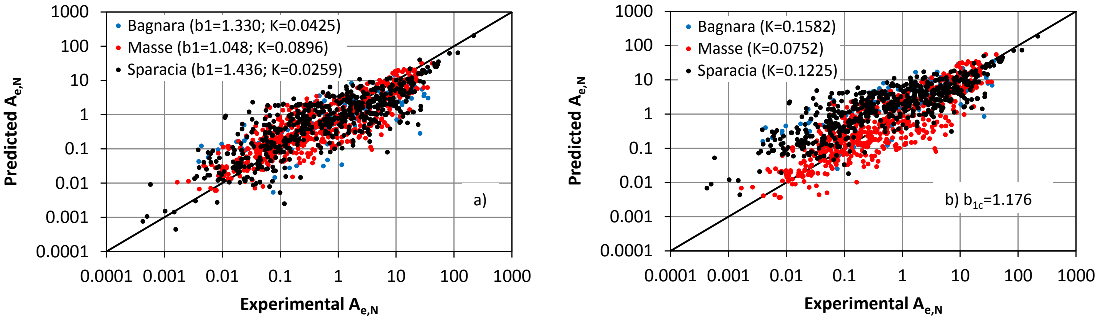

Figure 1: Comparison between the experimentally obtained normalized soil loss values, $A_{e,N}$ (Mg ha^{-1}), and the corresponding predictions

With the single model, prediction errors were largest for intermediate Q_REI_{30} values (Fig.2). Moreover, the highest errors monotonically decreased as Q_REI_{30} increased above a threshold of approximately 20 MJ mm ha^{-1}h^{-1}. Even this last result is very important in practice since it indicates that Q_REI_{30} can be used to predict both the normalized soil loss and the expected uncertainty of this prediction.

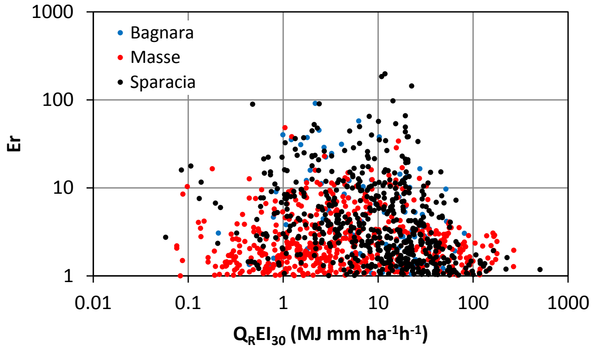

Figure 2: Prediction error of normalized soil loss plotted against Q_REI_{30}

With the optimization procedure, b_{1c}= 1.310 and NSEI=0.6055 was obtained. Therefore, this last procedure yielded a higher b_{1c} value as compared with that obtained by regression (b_{1c}=1.176). However, optimizing b_{1c} implied larger prediction errors for the most erosive events (Table 2). Therefore, the regression approach to estimate b_{1c} was considered to be preferable as compared with the optimization procedure.

Attempting to develop a single model by only considering the most erosive events was unsuccessful. The b_{1c} exponent was equal to 0.595 for $A_{e,N}$ > 1 Mg ha^{-1} and to 0.263 for $A_{e,N}$ > 10 Mg ha^{-1}. The $A_{e,N}$ vs. Q_REI_{30} relationships were highly scattered in both cases and the associated R^2 values were 0.359 and 0.193, respectively. These low coefficients of determination can be viewed as a sign of the fact that the model cannot be satisfactorily calibrated by considering a reduced sample size with a restricted range of normalized soil loss values.

4. Conclusions

A site-independent b_1 exponent of the USLE-MM implies that the erosivity term of the model is not geographically restricted to the calibration sites. This circumstance increases the practical interest for the model and allows it to be used in areas in which soil loss data for calibrating the model are not available. Moreover, such a choice is consistent with the original USLE scheme, that assumes erosivity and erodibility factors to be independent each other. This investigation supported the reliability of a model making use of a single exponent for different environments and it also suggested that this choice is advantageous to improve prediction of high soil loss values. Checking this conclusions in other sites is therefore advisable. Criteria to take decisions on the representativeness of a ($A_{e,N}$, $Q_R EI_{30}$) dataset for a given site should also be developed.

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Impact of reforestations with exotic and native species on water repellency of forest soils

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Keywords: Forest soils, Soil water repellency, WDPT test, EP test

Summary

Forest duff layer is usually water repellent due to the hydrophobic organic compounds resulting from degradation of tree tissues. Transition from hydrophobic to wettable conditions, or vice versa, is largely controlled by water content. The objective of this investigation was to assess the influence of soil moisture on the degree of soil water repellency (WR) in exotic and native tree forests. Occurrence of WR was investigated by the water drop penetration time (WDPT) and the ethanol percentage (EP) tests. Sampling was conducted in the forest soils of two exotic species (*Pinus pinaster*, P, and *Eucaliptus camaldulensis*, E), used in the past for reforestation, and two native species (*Quercus ilex*, L, and *Quercus pubescens*, R). The WDPT vs. θ relationships exhibited a decreasing trend with a transition from hydrophobic to wettable conditions in the range θ = 0.14 - 0.19 cm^3cm^{-3}. The EP vs. θ relationships showed a maximum in the range θ = 0.10 - 0.15 cm^3cm^{-3}. Hydrophobicity in soils of native species persisted at relatively higher water content compared to exotic ones and it is expected to influence the hydrological processes to a greater extent.

1. Introduction

Forest duff layer usually contains amphiphilic organic molecules, resulting from degradation of tree tissues, that coat soil particles and may be responsible for water repellency (WR) (Doerr et al., 2000). The interaction between these molecules and soil particles is largely governed by water content (Doerr et al., 2000; Ellies et al., 2005). The transition from wettable to hydrophobic status (and vice versa) was generally associated to a critical water content even if several studies defined it as a range of soil moisture rather than a single value (e.g. Dekker et al., 2001). The lower water content of this range defines the condition below which the medium is water repellent, the higher identifies the condition above which the medium is wettable. In Sicily, reforestation strategies have been undertaken to prevent soil degradation (La Mantia, 2002). To achieve timely and effective soil cover, fast-growing exotic evergreens species were preferred to native species but the potential negative impact on soil hydrophobicity has not been specifically assessed. The objective of this investigation was to compare the degree of soil WR induced by reforestations and, specifically, to explore the influence of soil water content on the WR of two exotic species, *Pinus pinaster* (P) and *Eucaliptus camaldulensis* (E), and two native ones, *Quercus ilex* (L) and *Quercus pubescens* (R).

2. Materials and Methods

Soil samples were collected in the duff layers (approximately 5 cm thick), air-dried and carefully sieved at 2-mm sieve. Soil was compacted into aluminum trays (19.7 x 14.7 cm^2) at a height of 1 cm and porosity, ϕ, determined from mass of soil and air-dried moisture content. Trays were then wetted to volumetric water content, θ, corresponding to fixed saturation ratios θ/ϕ = 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30. To explore a higher range of θ, two further trays were prepared using soil samples oven-dried at 40 and 70 °C. The persistence of WR was investigated by the water drop penetration time (WDPT) test (Wessel, 1988) whereas the degree of WR by the ethanol percentage (EP) test (Watson and Letey, 1970). The WDPT test involved placing 30 drops of distilled water onto the sample surface and recording the times required for their complete penetration. The EP test was carried out using ethanol concentrations of 5%, 7%, 10%, 13%, 15%, 20%, 25%, 30%, 35% by volume. For each soils, 30 EP values were obtained by interpolation of pairwise EP values characterized by infiltration times immediately higher and lower than t = 5 s. A medical dropper was used to displace the drops on the soil surface according a 1.5 x 1.5 cm^2 grid inside the tray.

3. Results and Discussion

The Lilliefors (1967) test (P = 0.05) showed that WDPT values were better represented by log-normal distribution whereas the EP values by normal distribution. Consequently, the results were summarized by calculating the associated statistics. For θ values corresponding air-dried conditions, the mean WDPT values ranged between 363 and 1767 s that corresponded to a WR classification from strong to severe (Bisdom et al., 1993). In particular, the most hydrophobic soil was that of Eucaliptus (E) and the different forest tree species affected soil WR in the following order: E>L>P>R.

The results of WDPT tests conducted at different water contents are shown in Figure 3.1a. In general, the WDPT values for the four investigated forest soils followed the same trend. In particular, for low θ values, WDPT was almost constant and independent of water content until it reached a critical moisture threshold value that varied between 0.08 and 0.14 cm^3 cm^{-3}, depending on the different tree species. Above this threshold, the WDPT values decreased to the condition of wettability (WDPT ≤ 5 s). The coefficients of variation were small in both the hydrophobic and wettable conditions but generally increased in the transition interval. In order to identify the critical θ values discriminating the transition interval from hydrophobic to wettable conditions, a Tukey test (P = 0.05) was applied to the mean values of ln(WDPT) corresponding to different soil moisture. For low θ values of the sequence, differences in WDPT values were generally not significant, but they became significant at higher θ values. In particular, it was possible to detect a critical water contents (CWCH) below which the soils are hydrophobic (Table 3.1). For θ > CWCH, WDPT values decreased linearly from the value corresponding to CWCH to a critical water content (CWCW) above which the soil was wettable. The CWCW values were determined as intersection of the regression line ln(WDPT) vs. θ for the transition zone and the line WDPT = 5 s (Figure 3.1a).

The substrates of exotic trees (P and E) generally showed CWCH values higher and CWCW values lower than those of the native species (Table 3.1). As a consequence, transition from hydrophobic to wettable conditions was more gradual in the native species (Figure 3.1a). In the soil of the L forest, the water content needed to restore a complete wettability increase up to 0.28 cm^3cm^{-3}. Among the exotic species, E soil showed WR levels that were generally higher than those of the P soil (Figure 3.1a). The L soil was always more hydrophobic than the soil of the other native tree forest (R).

The results of EP test conducted for θ values corresponding to air-dried conditions allowed to classify the L and R soils as very strongly hydrophobic and the P and E ones as extremely hydrophobic (Doerr et al., 2000).

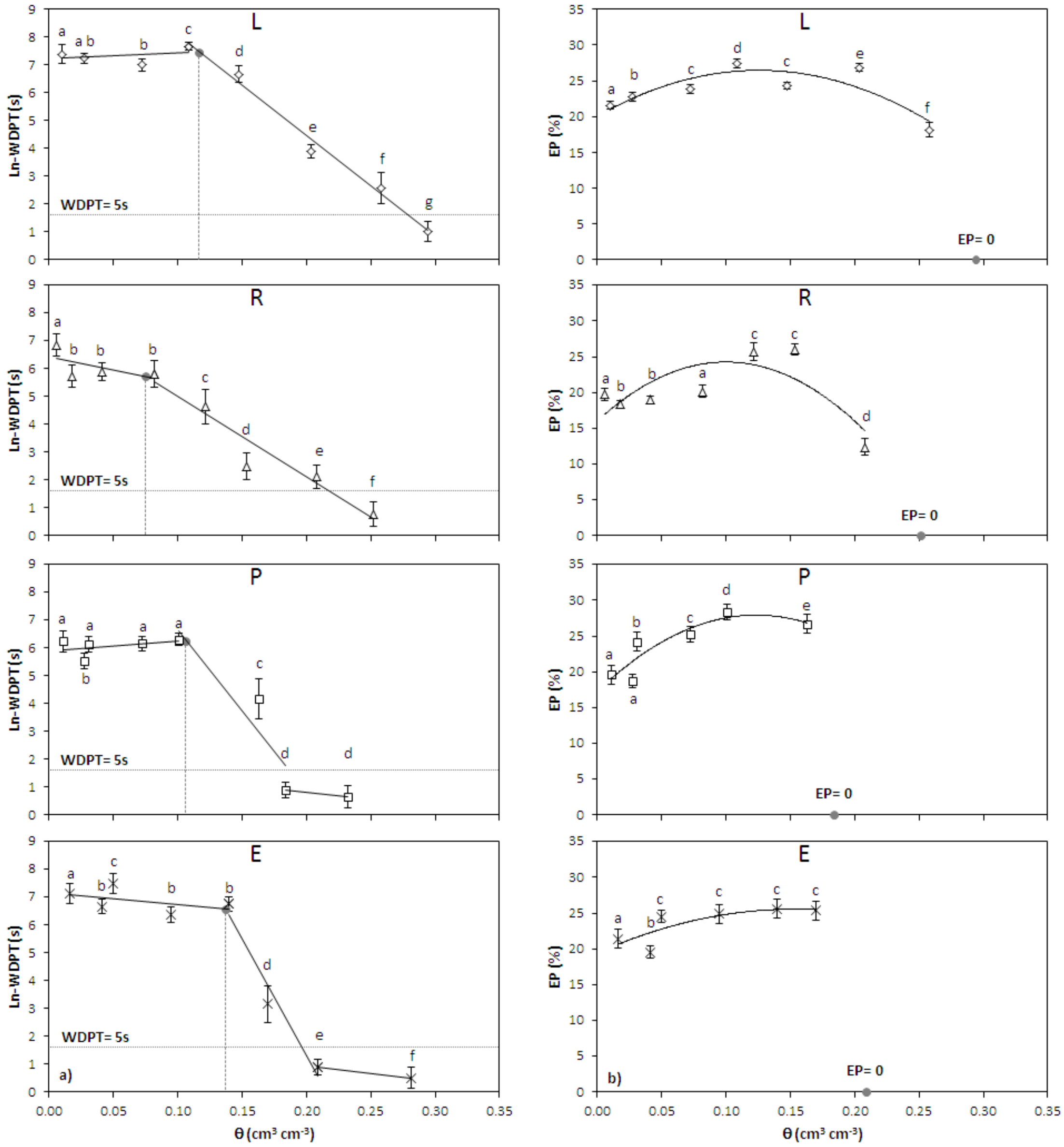

Figure 3.1: Measured WDPT (a) and EP (b) values for different initial soil water contents. Data points in a plot associated to the same letter were not statistically different according to a Tukey HDS test (P = 0.05).

The results of EP test were in agreement with the WDPT ones given that hydrophobicity affected the considered forest soils in the following order: E=P=L>R. However, the degree of WR increased in the θ range up to approximately 0.15 cm^3cm^{-3} and then decreased. In particular, the maximum degree of WR was obtained for a critical water content, CWCM, equal to 0.10 cm^3cm^{-3} for P and L soils and 0.14-0.15 cm^3cm^{-3} for E and R ones (Table 3.1). Beyond these values, the severity of WR sharply vanished to reach the condition EP = 0 for a critical water content, CWCO, varying between 0.18 and 0.29 cm^3 cm^{-3} depending on the considered soil (Table 3.1). In the soils of exotic species (P and E), WR severity vanished before than in native species soils (L and R) confirming the findings obtained by WDPT test (Table 3.1).
Significant differences between EP values measured at different water contents were generally found (Figure 3.1b) probably as a consequence of the lower variability of EP data. However, this last result could also be a consequence of a poor reliability of WDPT test compared to EP one. Particularly at high hydrophobicity levels, the identification of the complete infiltration of a water droplet can be subjective and, therefore, affected by operator's error. Instead, the EP test

required a simple assessment of the status of an ethanol drop (completely infiltrated or not) at a given time (t = 5 s) and, therefore, the evaluation of this index is less affected by intrinsic errors.

Table 3.1: Critical water contents identifying the condition of hydrophobicity and wettability according to WDPT and EP tests

	L	R	P	E
CWCH (cm^3 cm^{-3})	0.117	0.074	0.106	0.137
CWCW (cm^3 cm^{-3})	0.279	0.218	0.187	0.197
CWCM (cm^3 cm^{-3})	0.108	0.154	0.100	0.140
CWCO (cm^3 cm^{-3})	0.294	0.252	0.184	0.209

4. Conclusions

The persistence and the degree of WR on the forest soils of two native and two exotic trees species used in Sicilian reforestation was investigated by WDPT and EP tests. Both of them detected strong or even extreme hydrophobic conditions for water contents corresponding to air-dried condition. The highest WDPT values were measured at low θ contents ($\theta < 0.14$ cm^3 cm^{-3}) but soils rapidly become wettable when θ increased to around 0.19 cm^3 cm^{-3}. Two critical water contents discriminating, respectively, the upper threshold for hydrophobicity and lower threshold for wettability were identified. The relationship between EP and θ showed a maximum in the range of θ values around 0.10-0.15 cm^3 cm^{-3}. For higher θ values (θ = 0.18-0.29 cm^3 cm^{-3}) EP sharply declined to zero. Hydrophobicity in soils of native species persisted at relatively higher water content compared to exotic ones with potential negative effects on water infiltration and availability.

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TOPIC 5

HYDROLOGY, DEBRIS FLOW, SEDIMENT-LARGE WOOD CONNECTIVITY IN CHANGING ENVIRONMENT: PROCESS, CONTROL AND CONSEQUENCES

Quantification and spatial variability of rooted-soil reinforcement in managed and abandoned chestnut coppice forests

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Keywords: Root reinforcement, Slope stability, Sweet chestnut

Summary
Sweet chestnut dominates the Italian mountainous territories, and in particular the low- and mid- altitude areas, where it played a fundamental role in mountain economy and in people subsistence. In such areas, sweet chestnut stands have always been a source for woody material, and have been traditionally managed by coppicing in a short rotation. Due to socio-economical changes occurred in the last half century, the sweet chestnut stands have been largely abandoned. Most of these stands are now over-aged and stools uprooting events are very common, being a great concern among forest managers, especially in areas prone to shallow landslides and debris flows. To investigate the effects of chestnut abandonment on slope stability, this study focused on the spatial variability of root reinforcement in two different chestnut stands: (i) abandoned, and (ii) managed. Additional root reinforcement was estimated combining a root distribution and a root reinforcement model, both calibrated with field data. As expected, results emphasized that external factors, such as the age of plants, do not affect the mechanical properties of roots, whereas there is a significant difference in terms of root density and rooting depth according to the forest management.

1. Introduction

Forests are fundamental in protecting population and infrastructures from hydro-geological risks (Sidle et al., 1985). Many studies dealt with the effects of vegetation on slope stability since the Seventies, in particular, by modelling and quantifying the soil reinforcement provided by root systems, but few of them investigated the impact of forest management on such beneficial role in contrasting natural hazards. In Europe, forest management practices have been conducted from several centuries and sweet chestnut (*Castanea sativa* Mill.) is one of the most common species because it has always been a fundamental source of woody material and food. This species naturally develops several adventitious shoots from the same stool and is characterized by a rapid growth and for this reason, chestnut forests have been traditionally managed by coppicing in short rotation (< 20 years)., Due to socio-economical changes occurred in Italian mountain areas, the coppice chestnut stands have been largely abandoned since last decades and most of the stands are now abandoned and over-aged and stools uprooting events are very common problems.

Such situation represent a major concern, especially in areas prone to landslides and debris flows. On this background, this study aims to investigate the effects of sweet chestnut abandonment on slope stability considering the differences between managed and abandoned stands through: (i) quantification and modelling of spatial distribution of root population; and (ii) evaluating additional soil reinforcement.

2. Material and Methods

Study area

The study area is in the southern part of Mt. Fenera's regional park, in Lower Valsesia (Piedmont, North Italy). It is approximately 8 km^2 and the steepness reaches 38°. Nearly completely natural, chestnut forests (around 70%) cover large portion of landscape. According to Italian Landslide Inventory, the study area is medium-vulnerable to shallow mass movements. Inside the area, two different sites are identified with different features: (i) in turn managed coppice chestnut (7 years old) and (ii) abandoned and over-aged coppice chestnut (~40 years old).

Root tensile tests

Samples of live roots were carefully collected by digging pits without damaging the specimens. Once collected, roots were conserved in plastic containers with 15% alcohol solution to avoid any deterioration, and then, tensile tests have been conducted in laboratory. Tensile resistance was measured as a function of strain using a load cell (full scale = 500 N, accuracy = 0.5 N) connected to an acquisition system. Only specimens that broke near the middle of the root were considered to ensure that the rupture was due to the applied force and not to a previous structural damage. Finally, power laws interpreted the relationships between the ultimate tensile force, F, and the Young's modulus, E, as function of the root diameter, ϕ (Schwarz et al., 2013).

Root density measures

Spatial root distribution was estimated using the trench method (Böhm, 1979) and manually counting all roots on the trench profile (0.5 m x 1.0 m) using a pair of callipers. A total of 6 trenches were excavated, 3 for each site at different distances from the plant (1.5 m, 2.5 m and 3.5 m). Root population was classified according to four diameter classes: 0.5-1 mm, 1-2 mm, 2-5 mm and 5-10 mm.

Root reinforcement

Root reinforcement is strongly correlated to root population. A Root Distribution Model, RDM hereafter, based on the strong correlation between diameter at breast height and root zone around the tree (Schwarz et al., 2012), was adopted to evaluate the spatial distribution of root diameter. To apply RDM, it is necessary to calibrate the two main parameters, the pipe coefficient and the maximal rooting distance, minimizing the differences between observed and simulated number of roots. Once calibrated, a Root Reinforcement Model, developed by Schwarz et al. (2013) and called RDMw, which combines mechanical propertied and root density, was applied.

3. Results and Discussion

Spatial root density

Results showed that root population decreases increasing the distance from the plant as largely demonstrated in literature (e.g. Ammer and Wagner, 2005). Root density is greater in abandoned chestnut site than in managed stand, as shown in Fig.3.1. Most roots belong to 0.5-1 mm class: 53.6% ± 9.1% for the managed site and 40.3% ± 6.3% for the over-aged site. On the other hand, large roots with a dimeter greater than 5.5 mm are constant in both sites and are approximately 4%. Additionally, there is a significant difference among the sites in terms of rooting depth (Fig.3.1). In fact, the managed chestnut reaches a depth of 0.60 m at both three distances, whereas the over-aged chestnut a depth of 0.90 m. Such difference confirmed the observations made by Bassanelli et al. (2013) in a different context in the Italian Prealps.

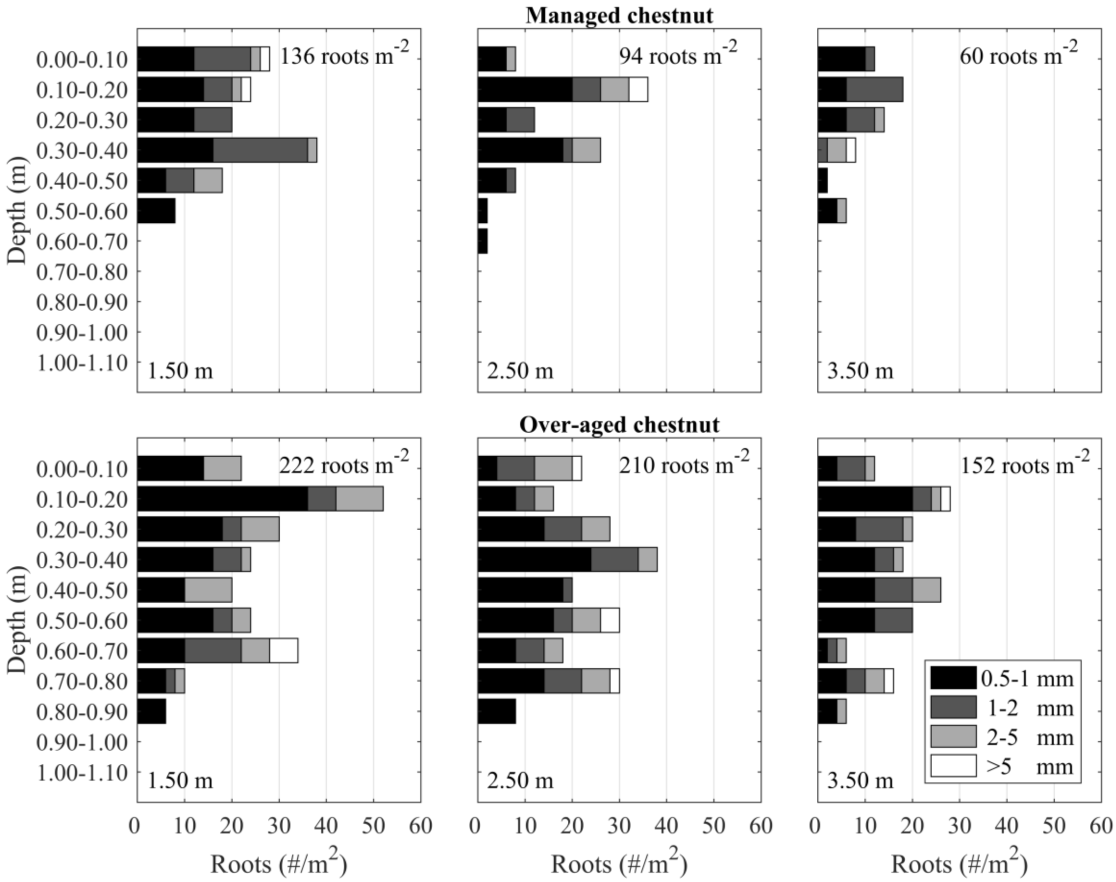

Figure 3.1. Spatial root distribution at three different distances from the plant for a managed chestnut and an over-aged chestnut site.

Mechanical properties

Two series of tensile test were conducted on live roots collected from the two study sites. The range of root diameter varies from 0.71 mm to 4.45 mm. F and E strongly depend on ϕ as demonstrated by fitting of two power laws. Additionally, to verify a possible influence of external factors, such as the age of plant, on the mechanical properties, ANCOVA tests (A-slo for the parallelism and A-int for the intercept) have been performed using ϕ as covariate. Previously, other statistical tests have been adopted to verify the ANCOVA test's assumptions: Levene's test, Lev, for the homogeneity of variance and Shapiro-Wilk test, S-W. for the normality. Results indicated that no significant difference can be detected as shown in Table 3.1.

Table 3.1.Results of statistical tests for the mechanical properties. a* and b* are the regression parameters of power laws. Lev.p, S-W.p, A-slo.p and A-int.p are the p-values of the conducted statistical tests.

	a*	b*	R^2	Lev.p	S-W.p	A-slo.p	A-int.p
F (N)	12.27	1.50	0.831	0.416	0.042	0.392	0.151
E (MPa)	196.87	-1.10	0.579	0.468	0.381	0.460	0.404

Root reinforcement

Once calibrated RDM and RBMw, additional root reinforcement values were calculated for each distances (Fig.3.2). As root population, root reinforcement decreases increasing the distance. The maximum value of bundle tensile force ranges from 1928 N at 3.50 m to 4498 N at 1.50 m in managed site, whereas from 5142 N at 3.50 m to 8107 N at 1.50 m in over-aged site.

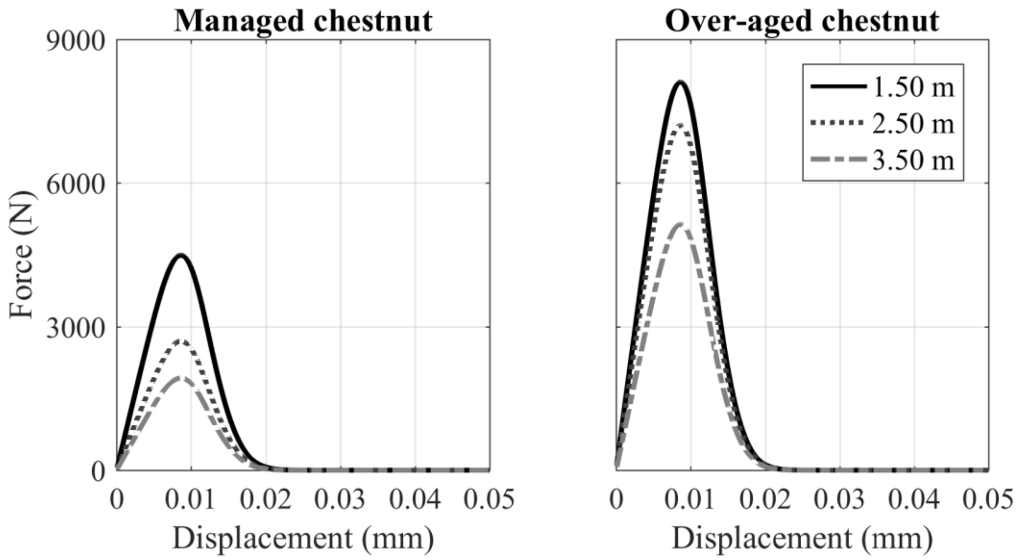

Figure 3.2. Root reinforcement evaluated by the combination of RDM and RBMw.

4. Conclusions

This study analysed the effects of slope stability caused by the abandonment of coppice chestnut forests. Results indicated that the age of plants do not affect the mechanical properties of chestnut roots. Root population, and, as consequence, root reinforcement are extremely variable in the two study sites. The root reinforcement of over-aged site is greater than that of managed one. The observations underlined a difference around 200% in terms of additional force. Although in this case the root system of a chestnut in over-aged conditions provided a greater contribution on slope stability than in managed, it should be verified that this is a general behaviour. Moreover, over-aged stools are more subject to problems such as instability and uprooting. For these reasons, future studies should consider other sites and focus on understanding and discussing advantages and disadvantages of different kind of forest management (for example the conversion to high forest) to control slope instability.

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Effects of under-vacuum and vessel soil sample saturation on soil hydraulic conductivity estimated by the core method in the case of paddy soils

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Keywords: soil saturated hydraulic conductivity, best practice, core method, soil saturation, under-vacuum saturation, vessel saturation

Summary
In paddy fields most of the percolation flux is regulated by the saturated soil hydraulic conductivity (*Ks*) of the hardpan. The core method performed on large undisturbed soil samples generally allows a good estimation of *Ks*. However, only little attention is paid in the literature to the saturation process adopted to prepare soil samples for analysis. Two methods are available: vessel saturation (*AtmSat*), and saturation under vacuum (*VacSat*).
In autumn 2015, ten large undisturbed soil samples were collected from the hardpan layers of three paddy fields located in Lombardy (Italy). In particular, five soil profiles were opened and two samples were collected from the hardpan of each profile. *Ks* was determined through the core method by adopting the two saturation methods. The first outcome of the research is that the saturation method strongly influences the obtained *Ks* value. In order to evaluate the accuracy of the estimated *Ks* values and to determine which saturation method is advisable in the case of paddy fields, the percolation flux estimated by the Darcy law (applied considering measured *Ks*) for the three paddy fields was compared to the flux obtained as the residual in the water balance equation for the same fields (where all the other terms were measured during the agricultural season 2015). Results show that *VacSat* provides better results with respect to *AtmSat*; however, vacuum must be applied slowly and the final *Ks* value is reached after a long convergence time.

1. Introduction

Saturated soil hydraulic conductivity (*Ks*) of the less conductive layer (LCL, usually the hardpan) is a key parameter in predicting soil water fluxes in paddy fields. The core method, reproducing the Darcy's experiment over large undisturbed soil samples, is considered the reference for *Ks* estimation. To saturate soil samples before the analysis, two different procedures are available: vessel saturation (*AtmSat*) and under-vacuum saturation (*VacSat*). *AtmSat* is a widely tested method where the sample is placed into a vessel and the water level is raised slowly (a few cm per day) to limit the air entrapment. *VacSat* is still a novel technique where the saturation is reached under vacuum to minimize as much as possible the risk of air entrapment. A standardized procedure for *VacSat* is still missing, thus differences may occur in the saturation process (e.g., final vacuum value, depressurization rate, time at which degassed water is added; compare, for instance: Dane and Hopmans, 2002; Petersen et al., 2008). While it is a common opinion that the two methods should provide the same results in the case of coarse soils, *VacSat* is often suggested for finer soils where *AtmSat*, even if carefully applied, was found to allow air entrapment taking to a reduction in estimated *Ks* up to 10 fold (Dane and Hopmans, 2002). However, a comparison between *Ks* obtained by adopting the two procedures is still missing in the literature. The main problem in the comparison is in the definition of a benchmark for the evaluation of *Ks* values obtained with the two saturation procedures. The percolation flux in paddy fields can be estimated as the residual term in the field water balance equation (e.g. Cesari de Maria et al., 2017), but also by applying to fields under flooding conditions the Darcy law considering the thickness and the *Ks* value of LCL and the difference in water pressure head between the upper and the lower faces of the same layer (Berge et al., 1995). In this study, in order to determine which saturation method can be recommended in the case of paddy soil samples, the percolation flux estimated by applying the Darcy law (based on laboratory measured *Ks* with soil samples prepared with the two different saturation methods) was compared to the one obtained computing the water balance for three paddy fields located in the main Italian rice basin (northern Italy). The study was conducted in the context of the WATPAD project founded by Fondazione Cariplo (grant n° 2014-1260).

2. Materials and Methods

All the relevant water fluxes and storages of three fields of the Cerino farm (PV) were monitored during the cropping season 2015 at an hourly time step. In particular, irrigation inflows and outflows, water level in the fields and soil water content (at four depths) were monitored following Chiaradia et al. (2015). Groundwater levels were monitored at an hourly time step through 14 piezometers placed around the monitored fields. Crop parameters (LAI, crop height) were measured in 16 campaigns along the season and used, together with agro-meteorological variables registered by a nearby meteo station, for computing potential evapotranspiration (ETc) with the FAO Penman-Monteith single crop coefficient method; Kc values were derived from a previous experiment conducted in a nearby area (Cesari de Maria et al., 2016; Chiaradia et al., 2015). The dataset was used for computing the fields' water balance obtaining the percolation of the three fields as the residual term.

During spring 2015 a geophysical survey with an EMI device (GSSI Profiler-EMP400) was carried out to obtain a zonation of the three fields based on soil characteristics. A thorough soil survey (32 hand auger soil observations and sampling at three depths, and subsequent laboratory textural analysis) was additionally conducted. As a result of the surveys, soil within one of the fields was found to be homogeneous, while the remaining two showed areas with two different soil types. During fall 2015, five profiles were opened to characterise LCLs of the different soil types. In particular, depth and thickness of LCLs were observed, and two large undisturbed soil samples (H 15 cm, ø 14.6 cm) were taken from each LCL for the laboratory *Ks* determination. The Darcy law was applied on the five areas accounting for LCLs features and dynamic values of water level within the fields and groundwater table depth. For fields characterized by two zones, total percolation was obtained by weighing percolation fluxes by the surface areas of the zones.

Different *Ks* determinations were carried out over the samples adopting the two saturation methods. In some cases the same sample, after a first *Ks* determination, was dried and then subjected to a second cycle of measurement. The Darcy apparatus used in the experiments (self-made) applies an upward water flux; water heads immediately upstream and downstream of the sample are measured by means of piezometers. The device can easily switch from constant to falling head and back again without stopping the water flux; falling head method was used for measuring low *Ks* values. The apparatus was filled with degassed water. Head applied during the experiments were at any time smaller than the ones to which LCL is usually subjected to in field conditions. Air temperature, measured close to the soil sample, allowed to account for water viscosity.

In this paper, the outcomes of the following two experiments are discussed: (A) two soil samples (A1 and A2, replicates) - collected form the LCL of the profile opened in the field zone covering the 80% of the most permeable field - were saturated adopting *VacSat*. Depressurization applied to A1 was rapid (30 min of continuous air extraction by means of a vacuum pump), while the one applied to A2 was slow (the pump was turned on for a minute every 20 minutes along 8 hours); (B) one soil sample - taken from the LCL of a field characterized by a low permeability (the one with homogeneous soil) - was subjected to a double cycle of measurement, in the first the sample was saturated adopting *AtmSat* (B1) and, after a slow and moderate drying, a gentle *VacSat* was applied to the same sample (B2). In experiments A1, A2 and B2 the degassed water was poured just before starting the depressurization process. To evaluate the resulting *Ks* values, percolation fluxes calculated by the Darcy's law (based on lab-estimated *Ks*) were assessed versus those obtained as residual terms in the water balance equations.

3. Results and Discussion

All the experiments performed on samples saturated adopting *VacSat* showed a strong decreasing trend during the experiment, with initial values up to 70 fold the final one (e.g. experiment A). A strong difference in the final value of *Ks* was obtained between A1 and A2, due to the applied depressurization rates (Figure 3.1 left panel), and between B1 and B2, due to the different saturation methods (*AtmSat* for B1 and *VacSat* for B2, Figure 3.1 right panel). Figure 3.2 shows the comparison between percolation fluxes calculated from the water balance equation and by applying the Darcy equation using the lab-estimated *Ks* for the two fields involved in the experiments A and B. It can be observed that percolation fluxes estimated by the Darcy law by using final *Ks* values estimated from A2 and B2 are very close to the residual terms in the water balance for the two fields.

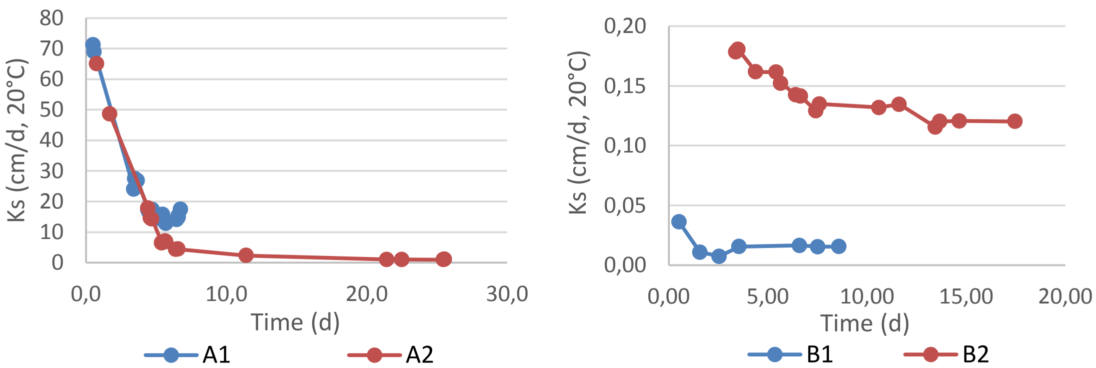

Figure 3.1: Ks patterns measured during the experiment A (on the left) and B (on the right)

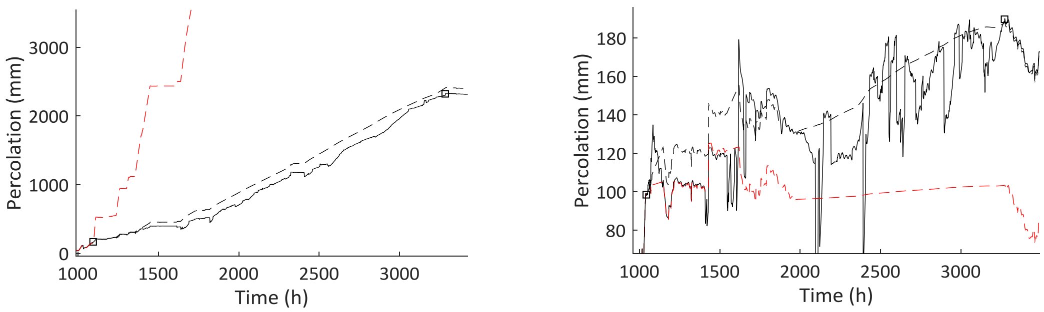

Figure 3.2: Cumulated percolation fluxes of the fields involved in experiments A (on the left) and B (on the right) computed from: the water balance equation (straight line), the Darcy law using respectively A1 and B1 (red dashed line), and A2 and B2 (black dashed line)

4. Conclusion

The main outcomes of the study, obtained by the two experiments shown in this paper and confirmed by other experiments not discussed here, are: (1) The transient-time behaviour of the flux was observed to start up to 26 h after the beginning of the experiment; therefore, we suggest to consider at least one day as the minimum duration for a flux experiment; (2) *AtmSat* showed to provide reasonable results only for coarse soils while, in the case of low *Ks*, the underestimation was found to be up to 10 fold (probably because of air entrapment); (3) Steady-state flux with *VacSat* was usually reached after a long time (up to 25 days), and initial *Ks* values were completely misleading; (4) When vacuum was applied slowly, *VacSat* provided accurate estimations of *Ks* at the steady-state, while a fast vacuum application may produce a relevant hydraulic gradient within the core that can lead in damaging the sample (Madsen, 2008); (5) In the case of *VacSat*, pouring water under vacuum increased the duration of the transient-time but allowed a smoother convergence; (6) Applying *VacSat*, the initial estimation of *Ks* was usually 10 times higher than the convergence value: this might be explained by changes in the electrical diffuse layer (EDL, Achari et al., 1999) due to interactions between pore water and within-aggregate water, and/or to a release of biological gasses due to vacuum conditions. These results, partially diverging from what reported in the literature, may in part depend on the peculiarity of the soils explored (paddy hardpan), and need to be verified with a higher number of samples and in the case of other soil types.

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TOPIC 6

POST HARVEST, LOGISTICS AND FOOD CHAIN EQUIPMENTS AND STRUCTURES

Exploitation of technological innovations along the olive oil milling process for an optimization of the plant performance

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Keywords: Olive, paste, husk, malaxer machine, leaf conditioner, UV, vis/NIR spectroscopy

Summary
This work aims to evaluate the production process of olive oil in terms of production yield and reducing waste of by-products with a view to enhancing the economic savings without leaving out the quality aspects. Some solutions in different critical points of the process were evaluated to optimize the oil extraction procedure.
The study focused on: (i) the use of a olive tree leaves conditioner to reduce the leaves volumes deriving from the cleaning machine of the mill and to facilitate the humification process in order to obtain a by-product rich in nitrogen, a crucial lacking element in composting processes; (ii) the conditioning of paste temperature using a continuous malaxer machine to increase, in a short time, the temperature of paste during processing, and to limit the oxygen exposure thanks to the controlled conditions and no water addition; (iii) the application of vis/NIR spectroscopy in order to correlate spectral data, acquired on intact olives and pastes, to the crucial parameters.

1. Introduction
The aspect of enhancing the quality and of recycling in the olive oil productions chain waste is a topic of relevance. Moreover, many farmers burn olive tree pruning materials with high CO_2 emission, olive pomace and wastewater are often spread directly in field, with consequent environmental impact (Cini & Regis, 2000; Altieri & Esposito, 2008). By the other hand these problems involve the olive oil chain, for little and medium companies. The solution here proposed consists of composting waste and residuals, directly in farm with the aim of closing the organic matter circle directly in the farm. The need to improve better performances in composting could be of interest to adopt the prototype performed by the authors, considering two aspects: minimize the waste costs and increase the process performances. Moreover, the actual frontier of olive oil quality enhancement is focused on the flavour's maximization. Since 2009 the authors performed a prototype of malaxer machine to increase, in a short time, the temperature of paste during processing.
The selection of olive fruit with defined properties that ensure positive attributes in olive oil is foreseeable using vis/NIR and NIR spectroscopy in olive oil production (Armenta et al., 2010). However, limited work has been undertaken about the implementation of vis/NIR and NIR spectroscopy directly in the mill.

2. Materials and methods
(i) Prototype of a leaves conditioner: considering the composting need and knowing the volume of leaves outbound the blowing in the olive mill, the study was carried out in Montepaldi (farm of the University of Florence) exactly in the specific area of the company, where it is situated the rectangular section cemented tank surrounded by a 1 meter wall. Moreover, a simple machine was used to reduce the leaves volume. The operative principle of this prototype consists in the use of the air vortex of the mill plant to allow the entrance of olive leaves in the opening placed at the top of the machine. On the bottom of the machine is positioned a set of

equidistant blades, which assures the partial or complete cutting and allow to obtain a final product with the volume reduced of about 1/3. The prototype of the chopper machine has been built entirely in stainless steel. The accumulation of residual waste has been realized by the union of: 400 kg of green stalk, 400 kg of walnut shredded, 400 kg of white marc unfermented, 1400 kg of olive wet pomace, 300 kg of olive leaves and 400 kg of grapevine shredded.
The mass was turned over every 2 weeks, to support aerobic fermentation and metabolic activity of microorganisms. The dimensions were 9,10 m x 2,20 m x 0,20 m (4.004 m^3).
(ii) The prototype of the continuous malaxing machine (Figure 2.1) consists of:
a knife crusher from which the olive pomace goes into the malaxer consisting of four tubes (each one of the length of 1 m), with internal cochlea, horizontally disposed in a vertical plane. The pomace velocity can be regulated, but in this study was fixed at 4 m min^{-1}.

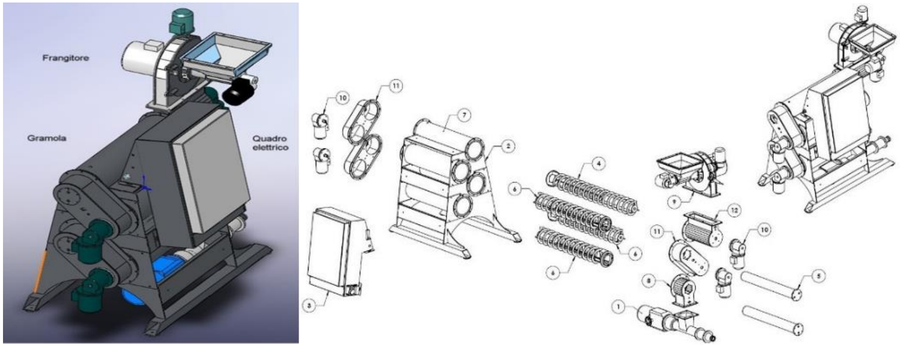

Figure 2.1: Prototype of the continuous malaxing machine

(iii) Testing of a vis/NIR device: a total of 54 olive samples (400-500 g), which presented no infection or physical damage, were quickly transported to the laboratory to be analysed, and for each sample a homogeneous batch of olives (i.e. approx. 300 g) was selected. For each sample, 30 olive fruit vis/NIR spectra were acquired, for a total of 1620 optical measurements. For each olive, using a portable spectrophotometer (Jaz, OceanOptics, USA), two spectral measurements were taken in reflectance mode and averaged. Physical measurements (i.e. yield point force and total deformation energy) were carried out on the olive samples and the maturity index (MI) was calculated; after, the fruit were crushed for olive paste production, and chemical analyses (moisture, oil and sugars content) were performed and correlated to the spectral data.

3. Results and discussion

(i) The use of olive tree leaves conditioner reduces the leaves volume deriving from the cleaning section by 30-40%, producing a good composting element (the chemical parameters are reported in Table 3.1).

Table 3.1: Chemical parameters results for 3 company's compost samples and 1 repetition respectively for each sample

Parameters	Sample 1	Rep. 1	Sample 2	Rep. 2	Sample 3	Rep. 3
pH	4.64	4.78	7.35	6.57	9.51	9.86
Residual after drying at 105°C (%)	41.30	41.70	42.90	48.20	40.80	47.10
Ashes (%)	2.40	2.10	2.50	2.60	4.30	5.40
Organic Carbon	26.40	32.90	28.60	33.60	30.44	33.20
Total Nitrogen	10.40	10.40	10.70	11.20	4.60	4.70
Total Phosphorus	3.30	4.04	3.70	4.25	3.70	4.15
Pb (mg/kg)	9.70	7.20	5.50	6.20	8.50	6.60
Total Cu (mg/kg)	9.70	14.40	10.30	10.40	8.90	18.60
Cd (mg/kg)	< 1	< 1	< 1	< 1	< 1	< 1
Hg (mg/kg)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ni (mg/kg)	9.70	14.40	6.30	8.60	6.30	8.60

Zn (mg/kg)	14.50	14.40	10.80	10.40	11.40	20.70
Inferior calorific power	-	-	-	-	3966.00	4047.40
Humification index	-	-	-	-	0.50	0.49

The humidity of 50% could be considered very good, pH tends to acidity in first sampling for CO_2 and organic acid formation, while successively it tends to neutrality thanks to aeration that induce CO_2 expulsion, and to ammonia production from corroded proteins. Finally, it tends to alkalinity with pH value around 9,5, while for high quality compost the expected result is at least 8,5 (D.lgs n 152 2006; D.M. n 21 2000). Organic carbon results are in accordance to the size of 30%. The results in terms of heavy metals content can be considered as good.
(ii) In Table 3.2 are reported the results of the test concerning the different temperatures of the interspace conditioning water in the four tubes of the malaxing machine prototype:

Table 3.2: Interspace conditioning water temperature (°C) in the experimental test

Tube	Test 1	Test 2	Test 3	Test 4
1	17.4	18.0	21.6	22.0
2	18.4	19.0	18.4	22.5
3	19.0	15.4	20.9	22.6
4	18.2	16.4	15.4	16.6
Pomace temperature	18.8	23.7	23.4	26.3
Final oil temperature	23.0	26.0	26.0	25.7

The presented results regard the physical performance of the machine. The chemical and sensorial analysis were also performed, showing a very good quality of the obtained oils (data not shown).
(iii) PLS regression models were built for each parameter measured (Table 3.3). Regarding textural parameters, the possibility to use the reference data on a single berry allowed to obtain acceptable results for the prediction of indices usually difficult to be predicted in an optical non-destructive way. Interesting results were obtained for the prediction of the yield point force. Slightly better results were obtained from spectra on olive pastes compared to those arising from the models calculated using spectra on intact olives. Also in this case, better results were achieved for the prediction of MI. This result may have interesting applicative implications, since the MI requires time for measuring and sample preparation.

Table 3.3: Descriptive statistics and statistics of the PLS models elaborated on vis/NIR spectra of intact olives for the prediction of chemical, maturity and textural parameters (Giovenzana et al., 2017)

					Calibration		Cross-Validation		
Parameters	**n**	**Mean**	**DS**	**LVs**	**R^2_{cal}**	**RMSEC**	**R^2_{cv}**	**RMSECV**	**RPD**
Moisture (%)	48	53.32	3.97	8	0.87	1.39	0.57	1.89	2.10
Oil content (g kg $^{-1}$)	44	371.11	49.93	9	0.85	18.67	0.74	25.85	1.93
Sugar content (g kg $^{-1}$)	46	38.87	5.69	7	0.65	3.31	0.42	4.35	1.31
Maturity Index	47	0.85	1.02	3	0.93	0.24	0.92	0.26	3.92
Yield point force (N)	14.10	41.26	17.26	9	0.63	12.32	0.62	12.44	1.39
Total deformation energy (N mm)	1373	450.35	103.69	10	0.42	78.83	0.4	79.96	1.30

SD standard deviation; LV latent variables

4. Conclusions

(i) The composting approach and the use of the presented prototype gained could be of interest in small farms and could be extended in different contexts of the agro-food industry.

(ii) The experimental plan aimed to provide a thermal stress to the pomace, before the extraction of the oil. This approach is performed to enhance the oil fragrancy, and the first tests were encouraging.

(iii) Regarding vis/NIR spectroscopy, the obtained results were encouraging for chemical analyses (moisture, oil and sugars content), physical measurements (yield point force and total deformation energy) and maturity index prediction, demonstrating the feasibility of real-time estimation of crucial indices for the milling plant settings.

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Monitoring of the vegetables quality in large-scale mass distribution channel: the potential role of vis/NIR spectroscopy

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Keywords: MDC, market, store, carrot, tomato, optical technique

Summary
Nowadays the vegetable market is controlled mainly by the "mass distribution channel" (MDC). The role of the MDC in the vegetable market is growing rapidly. MDC's buyers have not useful and rapid instruments to evaluate the quality of the products. Thus, decisions taken by the buyers are driven mainly by price policy and not correlated with the product quality. For these reasons, simple, rapid, and easy-to-use methods for objectively evaluating the quality parameters of the vegetable products are needed. The aim of this work is to apply the visible and near infrared (vis/NIR) spectroscopy in order to estimate some qualitative parameters of two case studies of low-price products (carrots and tomatoes) coming from different brands and evaluate the applicability of this technique directly at the stores.
A non-destructive optical system (vis/NIR spectrophotometer with a reflection probe, spectral range 430-1650 nm) was tested. The samples were purchased at 13 different MDC stores of the Milan city hinterland. It was studied the difference among carrots and tomatoes sold in different stores and among the dates of purchase. The reference quality parameters (firmness, water content, soluble solids content, pH and color) were correlated to the spectra.
The PLS models deriving from the optical data gave positive results, in particular for the prediction of the soluble solids content and the color (better results for tomato). In conclusion, the application of optical techniques could be of help for the vegetable sector for an easier monitoring of the products quality and it could therefore lead to an effective optimization of the entire supply chain.

1. Introduction
Today the vegetable market is controlled mainly by the "mass distribution channel" (MDC). In 2007 the market concentration in the hands of the MDC was about 37%, in 2010 it grows to 56% and it seems that todays the concentration is about 70%. It is evident that the role of the MDC in the vegetable market is growing rapidly, but this phenomenon can represent a problem for the farmers because the market power is completely unbalanced in favour of the buyers, who practice price policies often at the expense of quality.
In this contest, the buyers don't have any instrument to evaluate the quality of the product they choose to buy for their brand. Nowadays in fact the quality control is in practice just visual, focusing on the absence of defect on the peel, or on the uniformity of the colour or the calibre in accordance for example to the Regulation CE 1221/2008. The problem is that the classical analytical analyses for the estimation of quality parameters are too expensive and give results only after some days, so they are not applicable at the MDC level. Thus, the decision taken by the buyers are driven by intuition or by the price, but these aspects are not correlated with the quality of the product but rather with the market law.
Therefore, a simple, rapid, and easy-to-use method for objectively evaluating the quality parameters of the vegetables product is needed. The non-destructive techniques, and in particular the optical analysis in the region of near-infrared (NIR) and visible–near infrared (vis/NIR), have been developed considerably over the last 20 years (Guidetti et al., 2012; Nicolai et al., 2007) but interesting applications can be found since the beginning of the 1990s. In the last decade, vis/NIR spectroscopy has been successfully used for example to measure a range of apple quality attributes such as soluble solids content (SSC) (Quilitzsch and Hoberg,

2003; Zude et al., 2006), titratable acidity (Peirs et al.,2002), starch index (Menesatti et al., 2009), chlorophyll content (Zude-Sasse et al., 2002). Beghi et al. (2014) used vis/NIR spectroscopy for decay detection in fresh-cut Valerianella locusta. In literature, it is possible to find many other works regarding the use of vis/NIR spectroscopy in specific application such as the prediction of fruit firmness (Harker et al., 2002; Mehinagic et al., 2003) or the non-destructive analysis of nutraceutical properties (Beghi et al., 2013).
The aim of this work is to apply the visible and near infrared (vis/NIR) spectroscopy in order to estimate the qualitative parameters of two case studies of low-price products (carrots and tomatoes) coming from different brands and to evaluate the applicability of this technique directly at the stores.

2. Materials and Methods

A non-destructive optical system (vis/NIR spectrophotometer with a reflection probe, spectral range 430-1650 nm) was tested (Figure 2.1). The samples were purchased at 13 different MDC stores of the Milan city hinterland. It was studied the difference among carrots and tomatoes sold in different stores and among the dates of purchase. The reference quality parameters (firmness, water content, soluble solids content, pH and color) were correlated to the spectra.

2.1 Data processing

Physicochemical data were subjected to one-way Analysis of Variance (ANOVA) considering brands and then dates as factors, and parameters as dependent variables in order to highlight significant differences between them. Vis/NIR spectra and the quality parameters were used for multivariate analyses: principal component analysis (PCA) was used for explorative investigation and partial least square regression (PLS) was used to elaborate chemometric predictive models. Chemometric analysis was performed using The Unscrambler software package (version 9.7 CAMO ASA, Oslo, Norway).
PCA was performed on spectra to examine sample grouping and to identify outliers, and consequently to define the sample sets to be used for the PLS analysis. The vis/NIR spectra were correlated with the parameters (texture, water content, solid soluble content, pH, colour) using the PLS regression algorithm. Cross-validation was used as validation method. To evaluate model accuracy, the coefficient of determination in calibration (R^2_{cal}), the root mean standard error of calibration (RMSEC), the coefficient of determination in cross-validation (R^2_{val}), the root mean standard error of cross-validation (RMSECV) and the ratio performance deviation (RPD) were applied.

Figure 2.1: Particular of the spectral acquisitions on tomato and carrot

3. Results and Discussion

Results showed a substantially standardized quality along time with no differences among dates, while a significant difference regarding quality parameters can be noticed among the different brands. The PLS models deriving from the optical data gave positive results, in particular for the prediction of the soluble solids content and the color (better results for tomatoes).

Table 3.1: Descriptive statistics and statistics of the PLS models elaborated on vis/NIR spectra to estimate quality parameters of carrots

				Calibration			Validation			
Parameters	n°	Mean	SD	LV	R^2_{cal}	RMSE	R^2_{val}	RMSECV	RMSECV%	RPD
Texture (%)	167	82.03	6.33	9	0.5	4.47	0.41	4.98	6.07	1.27
C*	228	49.98	3.81	5	0.83	1.59	0.82	1.63	3.26	2.33
h	175	60.95	1.27	5	0.83	0.52	0.82	0.54	0.89	2.35
pH	173	6.19	0.10	15	0.61	0.06	0.43	0.07	1.13	1.38
WC (%)	175	89.68	1.14	15	0.8	0.51	0.72	0.61	0.68	1.86
SSC (°Brix)	173	8.98	0.94	15	0.79	0.43	0.69	0.52	5.79	1.80

SD standard deviation; LV latent variables; WC water content; SSC soluble solids content

Table 3.2: Descriptive statistics and statistics of the PLS models elaborated on vis/NIR spectra to estimate quality parameters of tomatoes

				Calibration			Validation			
Parameters	n°	Mean	SD	LV	R^2_{cal}	RMSE	R^2_{val}	RMSECV	RMSECV%	RPD
Texture (%)	204	51.8	14.7	15	0.76	7.14	0.68	8.37	16.15	1.75
C*	203	29.92	3.25	6	0.88	1.13	0.86	1.23	4.11	2.65
h	205	50.27	4.60	4	0.92	1.27	0.91	1.33	2.65	3.46
CSS(°Brix)	204	4.55	0.81	15	0.78	0.38	0.72	0.43	9.45	1.88

SD standard deviation; LV latent variables; SSC soluble solids content

4. Conclusion

In conclusion, the application of optical techniques could be of help for the vegetable sector for an easier monitoring of the products quality and it could therefore lead to an effective optimization of the entire supply chain. Moreover, the MDC could provide a better service for consumers with the final aim to be more competitive on quality also towards foreign competitors.

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3D finite element model of packaged frozen vegetable thawing

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Keywords: numerical model, heat transfer, frozen vegetable.

Summary
In order to avoid chemical-physical changes, the frozen products should not be subjected to temperature fluctuations. In between the packaging and cold storage step, the products are frequently subjected to the routine controls at an environment temperature of about 10 °C. This could induce an unwanted heating of the frozen foods.
The ambient temperature effect on heat transfer inside the products was study by a 3D finite element model.
The heat transfer by conduction and convection, inside and on the surface of the packages, was considered in a finite element model. An *apparent specific heat* was used to describe both the specific heat of the product and the released latent heat, during the phase transition. Model was validated by experimental temperature acquired in the center of the products (peas, spinaches and eggplants).
Numerical and experimental results were in good agreement. The model made possible to evaluate the temperature distribution inside the whole package and not only in specific points.

1. Introduction
Among all food preservation methods, freezing is the most important operation for long-term preservation of food qualities. The time-temperature tolerance of frozen products is the most important factor responsible for the final quality of products. In between the packaging and cold storage step (-18°C), the frozen products are generally subjected to the routine controls, which are performed in the environment with the temperature from 5 to 10 °C. During this time, the packaged products are subjected to unwanted heating. In order to set an optimal working environment temperature, considering also the wellness of the worker, it is essential to study the evolution of the temperature field in the food over the ambient temperature.
Temperature variation vs. time can be determined experimentally. However, experimental tests can be often time consuming and difficult to set up (Karthikeyan et al., 2015). Numerical heat transfer models are considered to be an alternative valuable tool to estimate food temperature change even under wide thermal environment fluctuations (Norton and Sun, 2006). The main advantages of the numerical models compared to analytical ones, are related to the higher complexity of geometry, materials and boundary condition that are possible to consider.
The aim of research was to develop a 3D parametric finite element model to evaluate how the temperature field inside a frozen products (e.g. peas, grilled eggplants and spinach cubes) if affected by environment temperature.

2. Materials and Methods
The packaged frozen products are subjected to the routine controls performed in the working environment, at temperature range of 5 to 10 °C. The unwanted heating of the frozen products (peas, spinach cubes and grilled eggplants) during this step, was study by using a parametric 3D finite element model.
The heat transfer by conduction $\rho C_P \frac{\partial T}{\partial t} + \nabla(-k\nabla T) = 0$ and convection $q = h(T_e - T)$, inside and on the surface of the packages, was considered. The *apparent specific heat* (C_P) was used to describe both the specific heat of the product and the released latent heat, during the phase transition:

$C_P = C_{P1}(1 - \alpha(T)) + C_{P2}\alpha(T) + H\frac{d\alpha}{dT}$

where:

$\alpha(T) = 0$ if $T \leq T_1$;

$\alpha(T) = 1$ if $T \geq T_2$;

$\alpha(T)$ is a smoothed function that linearly increses from 0 to 1 if $T_1 < T < T_2$;

H is the latent heat (kJkg^{-1}), while T_1 and T_2 are initial and final thawing temperature (°C).

Thermal conductivity of the packaged products were determined by using analytical models based on the phases distribution: Maxwell-Eucken-II (MEII) (Buonanno and Carotenuto, 2000; Rocha and Cruz, 2001) and Krischer models (Reddy and Karthikeyan, 2010).

Model was validated by comparing the temperature experimentally and numerically determined at the product center.

3. Results and Discussion

Numerical results and the experimental test were in good agreement. The percentage differences between calculated and measured temperature values (at product core, as maximum value during the thawing process) were 1.4, 4.5 and 3.7 %, for peas, spinach cubes and grilled eggplant, respectively. The model made possible to evaluate the temperature distribution inside the whole package and not only in specific points. Calculated temperature inside the package (peas, ambient temperature 5 °C) at 5, 10 and 20 min is reported in figure 2.1. The temperature values are represented by the gradation of colours spanning from -22 to -4°C. The highest temperature values were reached in the bottom part of the product in contact with the metallic plane. Similar results were achieved for all ambient temperature and tested products (spinach and grilled eggplants). Accordingly, the bottom zone were considered as the thermally most critical area.

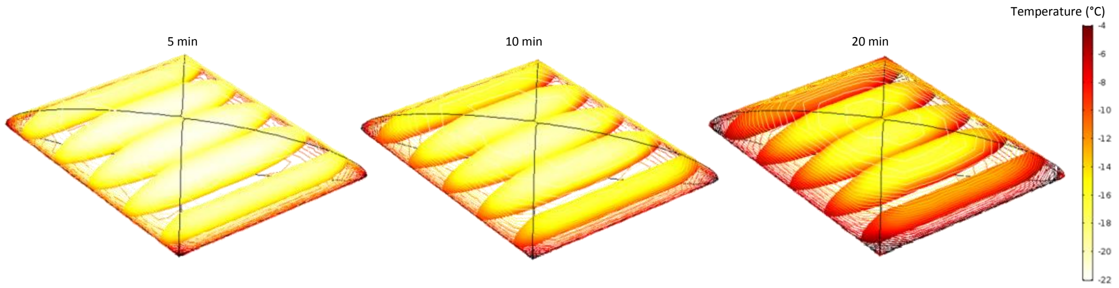

Figure 2.1:temperature calculated inside the product (peas), after 5, 10 and 20 min (ambient temperature 5 °C).

The relation between calculated temperatures on the bottom (z), ambient temperature (x) and time (y) was investigated. A good fit ($R^2 > 0.97$) was obtained by using the following equation: $z = a + (x^b + cy)/(e + xd + y)$, useful for industrial purposes. Furthermore, specific exponential relations were determined to identify the time required to reach the initial thawing temperature at the critical area, over the ambient temperature. Particularly, considering the peas package, the estimated time to reach the initial thawing temperature (-6°C) were 15 min ,8 min and 5 min for 5, 10 and 15°C ambient temperature, respectively (figure 2.2).

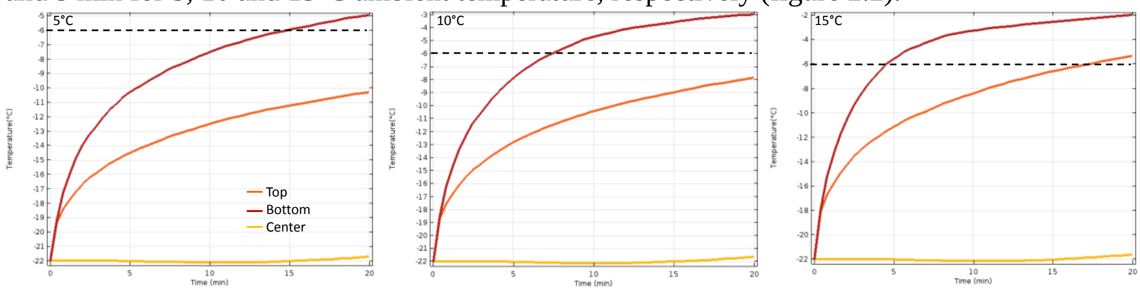

Figure 2.2: Temperature calculated on the bottom, top, and center of the peas package over time and ambient temperature (5,10 and 15°C). Dotted line identifies the thawing temperature.

4. Conclusion

To study the packaged frozen vegetables (peas, spinaches and eggplants) thawing as influenced by the working environment temperature, 3D finite element model able to describe the heat transfer, inside and on the surface of the packages, was developed and validate. From an industrial point of view, a specific exponential relation was determined to identify the time required to reach the initial thawing temperature at the critical area, over the working environment temperature.

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Evaluation of a mobile NIR spectrometer and cloud data analysis system for food quality rapid assessment

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Keywords: NIR spectroscopy, portable devices, food quality, multivariate statistical analysis

Summary
Near Infrared spectroscopy (NIR) is one of main techniques used in industry to determine food quality parameters in a rapid and nondestructive way. Recently, some simple and cheaper NIR spectrometers are becoming more common. The aim of this research was to evaluate the performance of the miniaturized NIR SCiO for the determination of quality parameters of some common foodstuff.
Vegetable (apples, peaches, pistachio and tomato paste), bakery (bread), diary (milk and cheese) and confectionary (chocolate) products were analyzed by using SCiO sensor and a common NIR tool (MATRIX TM-F, Bruker Optics). To estimate specific qualitative parameters classification and predictive statistical models were developed by using SCiO Lab tool and a commercial multivariate statistical software.
Similar results were achieved by using SCiO and classical NIR. In general, good models were obtained for all food products with determination coefficients (R^2) range from 0.765 to 0.991. Considering the final consumer demands, the SCiO solution appeared a suitable instrument for a rapid evaluation of many food quality indexes.

1. Introduction
In recent years a significant increasing of the interest for food quality was observed both in industrial and consumer environment (Zou and Zhao, 2015). Near Infrared spectroscopy (NIR) is one of main techniques used in industry to determine food quality parameters in a rapid and non-destructive way (Fu et al., 2015; Huang et al., 2008). However the common NIR tools are expensive and hard to use (Ozaki et al., 2007). Recently, some simple and cheaper NIR spectrometers are becoming more common (Girgenti et al., 2009). Particularly the SCiO solution (ConsumerPhysics, Inc) combines two powerful technological components, the SCiO NIR sensor, and the SCiO cloud.
The SCiO sensor is a low cost (about 250$) handheld NIR spectrometer (750-1050 nm) that fits in the palm of the hand and transmits the spectra, via bluetooth, directly to a smartphone app. The SCiO cloud can stores a huge database of spectral data and provides the statistical models for their interpretation. After collecting the required spectra, a specific web tool (SCiO Lab) can be used to analyze the data, and generate the model (www.consumerphysics.com).
The aim of this research was to evaluate the performance of the SCiO System for the determination of quality parameters of some common foodstuffs and compare the results with those obtained by a *professional* NIR spectrometer.

2. Materials and Methods
SCiO solution (Consumer Physics Inc.) combines two integrated technological components, the SCiO Sensor and the powerful SCiO Cloud. The sensor is a miniaturized Near Infrared Spectrometer (750-1050 nm), composed by a patented optical head of just a few millimeters in size. The low power consumption and zero warm up time make it highly responsive and extremely efficient, allowing it to perform hundreds of scans from a small rechargeable battery (Figure 2.1).

Figure 2.1: SCiO sensor.

In order to evaluate the potential of SCiO sensor for estimating food quality parameters, several foodstuff categories (fresh and packaged) have been analyzed:
- egg-product: yolk percentage (5-90%);
-chocolate bars: cacao percentage (46, 50,52,60, 70, 85, 90 e 99%);
-cheese: fat content (range: 9-34%);
-milk: fat content (0.05-3.6%);
-bread: four typology (cereals, white, durum wheat and integral); carbohydrate content (37.5-48%);
-apples: four typology (Fuji, Golden, Granny Smith and Stark); solid soluble content (10.9-14.4 °Brix);
-peaches: solid soluble content (10-13.7 °Brix);
-tomato paste: solid soluble content (4-7.8°Brix).
-pistachio: geographical origin (Italy, Iran, Turkey);
To estimate specific qualitative parameters, classification and predictive statistical models were developed by using SCiO Lab tool. This web app is an easy-to-use tool that enables you to customize SCiO to meet your specific material analysis needs. After collecting the required spectra, by using SCiO Lab it is possible to pretreat the spectra, create the models, and generates the algorithm. Models are then deployed in the cloud and used to analyze materials with SCiO devices. Chemometric models run on a linearly scalable architecture, which allows us to provide fast response times to a practically infinite number of users and devices.
In order to compare the performance of the SCiO sensor with those obtained using a professional NIR spectrophotometer, some products were also analyzed by using a Matrix-F spectrophotometer (Bruker Optics) equipped with a fiber optic probe. Each spectrum (800-2500 nm) was obtained from an average of 32 scans, and a spectral resolution of 5 nm. Predictive (PLS) and classification (PCA) models were developed by using The Unscrambler 9.7 (Camo Software).

3. Results and Discussion

In general, good models were obtained for all food products (Table 1). As concerning the dairy products, fat content was predicted by a R^2 of 0.947 and 0.952 for milk (RMSE=0.28%) and cheese (RMSE=1.8%), respectively. Samples belonging at five type of bread (white, cereal, integral and durum wheat) were corrected classified (97%) and the carbohydrate content was estimated by a R^2=0.937 (RMSE=1%). Optimal results was achieved for the cacao percentage in chocolate bars (R^2=0.979, RMSE=2.3%) anf for the °Brix in tomato paste (R^2=0.975, RMSE=0.23°Brix). Results obtained for the fruits are slightly lower, probably due to the high heterogeneity of the product and to the unsuitable sampling (restricted reference value range).

For the peaches, soluble solid content was determined with a R^2=0.765 (RMSE=0459°Brix), while five type of apples were classified with a performance index of 89%.
On average, 86.2% of pistachio samples are correctly classified (98%, 76% and 71% of samples from Italy, Iran and Turkey). It is interesting to note that incorrectly classified Turkish samples are confused with Iranian ones and vice versa. This is probably due to a more similar composition of Iranian and Turkish pistachios than Sicilian one.
Good results were achieved by developing two different classification models between Italy and Iran and Italy and Turkey, respectively. All samples have been correctly classified.

Table 3.1: Results obtained by using SCiO solution.

Product	Reference parameter range	R^2	RMSE
Egg product	Yolk: 0-90%	0.991	2.5%
Chocolate bars	Cacao: 46-99%	0.982	2.6%
Cheese	Fat: 5-35%	0.954	1.8%
Milk	Fat: 0.05-3.7%	0.947	0.28%
Bread	Carbohydrate: 37.5-48%	0.937	1.0%
Apple	°Brix: 10.9-14.4	0.769	0.41°Brix
Peach	°Brix: 10-13.7	0.765	0.46°Brix
Tomato paste	°Brix: 4-7.8	0.975	0.23°Brix

Similar results were obtained also by using the professional NIR. Cacao percentage, bread carbohydrate percentage and apple soluble solid content (°Brix) were estimated with R^2 of 0.993 (RMSE= 1.49%), 0.937 (RMSE = 0.9%) and 0.774 (RMSE=0.42°Brix), respectively (*full-cross validation*).

4. Conclusion

Results obtained using SCiO and the *professional* NIR are clearly comparable, considering also that the operating spectral ranges are different. Specifically, the professional NIR operates in a much wider range (800-2500 nm) that allows to obtain more information on the product composition.
Furthermore, differences between results can be ascribe to the statistical techniques used to develop estimation and classification models.T he statistical models used by the SCiO system are considered as an unpublished company data.
Considering the final consumer demands, the SCiO solution appears a suitable instrument for a rapid evaluation of some food quality indexes.

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Application of NIRs spectroscopy for rapid evaluation of grape health status directly at the grape consignment: comparison of measurement methods

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Keywords: Quality, Optical analysis, winery, chemometric

Summary
The aim of this work was to investigate the applicability of NIRs spectroscopy for rapid grape infection assessment in a view of a grape classification directly at the check point station entering the winery.
The experimentation was conducted on white and red varieties (Vitis vinifera L.), using grape bunches naturally infected with Botrytis cinerea, powdery mildew (Erysiphe necator) and sour rot, the major grape diseases. The research tested two devices: (i) a compact vis/NIR device for analysis of flows and/or non-homogeneous product, on grape bunches and (ii) a vis/NIR and NIR device suitable for grape musts. Classification analysis (Partial Least Squares – Discriminant Analysis, PLS-DA) was applied on bunches and musts spectra in order to test the performance of NIRs devices to classify healthy and infected samples.
The results obtained from PLS-DA models, in validation, gave values of correctly classified samples (accuracy, %) between 89.8% and 91.1% for grape bunches and between 70.5 and 87.5% for grape musts.

1. Introduction
The grape selection at the check point station entering the winery is a particularly delicate phase to obtain a qualitatively good product, especially for big companies such as cooperatives with a high number of partners, hence with different soil characteristics, cultivation methods, and cultivation techniques.
Nowadays, quantification of diseases on wine grapes is commonly visually performed, estimating the infected portion of grape bunches by wineries experts (Hill et al., 2014, 2013). A price penalty downgrades the grapes value up to 50% of vine growers' income.
A more objective quantification method is desirable to help wineries in taking decisions about downgrading of grapes. Therefore, the development of an objective and timely method for measuring the quality and the infection status of the grape, directly at the check point station, could be the solution. The application of optical techniques could minimize contentious between the members and the winery inspectors and could improve the management of the vinifications standardizing the grape quality and therefore the wine. Visible near infrared (vis/NIR) and near infrared NIR (NIRs) spectroscopy, image, and multi/hyperspectral analyses are the most applied techniques in the food sector for the quality evaluation (Guidetti et al., 2012).
The aim of this work was to investigate the applicability of NIRs spectroscopy (initial testing phase in controlled lab-scale condition) for rapid grape infection assessment in a view of a grape classification directly at the check point station entering the winery.

2. Materials and Methods
Sampling was performed during the grape harvest period on bunches deriving from different white and red grapes varieties (Vitis vinifera L.). Grape bunches were naturally infected with Botrytis cinerea, powdery mildew (Erysiphe necator) and sour rot, the major grape diseases, and were collected directly from the consignment wagons at the check point station entering the

winery. Grape musts were obtained using a mechanical arm (Figure 2.1), equipped with pump and mechanical shredder to pick and cut the bunches at different levels of consignment wagons. The grape musts are then directed to the tank (quality assay apparatus), where the musts wait for the traditional and commonly quality analysis (soluble solid content and acidity).

Figure 2.1: Mechanical system for the grape musts production to be sent to the quality assay apparatus

Two devices were tested:
- device I: a compact vis/NIR device (Corona process, Zeiss, Germany) capable to perform measurements at a variable distance between sensor and sample of 80-600 mm. The optical system (400-1650 nm) was applied on bunches, and spectra were acquired in reflectance mode (Figure 2.2a), simulating measurements on consignment wagons, at the check point station. The measurements were performed at about 30 cm between sensor and sample, simulating the real distance between sensor and samples in a future real scale application.
- device II: a vis/NIR and NIR device (MCS600, Zeiss, Germany) suitable also for liquid matrices, with a reflection probe (Gladius, Hellma, Germany) for grape must measurements in the optical range from 430 and 1650 nm (Figure 2.2b). For the real application on must, resulting from the grape taken in a representative way from the consignment wagons at the check point station, this measuring system could be implemented to the quality assay apparatus.

Spectral measurements were carried out on healthy and diseased samples, for a total of 2559 bunches, and on musts, derived from healthy and diseased grape, for a total of 88 samples (Table 2.1).

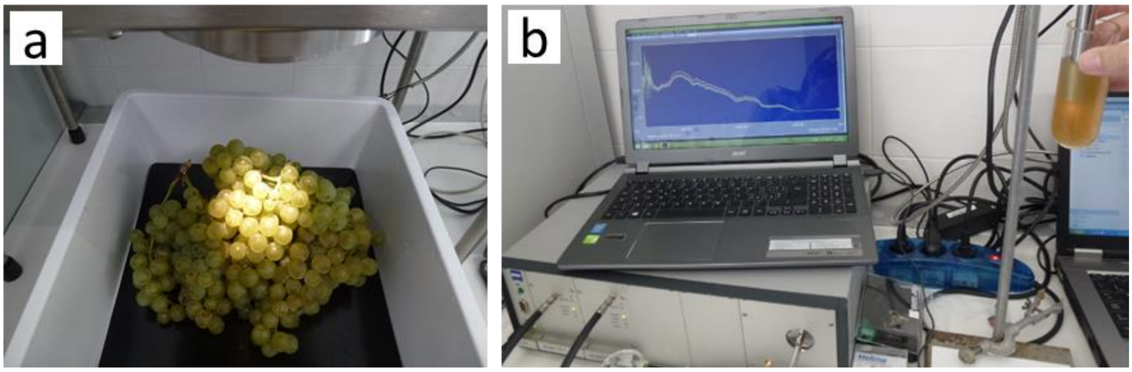

Figure 2.2: Acquisition method using (a) device I on grape and (b) device II and immersion probe on grape must

Table 2.1: Sampling of grape bunches and grape musts

Samples	Healthy samples (%)	Infected samples (%)	Total (n° of samples)
Grape bunches			
White grape	50	50	1184
Red grape	47	53	1375
Total	48	52	2559
Musts			
White grape	63	37	40
Red grape	61	39	48
Total	62	38	88

Regarding the data analysis, partial least square discriminant analysis (PLS-DA) method was applied to classify healthy and infected samples, for both bunches and must spectra. The chemometric analyses were performed using the Unscrambler 9.8 software package (CAMO ASA, Oslo, Norway). Vis/NIR spectra were pre-processed using moving average smoothing for a reduction of the effects caused by the physiological high variability of samples. PLS-DA accomplishes a rotation of the projection to latent variables focusing on class separation. A matrix of artificial (dummy) variables, assuming a discrete numerical value (zero or one), was used as Y data. The Y dummy matrix is constructed to ensure that the value of the objects belonging to the class corresponds to one, and the value of all other objects corresponds to zero (Musumarra et al., 2005). All the classification rules were evaluated using a cross-validation leave-more-out procedure (Casale et al., 2008) and the PLS-DA cut-off value was fixed at 0.5. To evaluate the effectiveness of the classification models correctly classified samples (accuracy, %), were calculated.

3. Results and Discussion

The spectral data were used for the elaboration of PLS-DA classification models to classify the spectra as healthy or diseased samples, for both grape bunches and grape musts. Table 3.1 shows the results arising from the different analyzed groups of samples, obtaining different classification models considering (i) the white cultivars, (ii) the red cultivars, and (iii) the combination of all the analyzed samples; for both bunches and musts. For each PLS-DA model, the percentage of correctly classified samples (accuracy) was reported (Table 3.1).
In this preliminary work, overall results are encouraging. For grape bunches, the percentage of accuracy (in cross-validation) ranged from 89.8%, for the red grape set to 91.1%, for the white grape group.
Regarding the spectra acquired on grape musts, classification models showed in cross-validation a percentage of accuracy ranged from 70.5% (total model) to 87.5% (white grape model). Considering separately spectra acquired using the two devices and hence the different matrices, the best models were obtained for grape bunches, and better for the white grape data set. This behaviour is possible to the clear color of the white grape that allow a clearer identification of infected bunches, specially in the visible range.

Table 3.1: Correctly classified samples (%) derived from the PLS-DA classification models calculated for different sample sets (white varieties, red varieties and total samples) of grape bunches and grape musts

Samples	Total (n° of samples)	Accuracy (%)	
		Calibration	Cross-validation
Grape bunches			
White grape	1184	91.6	91.1
Red grape	1375	90.0	89.8
Total	2559	90.2	89.9
Musts			
White grape	40	92.5	87.5
Red grape	48	89.6	81.1
Total	88	75.0	70.5

4. Conclusion

Overall, chemometric models deriving from the elaboration using bunches spectra are better than models calculated using musts spectra. The sample number used for calculating the PLS-DA models from bunches spectra is more than 10 times higher than that from musts acquisitions. Enhancing the number of must samples, the classification models could improve their performance.

However, further studies are needed to determine the best operating conditions and the engineering phases to perform the measurements directly at the consignment check point station, in a view of a final online application.

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Influence of pressing temperature on hemp seed oil quality

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Keywords: hemp oil, mechanical oil extraction, oil acidity, peroxide value, sensory analysis, volatiles

Summary
For pressed seed oils, as well as in virgin olive oils, the sensory properties have a great importance in define oil perceived quality, being the pressed oils are subjected only to filtration. This way, flavour and sensory notes of pressed oil reflects the kind of plant seed used, the quality-freshness of seeds and the post-harvesting history, the pressing technology and conditions used during oil extraction. This work was designed to evaluate the effect of pressing temperature on extraction yield, fatty acid composition, sensory properties and flavor of pressed hemp (*Cannabis sativa L.*) oils. Volatile compounds, studied by SPME-GC/MS, showed clear differences in oils obtained at 50°C and 70°C as well as the seed pre-heating step have an effect of volatile and sensory profile. The relationship among sensory notes and volatile molecules find in the headspace profiles are discussed with emphasis of some 'cooked' and 'roasted' notes.

1. Introduction
Hemp (*Cannabis sativa L.*) is an annual herbaceous plant, not very demanding and adaptable at any soil type, cultivated since the ancient times as food source and medicine (Callaway, 2004). Not only the fiber is interesting for its numerous uses, but also the seeds can be used in different applications (Matthaus and Bruhl, 2008). Hemp seed contains 20-25% in protein, providing reasonable amounts of eight amino acids essential to human nutrition (Matthaus and Bruhl, 2008; Deferne and Pate, 1996), 20-30% in carbohydrates and 10-15% in insoluble fiber (Deferne and Pate, 1996), as well as a rich array of minerals, particularly phosphorous, potassium, magnesium, sulfur and calcium, along with modest amounts of iron and zinc (Deferne and Pate, 1996). Hemp seeds contain approximately 25-35% oil (Deferne and Pate, 1996; Matthaus and Bruhl, 2008; Teh and Birch, 2013). Hempseed oil contains 80% of polyunsaturated fatty acids (PUFAs) (Teh and Birch, 2013), notably linolenic acid (C 18:3, n-3) and linoleic acid (C 18:2, n-6) (Teh and Birch, 2013). Hemp seed oil possesses a well-balanced proportion of linoleic acid (n-6 PUFA) and α-linolenic acid (n-3 PUFA) in the ratio 3:1 (Teh and Birch, 2013; Oomah et al., 2002). These essential fatty acids possess beneficial properties to human health such as anti-inflammatory, anti-hypertensive, anti-vasoconstrictive, anti-cancer, anti-thrombotic, lowering of low density lipoprotein (LDL) (Teh and Birch, 2013). Because of the high grade of unsaturation, hemp oil should be stored in dark and cool places in order to avoid oxidation and development of rancidity. Currently, oil extraction from hemp seed, suitable for human consumption, is carried out by cold-pressing methods (screw press or hydraulic press), that not require organic solvents or heat. Cold-pressing process neither involves heat or chemical treatments, and is becoming more interesting than the conventional practices, also because the increasing consumers' desire for natural and safe food products (Yu et al., 2005). Very few data are available on the sensory properties of hemp oils obtained by pressure (Callaway and Pate, 1996). Processing parameters, in addition to seed composition and

storage, may affect the quality of pressure seed oils both in term of its nutritional and sensory properties. Hemp oils, in fact, due to the high PUFA content can be deteriorated by oxygen, temperature, light, moisture, enzymes and metal trace. No data are present in the literature on the effect of pressing conditions on the quality and composition of hemp oil, as well as on the flavour modification of hemp oil during storage and shelf-life. For this purpose, volatile compounds of hemp oils obtained by the same seed batch extracted by using different pressing temperature and thermal pre-treatment of seeds were analyzed by solid phase micro-extraction coupled with gas chromatography / mass spectrometry (SPME-GC/MS) and sensory properties assessed by a trained panel.

2. Materials and Methods

2.1 Hemp seed material

In this study, dried hemp seeds ('USO 31' variety) were obtained from an experimental trial in Southern Italy. The oil content from untreated samples was about 33.77 ± 0.12 (% w/w) and it was determined using solvent extraction with ASE®200 (Accelerated solvent extraction) Dionex (Faugno et al., 2016).

2.2. Oil extraction by mechanical pressing

In this study hemp oil was obtained with a mechanical screw press powered by 2.2 kW electric motor. Different sensors were installed for measuring temperature (RTD, Pt100), rotation speed of the screw and oil recovery (Karaji and Muller, 2011; Faugno et al., 2016). The sensors were connected to a data-logger and data transferred to a laboratory computer (Sigh and Bargall, 2000; Uquiche et al., 2008; Stanisavljevic et al., 2009; Bordoni et al., 2010; Faugno et al., 2016). To evaluate the thermal effects of the mechanical extraction on virgin hemp oil quality, two parameters were studied: a) the initial temperatures of extraction: 50°C (T50) and 70°C (T70) of head press (Tambunan et al., 2012; Faugno et al., 2016); b) thermal pretreatment: yes (H) or not (NH) (Galloway, 1976; Singh and Bargale, 2000; Faugno et al., 2016). In order to determine the effect of extraction parameters on oil chemical quality, two different experimental setups were considered: Setup 1 with temperature of the press kept constant at 70°C, whereas the heating pretreatment was varied, and Setup 2, with temperature of the press kept constant at 50°C and the pretreatment was varied (Faugno et al., 2016). A nozzle of 8 mm diameter was used and a rotational speed of the screw of 22 rpm (Faugno et al., 2016). For each sample, 1000 g of seeds were used and three replicate were done (Unquiche et al., 2008; Faugno et al., 2016). The extracted seed oil was then centrifuged in a laboratory centrifuge in order to remove components that settled during storage (Unquiche et al., 2008; Faugno et al., 2016).

2.3. Chemical and Sensory analysis of hemp oils

Olive oil acidity (% oleic acid per 100 g oil) and peroxide value (meq O2 kg-1 oil) were carried out according to the UNI EN ISO 660:2009 and UNI EN ISO 3961:2013. Sensory analysis was carried out by eight assessors who were fully trained in the evaluation of VOO according to the IOOC method (1996) for virgin olive oils. Analysis of fatty acid methyl esters (FAMEs) were carried out by cold trans-methylation in KOH/methanol. The clear supernatant was used for GC analysis. Analyses of FAME were performed using a Shimadzu GC17A gas chromatography (Shimadzu Italia, Milan, Italy). Peak identification was performed by comparing the retention times of the fatty acids with those of pure compounds (mixture of pure methyl esters of fatty acids; Larodan, Malmoe, Sweden) injected under the same conditions. Volatile compounds analysis was carried out with a headspace solid-phase micro-extraction (HS-SPME) method coupled to gas chromatography-mass spectrometry (GC/MS) has been applied for profiling volatile compounds released from hemp oils according to Vichi et al. (2003), with slight modifications. Compounds identification was based on comparison of the retention times with those of pure reference compounds, analysed in the same conditions, and on computer matching against commercial (NIST 27, NIST 147, SZTERP) library mass spectra. Quantification was given in relation to the internal standard. Peak areas were calculated by using Labsolution acquisition system (GCMS Solution version 1.20; Shimadzu, Kyoto).

3. Results and Discussion

The extraction yield, basic quality parameters (free acidity and peroxide number) and fatty acid profiles of hemp oils obtained from the same seed batch by applying four different processing conditions are reported in Table 3.1. Free acidity and peroxide number do not show significant differences. A little effect of temperature can be observed for linolenic acid, which show lower levels at higher temperature treatments.

Table 3.1: Basic quality parameters and fatty acid composition of pressed seed hemp oils obtained with different pre-heating/pressing temperature (50-70°C)

	50° C	**H/50° C**	**70° C**	**H/70° C**
Free acid.	2.01 ± 0.10	2.31 ± 0.09	2.26 ± 0.12	2.48 ± 0.07
Perox. num.	1.38 ± 0.83	1.08 ± 0.60	2 ± 0.52	1.08 ± 0.09
Fatty acids:				
C 14:0	0,02 ± 0.1	0,02 ± 0.0	0,06 ± 0.2	0,02 ± 0.0
C15:0	n.d.	0,01 ± 0.1	0,02 ± 0.3	0,01 ± 0.1
C16:0	7,1 ± 0.2	7,89 ± 0.2	7,18 ± 0.4	8,22 ± 0.2
C16:1 ω9	n.d.	0,02 ± 0.3	0,07 ± 0.6	0,01 ± 0.2
C16:1 ω7	0,02 ± 0.0	0,01 ± 0.1	0,11 ± 0.1	0,04 ± 0.2
C17:0	0,01 ± 0.1	0,01 ± 0.2	0,07 ± 0.7	0,03 ± 0.4
C17:1	0,01 ± 0.3	n.d.	0,02 ± 0.5	0,01 ± 0.5
C18:0	2,75 ± 0.5	2,65 ± 0.1	2,85 ± 0.6	3,27 ± 0.1
C18:1 ω9	15,04 ± 0.3	14,98 ± 0.1	16,8 ± 0.4	16,02 ± 0.3
C18:1 ω7	0,67 ± 0.2	0,68 ± 0.2	1,11 ± 0.2	3,77 ± 0.2
C18:2	55,02 ± 0.1	54,95 ± 0.1	52,6 ± 0.1	54,37 ± 0.3
C20:0	0,94 ± 0.1	1,05 ± 0.1	0,86 ± 0.0	0,53 ± 0.0
C18:3 ω6	2,04 ± 0.1	2,14 ± 0.2	2,01 ± 0.0	1,73 ± 0.4
C18:3 ω3	15,34 ± 0.3	15,12 ± 0.1	14,8 ± 0.2	11,06 ± 0.2
C18:4 ω3	0,5 ± 0.2	0,03 ± 0.5	0,54 ± 0.1	0,22 ± 0.1
C20:2	n.d.	n.d.	0,06 ± 0.5	n.d.
C22:0	0,3 ± 0.3	0,01 ± 0.3	0,42 ± 0.3	0,32 ± 0.0
C22:1	n.d.	n.d.	n.d.	0,03 ± 0.2
C23:0	0,04 ± 0.2	0,08 ± 0.2	0,04 ± 0.2	0,01 ± 0.0
C24:0	0,09 ± 0.1	0,04 ± 0.2	0,19 ± 0.2	0,14 ± 0.2

The sensory attributes found on hemp oils by a panel (trained on virgin olive oil according to the IOOC procedure) were: “green-grass”, “hay-straw”, “woody”, “toasted-cooked-roasted”, “hazelnut”, “pumpkin-like”, “cucumber-like”. The extraction temperature seems to influence the intensity of different notes with a slight modification of the sensory profile in different oils. The composition of volatiles in hemp seed oils obtained by applying different processing temperatures was also studied by SPME-GC/MS. 63 molecules were detected and quantified, in particular aldehydes, esters, terpens, alcohols, ketons, hydrocarbons and furans. Oils obtained at lower temperature showed a lower concentration of volatiles except to furan-2-methyl. Hemp oils extracted at a temperature of 70°C, on the contrary, appear characterized by a high level of volatile compounds, mainly arising from lipid oxidation. The pre-heating of the seeds extracted at 70°C increases the concentration of some alcohols and aldehydes. The higher level of alcohols, terpenes, furan-2-ethyl and furan-2-pentyl was found in samples extracted at a temperature of 70°C without pre-heating of seeds. The analysis of these oil samples suggest that some volatile compounds arise from oxidation or Maillard reaction. These chemical phenomena can occur both during seed storage or pressing, and may strongly influence the final flavor and perceived sensory quality of pressure hemp seed oils, with particular emphasis on the 'roasted' and 'hazelnut' sensory attributes.

Conclusions

Our data indicate a strong influence of pressing temperature on the sensory and flavour profile of pressed hemp oils, thus inducing to optimize the technological condition of pressing. The fatty acid profile also confirmed that strong heating conditions can cause a decrease of the main PUFAs present in hemp seed oils. Further studies are in progress to optimize the seed conditions before pressing, the pressing temperatures and application of pre-treatments (i.e. ultrasound) in order to enhance the extraction yield and to ensure the hemp oil acceptability and shelf-life.

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Investigating and modeling the effect of temperature and shelf life in osmotic solutions on qualitative properties of Button Mushroom (*Agaricus Bisporus*)

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Keywords: modeling, mushroom, osmotic solution, temperature

Summary
The Button Mushroom (*Agaricus Bisporus*) includes the highest production of edible mushrooms in the world and its production rate is about 40% of the global production of edible mushrooms. Due to high moisture, the increase of its storage and shelf life should be critically attended. The purpose of modeling is to choose the most appropriate method for drying and the best operating conditions for producing the mushroom. First, mushroom is cut into uniform vertical slices of 5-mm-thickness and soaked in 1% citric acid solutions. During osmotic drying process, samples were removed from the solution under the effect of concentration at 3 levels (25%, 35% and 45% w/w) and temperature at 3 levels (40°**C**, 50°**C** and 60 °**C**), and in 14 consecutive times from 10 to 300 min. Reducing the variations of osmotic pressure and concentration between mushroom and osmotic solution, the driving force mass transfer, the intensity of moisture, and the brix increase will gradually reduce. At higher concentrations of sucrose in constant temperature and weight ratio, the absorption of solid substances rises by concentration increase. The absorption amount of solid substances has an increasing trend by temperature rises on the passage of time. According to kinetic of brix and result of water removal and absorption of solid substances during time, the high values of R^2 indicates that a model that proposed by Aurora et al. is suitable for predicting the percent of solid substances absorption and water removal.

1. Introduction

The Button Mushroom (*Agraicus Bisporus*) contains the highest production of edible mushrooms in the world and its production rate is about 40% of the global production (Giri and Prasad.2007). As FAO reported, the total production of edible mushroom in Iran is about 28000 ton. Mushrooms contain 20-40% protein which is based on its dry weight and have more and better quality protein than vegetables and fruits. However, due to high moisture, the increase of its storage and shelf life should be critically attended. The corruption of mushroom is high and it has short shelf life at environmental conditions.

Walde *et al.* reported that drying method is cheaper way than other ways of food keeping, despite mushroom is a heat sensitive material (Walde *et al.*, 2006). Due to use of temperature and long drying time drying method is harmful for mushrooms quality indicators. So choosing an appropriate way for drying is the main reason of a successful process. (Giri and Prasad 2007).

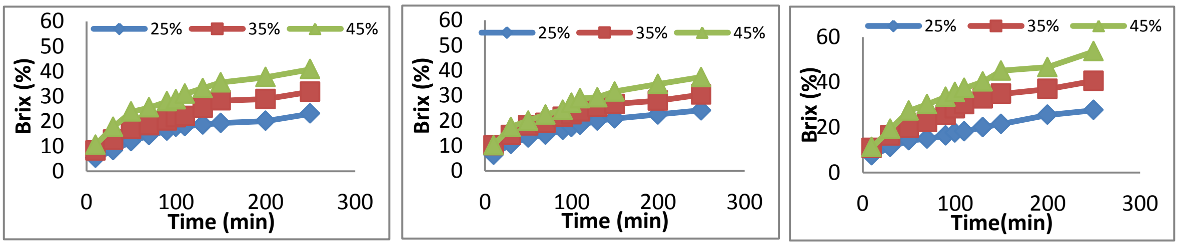
Using pre-treatment in preparation of the product can reduce the thermal harmful effects on qualitative indicators such as color in supplementary drying, energy consumption, and drying time; furthermore, it can increase the process efficiency. Osmotic dehydration is a pretreatment of removing some water of foods by putting them in a hypertonic solution. In this process the cells walls of foods acts as a semi permeable membrane. The density gradient among osmotic solution and other liquids in the cells make propulsion needed for removing water from the foods. Osmotic drying process is used for reducing water activations and increasing the shelf life (the maintenance time) of the products. Various parameters (i.e. temperature, osmotic solution concentration, and time) on the kinetics of solid substances absorption, removal of water and brix are investigated and analyzed. The purpose of modeling is to choose the most appropriate method for drying and the best operating conditions for producing the mushroom. In this study, the effect of osmotic dehydration process with supplementary drying for quality improvement and reducing energy costs on mushroom product were investigated.

2. Materials and Methods

At first mushrooms which sorted by size and maturity is choose for washing and cutting in to uniform vertical slices of 5mm thickness. In order to prevent sliced samples contacting with air and limiting browning reactions, the provided slices are soaked in 1% citric acid solutions food grade. The surface moisture of mushroom samples is removed then a drop of mushroom which is extract by squeezing is distilled on refract meter for measuring primary brix of sample and the measure which shows the brix of sample. The samples are weighted with a scale of 0.001 gram precision.
The osmotic solutions were prepared with dissolving sugar in water with weight ratio of 1:15 of product turned to osmotic solutions with 25-35-45 percent density. Before doing each test, the solutions is put in water bath (WNB,Memmert laboratory, Germany) then mushroom samples is submerged in solution by observing the weight ratio of mushroom to osmotic solution. Osmotic drying is done in 40, 50, 60 °C tempratures.
The water bath is used for providing the temperature needed for this test and in 14 consecutive times of 10, 20, 30, 40,…300 minutes. The samples extracted from solution then after rinsing, the remained solution removed from the surface of samples with filter paper. The brix, removal of water and solid substances absorption of osmotic samples are measured and recorded in these times. This investigation was conducted in a completely randomized design (CRD) by factorial method.

3. Results and Discussion

In order to check the kinetic of button mushroom osmotic drying, the changes of mushroom samples brix is weighted at consecutive time and different temperatures which are shown in Fig. 1.



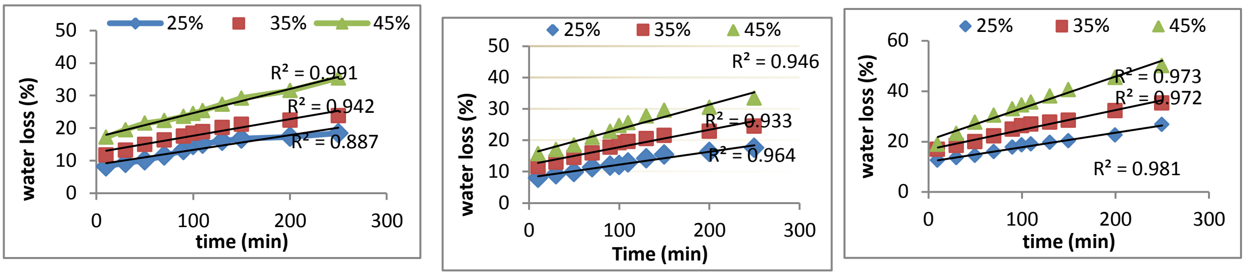
a) 40°C b) 50°C c) 60°C

Fig. 1: The effect of time and concentration of osmotic solution on the Brix at a) 40, b) 50, c) 60°C

In osmotic drying some amount of soluted substances penetrated in the tissue of mushroom at the same time of moisture exiting from foods because of density changing. As expected, the amount of mushroom brix increased during the osmotic process.
The results showed that there is a meaningful difference for mushroom in 40, 50°C temperature but it is obvious that the amount of mushroom brix increased with increasing of solution temperature and it was high at the beginning of the process. Rapid sucrose absorption at the beginning of process causes structural changes, surface layers compaction and increasing of resistance against mass transfer (Sutar and Gupta 2007).
The percentage of water removing in different density (25%, 35%, 45%) are shown in Fig. 2. It is evident that water removing of mushroom increased with passing the time. The finding was confirmed by Sutar and Gupta, 2007; Abud-Archila et al., 2008. According to Fig. 2c, the amount of water removing in 60°C is more considerable. To access the more water loss, higher temperature can be used. Doing osmotic process in higher temperatures causes penetrating

changes in cell wall. So the permeability and sucrose increases (Abud-Archila, 2008). Using higher temperatures causes swollen and plasticize of cell membrane and increase the moisture emission.

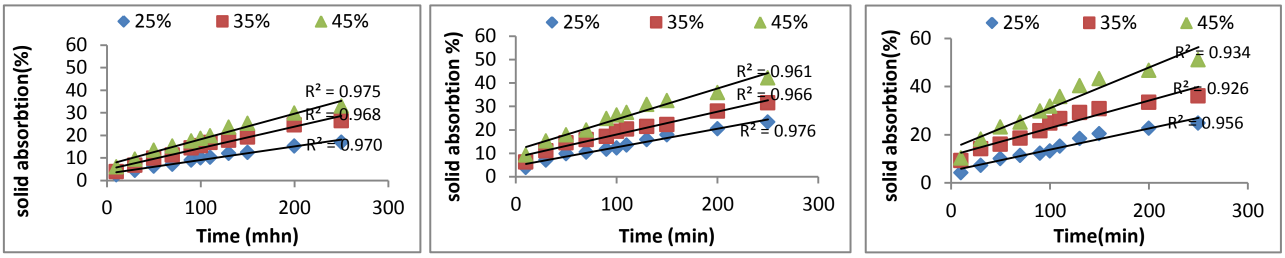
Furthermore, the osmotic solution viscosity reduced with increase of temperatures. It can be effects on chemical mixture and product properties. In addition to increasing mass transfer rate, temperature increasing causes speed up chemical reactions which is effective on choosing optimum process (Mujumdar 1995)



a) 40^{o}C b) 50^{o}C c) 60^{o}C

Fig 2: The percentage of water removing in three density levels and temperatures of a) 40^{o}C, b)50^{o}C, c)60^{o}C

Fig. 3 shows the percentage of solid substances at three density level (25%, 35%, 45%) and temperatures (40, 50, 60^{o}C) during 250 min. As shows in Fig 3a & 3b, there is not a considerable change in both densities for solid substances absorption of mushroom in 40^{o}C and 50^{o}C temperatures during 250 min.



a) 40^{o}C b) 50^{o}C c) 60^{o}C

Fig. 3: Percentage of solid substance absorption at three density level (25%, 35%, 45%) and temperatures (40, 50, 60^{o}C)

However As expected the trend of progressive increases in the amount of mushroom solid substances absorption with increasing of temperature by increasing the time until 250 min (Fig 3). A similar solid substances absorption trend was observed by Jalaee *et al.*, (2010).

4. Conclusion

The high value of R^2 shows consistency of Arora *et al*., (2003) proposed model for predicting the percent of solid substances absorption and water losses. As it is expected because of mass transfer propulsion increases in higher density of sucrose with fixed temperature and weight ratio, solid substances absorption increase with density increasing which is consistent with the Sutar and Gupta (2007) results.

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Rotased - A Patented Innovative system for the clarification of Olive Oil

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Keywords: Separation plant, Disc stack Centrifuge, Polyphenols content, Oxidative reactions

Summary

Extra virgin olive oil (EVO) quality is strictly related to the extraction process, which consists of the breakage of olive fruits to obtain a paste that is firstly malaxated and then centrifugated to obtain an oily must, which still contains small amounts of residual vegetative water and impurities. In order to improve the clarification a further stage is required, generally performed by a vertical disc stack centrifuge separator, but some authors showed that using that separator, negative effects are produced on olive oil quality mainly due to the loss of stability and oxidative reactions.

In the present paper, authors, using a patented innovative clarification system named Rotased in comparison with the traditional separation system, show the results on clarified olive oil in terms of both chemical and physical properties. Rotased shows a positive effect on olive oil quality, both after 48 hours and 5 months from the treatment. In particular, olive oil obtained with Rotased was characterized by significant differences (p-values<0.05) in Polyphenols content (POL), Peroxide values (PV), and other chemical properties. Collected data will be useful in order to optimize the operating parameters of Rotased and develop the machine to apply at industrial scale.

1.Introduction

Extra virgin olive oil (EVO), the most characteristic fat used in the Mediterranean region, is a natural product obtained by simple pressing of olive fruit (*Olea europea*), using only mechanical or physical methods, such as pressing, washing, decantation, centrifugation and filtration that do not modify its characteristics (Koidis *et al*., 2006; Fortini *et al*., 2015).

EVO quality is strictly related to several factors: olives and harvesting system, extraction process, olive-paste kneading (Leone *et al*., 2014) and separation of oil from the other phases by pressure or centrifugation (Di Giovacchino *et al*., 2002; Tsimidou *et al*., 2015). The mechanical extraction process of EVO mainly consists of three phases: (a) preparation of paste (crushing and malaxation); (b) separation of oil from solid and liquid phases, known as oily must (oil and wastewater), (c) separation of the liquid phases (oil and wastewater) (Altieri *et al*., 2014). After the extraction, final cleaning of the olive oil is required because the extracted oil still contains a certain amount of residual water and impurities. A vertical disc stack centrifuge separator generally performs this further cleaning step, but recently some authors showed that negative effects are produced on olive oil quality, due to the loss of stability and oxidative reactions (Masella *et al*., 2009). In this paper, authors show the design criteria and operation of an innovative clarification system named Rotased.

2. Materials and Methods

The effects of the innovative separator with vertical axis, used for the solid/liquid and liquid/liquid separation of liquid foods (see Fig. 1) were assessed in terms of chemical-physical properties change on olive oil, through comparative tests carried out in an olive oil mill.

Five replicates of approximately 2500 kg of olive drupes (*mix of* Coratina, Ogliarola and Leccino olives) were processed and, at regular time intervals during the olive oil extraction process, the following samples were collected: *Control* (oily must samples collected from the decanter), *Sedoil* (oily must samples collected from Rotased) and *Cenoil* (oily must samples collected from the traditional vertical disc stack separator).

Figure 1. Rotased used for Sedoil treatment.

Within 48 hours after the treatment, and after 5 months, the following parameters were evaluated: free acidity (FA), peroxides (PV), chlorophylls (Chlo), carotenoids (CAR), specific extinction coefficients K_{232} and K_{270}, total polyphenols (POL) and turbidity (TUR). All parameters were determined in triplicate.
FA, PV and UV-specific extinction coefficients (K_{232} and K_{270}) were determined according to the analytical methods of the European Official Method of Analysis (EU Regulations 2568/91). Acidity value, expressed as percentage of oleic acid, was determined by titration of a solution of oil in ethanol/ether 1:1 (v/v) with an ethanolic solution of potassium hydroxide.
PV, expressed as milliequivalents of active oxygen per kilogram of oil (mEqkg^{-1}) was determined as follows: a mixture of oil and chloroform/acetic acid 2:3 (v/v) was left to react in darkness with a saturated potassium iodine solution; the released free iodine was titrated with a sodium thiosulphate solution (0.01 N).
K_{232} and K_{270} extinction coefficients were calculated from absorption of oil samples at 232 nm (K_{232}) and 270 nm (K_{270}), respectively, with a spectrophotometer (UV/Vis Spectrophotometer, Ultrospec 2100 Pro) using isooctane as a blank.
Chlorophylls and carotenoids contents were determined by measuring the absorbance at fixed wavelengths of 670 nm and 470 nm, respectively, in hexane using spectroscopy. Results are expressed as mg kg^{-1}.
Total polyphenol content was evaluated using a spectrophotometric method. Phenolic compounds were isolated by a double extraction of oil with a methanol and water mixture (80:20 v/v). Total polyphenols were determined by adding the Folin-Ciocalteau reagent and a 20% sodium carbonate solution to a suitable aliquot of the combined extracts. After centrifugation, the absorbance at 725 nm was measured. The results are expressed as mg L^{-1} of gallic acid.
Turbidity (TUR) was evaluated by the nephelometric method with a turbidity meter (Delta Ohm HD25.2, Delta Ohm s.r.l.).The turbidity meter used in the study was carefully calibrated with formazine standards (0.05e800 NTU).

3. Results and Discussion

FA, measured 48 h after extraction, was not significantly different between *Sedoil* and *Cenoil*, and values were lower respect to the *Control* samples. This result suggests that olive oil cleaned using Rotased are stable as Cenoil, so suitable for long-term storage. With reference to PV, values were significantly different among the treatments: *Sedoil* highlights a significant PV reduction (-16.15%) with respect to *Control*, conversely, *Cenoil* highlights a significant PV increase (+14.63%) with respect to *Control*. PV measures hydroperoxides formation from polyunsaturated fatty acids in presence of oxygen, this value indicates how much product quality is affected by processing operations with regard to contact of oxygen both in environmental air and olive oil during the cleaning operation. This result confirms that the prolonged contact between oil and oxygen from environmental air, occurring into disc stack centrifuge, increases the olive oil oxidative alterations, as reported in other previous papers. The value of K_{270} and K_{232} extinction coefficients showed a lower value in *Sedoil* (0.183 and 1.489 respectively*)* with respect to *Cenoil* (0.205 and 1.693 respectively) and this result demonstrates that the influence of oxygenation during the disc stack centrifuge oil cleaning operation is significant in terms of primary oxidation. Besides their participation in redox reactions, chlorophyllic and carotenoid pigments are responsible for the oil color, considered an important quality parameter and an influent factor in consumer's preference. Pigments level seems to be not different both in *Sedoil* and *Control* treatment, while *Cenoil* results different respect to *Control*.

Mean values for total polyphenols content in *Sedoil* is 180.9 mg L^{-1} while in *Cenoil* and *Control* is 171.2 and 185.2 mg L^{-1} respectively. Polyphenols are recognized as antioxidant compounds and their presence in olive oils has been related to their general quality, improving stability, nutritional value and sensorial properties.

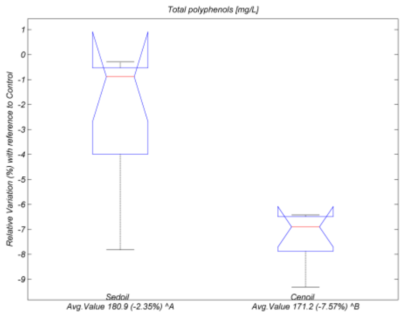

Figure 2. Box plot of polyphenols of olive oil collected sample after 48 h. For Sedoil and Cenoil treatment, in parenthesis is calculated the relative percent difference with respect to the Control's mean value.

TUR value of 93.7 NTU in *Cenoil* was significantly different respect to both *Sedoil* (94.1 NTU) and *Control* (129.6 NTU) confirming the efficacy of the innovative separation in the removal of impurities. Likewise, the *Sedoil* presents a cloudy aspect due to the content of small solid particles that are still present in the oil, providing an "organic" aspect in the respect of the required long term stability.

The results after 5 months show that storage time, regardless of the used treatment, dramatically affects the oxidation level of the olive oil. All the parameters used to evaluate the oxidation level (including FA, PV and K_{232}) increased after 5 months of storage. Conversely, the content of natural antioxidants (POL) and pigments (CHLO and CAR) in the olive oil decreased. Furthermore, whereas the PV, POL, CHLO, CAR, K_{270} and K_{270} average values show significant differences between treatments, the FA and K_{232} values do not show significant differences.

4. Conclusion

In this paper, the authors showed the experimental data obtained with an innovative separator, named Rotased, used for the final cleaning of the oily must before its subsequent bottling. From the data obtained at the end of the treatment, it is evident that the innovative separator is effective in cleaning the oil as well as traditional vertical axis separators, and it preserves the most important sensory and nutritional properties for the production of an extra virgin olive oil. After 5 months of storage, data shows that some parameters deteriorate due to the aging of the oil, not differently, from what would happen with the traditional process. Overall, the data represent the first step in the set-up of the plant to be used at industrial level for the production of a "cloudy" extra virgin olive oil.

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CFD modelling and simulation for assessing temperature distribution inside flour mills during heat treatments for insect pest control

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Keywords: Computational fluid dynamics, Thermal behaviour, Milling industry, Heat flux.

Summary
The heat treatment of the indoor environment of flour mills is an alternative to chemical fumigation for controlling insect pests. This method requires the increase of air temperatures between 45°C and 55°C, which should be maintained for a time interval of 36-48 hours to eliminate all the insect vital stages. However, some building components of the mill, such as floors, walls, and ceilings, can provide a refuge for insects from the heat, because their surface temperatures usually do not reach levels that are lethal to insects. Therefore, the objective of this research was to assess temperature distribution inside a flour mill during a heat treatment for insect pest control by computational fluid dynamics (CFD) modelling and simulation. The model was validated by means of experimental data acquired during a heat treatment carried out in a flour mill located in Sicily (Italy), representative of building materials and techniques used in the milling industry of South Italy.

1. Introduction

Milling is the operation of grinding cereals for the food industry. One of the most relevant problems, which regards the hygiene requirements of the grain processing environment, is the proliferation of insect pests at each life stage (Campolo et al. 2013). This happens because the products treated in the mill represent the ideal habitat for the proliferation of these pests.
In recent years, many techniques ecologically valid and alternative to the use of methyl bromide, which is a Class I ozone depleting substance, have been studied. Among these, heat treatment causes insect death by dehydration or alteration of basic functions of the organism. The heat treatment does not require the use of toxic substances but exposes the pests to high temperatures. The effect of the heat treatment depends both on temperature levels and exposure time (Mahroof, Subramanyam, and Eustace, 2003).
Since during the heat treatment unusual temperatures and air movements establish within the built environment of the mill, the objective of this study was the development of a CFD (Computational Fluid Dynamic) model for investigating the thermal behaviour of the mill indoor environment when subject to the forced ventilation of the fan heaters used to rise the indoor air temperature up to levels lethal to insects.

2. Materials and Methods

The flour mill analysed in this study is located in the province of Syracuse (Italy) and it was built in the 1980s. The plan of the mill is approximately rectangular and the five levels are connected by a reinforced concrete staircase and an elevator. The rooms used for grain processing have a reinforced concrete frame and insulated brick walls. The floors have cavities for the passage of the processed products from a floor to another.
The heat treatment of this mill was carried out on April 2014 and lasted 48 hours, from 4:00 p.m. of 24 April 2014 to 4:00 p.m. of 26 April 2014. The monitoring was carried out on the second floor, which was chosen for the presence of the plansifters, which are equipment sensible to high temperatures. The temperature increase is obtained by using fan heaters, which provided an output temperature of 70°C and a volumetric flow rate of 2500 m^3/h.

In the first phase of the modelling, a three-dimensional model of the second floor was built in CAD by using Autodesk® Autocad 2016 software. The building components of the mill, the size of the machinery within the grain processing environment, and the fan heaters were modelled by using the geometrical dimensions measured during specific field surveys.
The 3D model running with Autodesk® Autocad 2016 was imported into Autodesk® CFD 2016 in the second phase of the research aimed at the study of the indoor temperature distribution of the flour mill during the heat treatment. This software utilises a finite element approach (FEM) for model resolution and solve the set of partial differential equations governing fluid flow and heat transfer, which are the *Continuity equation*, the *Momentum equations*, and the *Energy equation*. Moreover, in the analysed model, forced convection was considered. At a preliminary stage, materials were assigned to the modelled building components. With regard to the properties of these materials, they were partially replaced to make them more similar to the real ones, using data acquired during the survey, from bibliographic researches related to similar constructions, and by using TerMus-PT Software (Acca Software, Italy). The final conductivity of the materials is shown in Table 2.1.

Table 2.1: Conductivity of materials

Materials and components	Conductivity (X, Yand Z) [W/mK]
Wall	0.231
Glass	0.78
Concrete	1.01
Steel	Linear relations with temperature
Roof	0.534
Air	0.02563

The domain of the three-dimensional model was discretised by the Automatic Mesh Sizing. In this way, the geometry was entirely evaluated and the meshes were automatically distributed on each edge, surface, and volume of the template.
Then, by setting the boundary conditions, the model was connected to the surrounding physical world and characterized by the internal thermal load. Boundary conditions, constant and non-provisional, defined the inputs and outputs of the model: in this model, according to the forced convection, one inlet region, located at the bottom of the cavity and two outlet regions, located at the top of the cavity and the top of the staircase, respectively, were identified. The outdoor air temperature (°C) was detected using a portable thermo-hygrometer and was reported in the model as surface temperature of both the external air volume and the external surfaces of the façades. The values of the mean air temperatures of the first and third floors, which were acquired by the company that performed the heat treatment, were input data for the model as the temperatures of the upper surface of the third floor and the underside of the first floor, respectively. At the cavity, the air velocity (m/s) was measured by using a portable anemometer. Finally, the incoming and outgoing air temperatures and volumetric flow rate (m^3/h) of the three fan heaters were assigned to the air output surfaces of the 3D models of the fan heaters.
With regard to the physical characteristics of the model, the fluid was considered incompressible, and a k-ε turbulence model was applied.
Concerning the measurements of air temperature and air relative humidity required for model validation, they were recorded before and during the heat treatment by using eight data-loggers Grillobee of Tecnoel (Italy), which were connected to temperature transducers manufactured by Rotronic Italia s.r.l. (Italy) and placed at different points on the floor in order to obtain a uniform field of temperatures. The measurements used for the validation were those acquired from 00:00 a.m. to 06:00 a.m., because in this time interval they could be considered stationary.

3. Results and Discussion

During the stationary period, the mean outside are temperature was about 20 °C, while the average temperatures of the lower and upper floors were 57.3 °C and 56.4 °C, respectively. Finally, the air velocity of 4 m/s was recorded at the cavity.

In the validation time interval considered, the temperatures detected by the data-loggers were stable with variations reaching a maximum of 2.22 °C and being 0.935 °C on average (*Figure 3.1*).

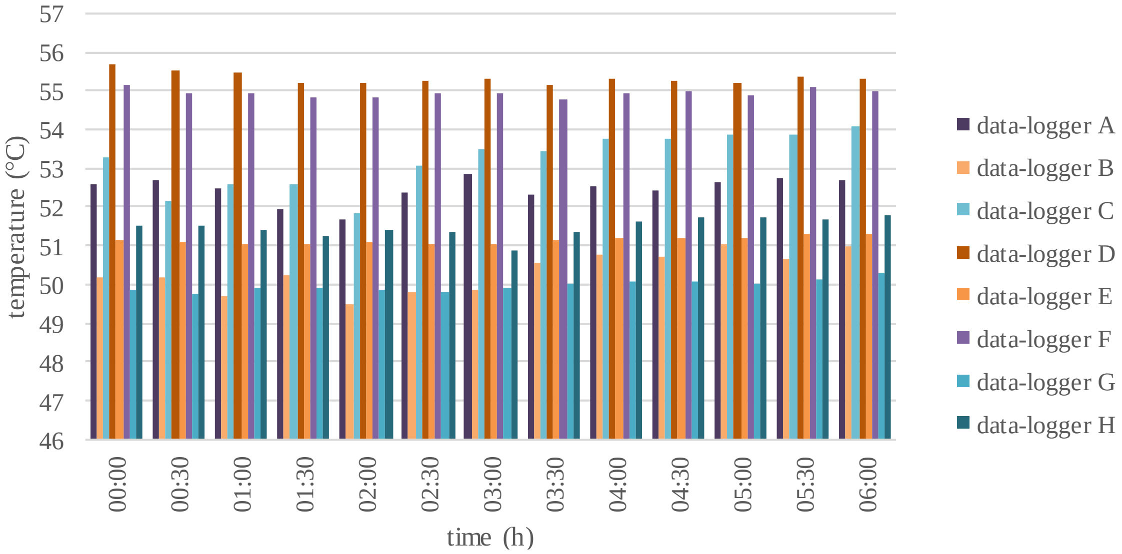

Figure 3.1: Air temperatures detected by data-loggers from 00:00 a.m. to 06:00 a.m. on 26/04/2014

In order to validate the model, the average air temperatures recorded by the data-loggers during the stationary period were compared with the air temperatures provided by the CFD model in the same positions of the data-loggers (*Figure 3.2*).
From the comparison between the average temperatures recorded by the data-loggers and the temperatures recorded at the same points within the CFD model, it was observed that the average deviation, in absolute value, was about 1.48 °C. Consequently, the CFD model is a realistic representation of indoor environment conditions during heat treatment.

Figure 3.2: Air temperatures detected by data-loggers from 00:00 to 06:00 on 26/04/2014

4. Conclusion

With the aim of improving the thermal performance of the building, the outcome of this study is of relevant importance in view of carrying out future building interventions in the mill. The building showed, in fact, "weak points" near the thermal bridges during the heat treatment, as found in other studies (Porto et al., 2015). Suitable interventions, which could be driven by both thermal and CFD simulations, can improve both machinery and building performances by modifications concerning the fan heaters and the building envelope, respectively.

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TOPIC 7

ORGANIC FARMING, SUSTAINABLE PLANT AND LIVESTOCK PRODUCTION PROCESSES AND TECHNOLOGIES

Assessment of an innovative aerobic treatment system based on hydrodynamic cavitation for N removal from the liquid fraction of pig slurry

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Keywords: hydrodynamic cavitation, manure, ammonia, greenhouse gases

Summary
Pilot-scale tests were performed with the objective to assess the effectiveness and environmental performance, in terms of ammonia (NH_3) and nitrous oxide (N_2O) emissions, of an innovative treatment method for nitrogen (N) removal from the liquid fraction of pig slurry (LFPS). The treatment method consists of the intermittent aeration of manure in a single tank by hydrodynamic cavitation (HC). It was found that the average N removal efficiency increased with increasing temperature (30.0% in winter under average environmental temperature of 8.4°C, vs 70.4% in summer with average environmental temperature of 25.3°C), and decreased with increasing the air bubbles diameter (23.3% with bubbles of air ~80 µm in diameter vs 38.6% with bubbles of air ~2.0 µm in diameter). High NH_3 and N_2O emissions were detected, regardless of HC performance and settings. When LFPS was exposed to a longer period of anoxic conditions both NH_3 and N_2O emissions increased. The air flow rate and air bubbles diameter did not affect N_2O emissions. In contrast, NH_3 emissions increased by 41.1% and 29.7%, respectively, when the air flow rate was reduced from 0.25 to 0.12 m^3 m^{-3} slurry h^{-1} and the average air bubbles diameter was reduced from ~80 µm to ~2.0 µm.

1. Introduction
In most European countries, animal manure is the major contributor to nitrate contamination of groundwater. In the context of the national and regional regulatory framework implementing the European Directive 91/676/CEE (Nitrates Directive), nitrogen (N) removal from animal slurry by biological processes is often a relevant approach for improving the management of manure on farms with a N surplus. Extended aerobic processes-based technologies in many configurations have been used successfully to reduce N concentration in animal slurry to low level (Burton and Turner, 2003). These systems are based on intermittent aeration of the manure so that specialized microorganisms can convert ammonium nitrogen in manure to nitrogen gas (N_2) through an aerobic (nitrification) phase and an anoxic (denitrification) phase. However, both processes can lead to high emission of ammonia (NH_3) and nitrous oxide (N_2O), especially with insufficient oxygenation conditions during nitrification (Beline and Martinez, 2002).
Traditional aeration systems used for this process are subsurface and mechanical (e.g., propellers, blades, or brushes). However, such systems have some limitations including low aeration efficiencies (mass oxygen transferred per unit power per unit time) and high energy demand (up to 10-20 kWh m^{-3} of treated manure) (Flotats et al., 2009). According to Groves et al. (1992), traditional aeration systems in wastewater treatment plant can account for up to 50% of total running costs. Recently, there has been increased interest in fine pore diffusion of air (FPDA) as a competitive system to increase treatment efficiency and oxygen transfer, as well as reduce power costs. However, FPDA has had limited investigation and the potential of air pollution related to the use of such a technology is also little known. This paper reports the results of a comparative study carried out with the objective to assess the effectiveness and environmental performance, in terms of NH_3 and N_2O emissions, of an innovative treatment method for N removal from the liquid fraction of pig slurry (LFPS). The treatment method consists of a single tank for the aerobic treatment of manure in which nitrification/denitrification process is activated by an aeration system (Biokavitus®) based on hydrodynamic cavitation

(HC). The effects of temperature, lengths of HC and anoxic periods, air flow rate, and cavitation air bubble diameter on N removal efficiency and gaseous emissions were assessed in pilot scale tests.

2. Materials and Methods

Two pilot scale batch experiments were carried out (Table 1), in summer (average environmental temperature: 25.3°C; Exp. 1) and winter (average environmental temperature: 8.4°C; Exp. 2) conditions, in an open-sided, roofed facility at the Dept. of Agriculture, Forest and Food Science (DISAFA) of the University of Turin (Italy).

Table 2.1: Experiments carried out and details of hydrodynamic cavitation (HC) settings.

	Environ. conditions	HC settings			Treatment ID
		Aeration cycles day^{-1} (n)	Air flow rate (m^3 m^{-3} slurry h^{-1})	Air bubble diameter (µm)	
Exp. 1	Summer	0	-	-	B0
		8	0.25	~80	B1
		1			B2
Exp. 2	Winter	8	0.25	~80	B1
			1.25	~80	B3
			0.25	~2	B4

For each experiment three plastic storage tanks (internal surface area: 1.0 m^2; total volume: 1.0 m^3), specifically equipped for this study, filled with 0.8 m^3 of the same LFPS, were used. Manure used in the experiments was collected from a pig-fattening farm in Cuneo, Piedmont (Italy). Each experiment lasted for 60 days. In Exp. 1 the effects of two management settings of HC (B1: 8 repeated treatment cycles per day, each consisting of 2h cavitation followed by 1h non-aerated stages; B2: one treatment cycle per day consisting of 8h cavitation followed by 16h non-aerated stages) were assessed and the results compared to those obtained with a control (B0: LFPS storage without cavitation). In Exp. 2 the effects of two air flow rates (0.12 m^3 m^{-3} slurry h^{-1}, 0.25 m^3 m^{-3} slurry h^{-1}) and two cavitation air bubble diameters (~80 µm; ~2.0 µm) were assessed. Ammonia and N_2O emissions during both HC and non-aerated stages were measured at least twice a week by dynamic chamber method using a photoacoustic gas trace analyzer (INNOVA 1412, AirTech Instruments A/S, Ballerup, Denmark) (Gioelli et al., 2016). At each sampling time, a floating polyvinyl chloride chamber (volume 0.05 m^3, surface area 0.18 m^2) was placed on the surface of the slurry and fixed in the middle of the tank for the entire measurement period. Each sampling lasted for 1 h. During measurements, a fan was linked to the chamber through a pipe to produce an air flow of 0.57 $m^3 \cdot min^{-1}$, equal to an air exchange rate of 11.2 min^{-1}. At the beginning and at the end of each trial, manure samples were collected and analysed for total solids (TS), total nitrogen (TN), total ammonium nitrogen (TAN), and pH according to standard methods (AOAC, 1990)

3. Results and Discussion

The main chemical characteristics of the slurry samples collected at the beginning and at the end of each trials are listed in Table 3.1. The average N removal efficiency increased with increasing temperature (30.0% in winter – Exp. 2, vs 70.4% in summer –Exp. 1), and decreased with increasing the air bubbles diameter (23.3% with bubbles of air ~80 µm in diameter vs 38.6% with bubbles of air ~2.0 µm in diameter, Exp. 2). Total solids removal efficiency averaged 44.2% in summer (Exp. 1) and 42.3% in winter (Exp. 1) conditions.

Table 3.1: Characteristics of pig slurry liquid fraction (LFPS) *at the beginning and at the end of each trial.*

Management	TS	TN	TAN	pH

	settings of HC	(%)	(g kg^{-1})	(g kg^{-1})	
Exp. 1 (Summer conditions)	Start (influent)	2.14	2.33	2.18	8.19
	End (effluent): B0	1.49	1.10	0.76	8.02
	B1	1.14	0.83	0.55	7.99
	B2	1.25	0.55	0.19	6.98
Exp. 2 (Winter conditions)	Start (influent)	2.19	2.02	1.47	8.04
	End (effluent): B1	1.46	1.55	1.30	8.06
	B4	1.27	1.45	1.21	8.50
	B5	1.06	1.24	1.21	8.34

High NH_3 and N_2O emissions to the atmosphere were detected during both the HC and non-aerated stages (Figure 3.1).

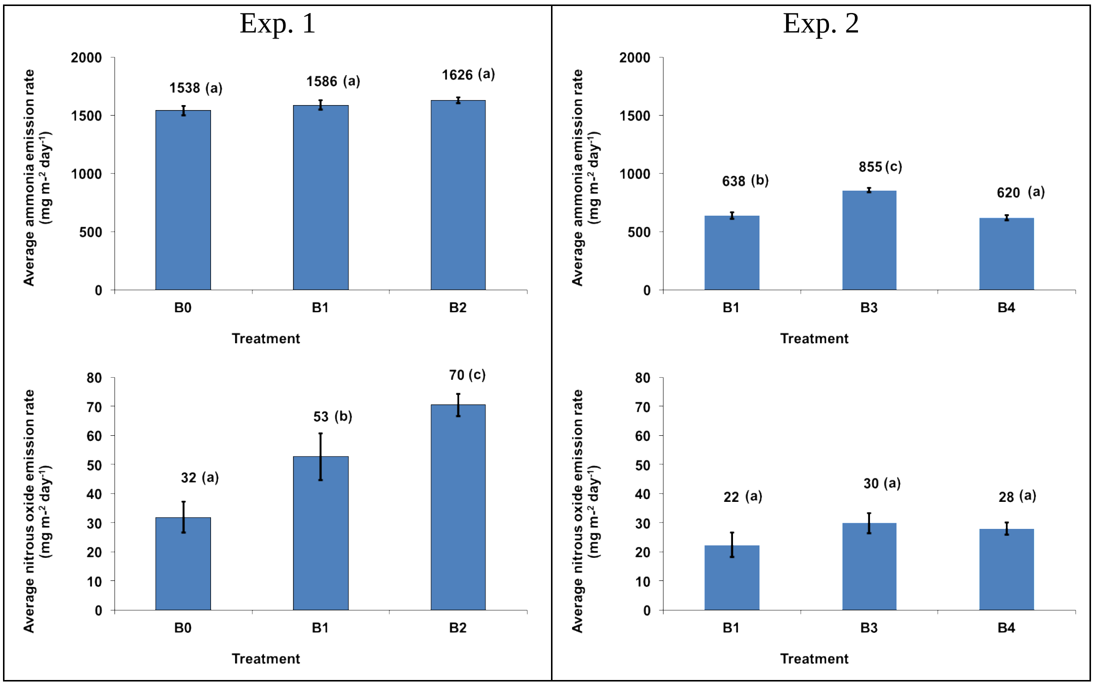

Figure 3.1: Ammonia and nitrous oxide emission rate recorded during Exp. 1 (summer conditions) and Exp. 2 (winter conditions). Values with the same letter are not statistically different each other for P>0.05 (Tukey Test)

Gaseous emissions varied seasonally, with the least emissions occurring in winter. When LFPS was exposed to a longer period of anoxic conditions (treatment B2, Exp. 1) both NH_3 and N_2O emissions increased. Specifically, the average daily N_2O emissions recorded during Exp. 1 from B1 and B2 resulted, respectively, 65% and 121% higher than those obtained from the control (B0). The air flow rate and air bubbles diameter did not affect N_2O emissions (Figure 3.1, Exp. 2). In contrast, it was found that NH_3 emissions increased by 41.1% and 29.7%, respectively, when the air flow rate was reduced from 0.25 (treatment B1, Exp. 2) to 0.12 (treatment B3, Exp. 2) m^3 m^{-3} slurry h^{-1} and the average air bubbles diameter was reduced from ~80 μm (treatment B1, Exp. 2) to ~2.0 μm (treatment B4, Exp. 2).

4. Conclusion

The present work confirmed that HC can be effectively used for N removal from the liquid fraction of pig slurry. However, high NH_3 and N_2O emissions were detected, regardless of HC performance and settings. Further trials are in progress to identify the optimal operating conditions (e.g., air flow rate, air bubbles cavitation diameter) for the successful implementation of this manure treatment technology in the livestock sector.

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Onion seeds: mechanical versus manual threshing, survey on quality parameters.

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Keywords: Seeds germination, Allium cepa, complete survey.

Abstract
Seed crops in Italy and in particular in Marche region represents a key sector thanks to the high value attributable to the productions [1] and the favourable environmental conditions. The total surface devoted to the production in 2014 was 26753 ha divided in main species of horticultural interest and aromatic plants. The sector was in steady increase (in term of cultivated surface) in the last decade. In 2014 Marche region represented the second producer in Italy with over than 7000 ha [2]. Excluding the aromatic plants, onion has the higher dedicated surface (in 2014). From a geographical point of view, three regions hold the absolute primacy, Emilia Romagna, Marche and Puglia. The total market value of seed crops in Italy was over 600 million euros and horticulture crops contributed with 28% of the total [3]. One of the shortcomings in seeds production is the high labour requirements for planting, harvesting and threshing. In order to reduce the economic costs of post-harvest and logistic operations some companies are making use of specific equipment for mechanical threshing. Unlike other crops, where high productivity is the primary object, for seed crops, the first target is the respect of high and narrow qualitative parameters. The beating elements movement could be the reason of breakage and squashing. The main object of this study is the evaluation of two threshing methods for biennial onion seed collection through the assessment of standard germination parameters. Considering the parameters of germination, germination energy, abnormal seeds and rotten seeds, some enterprises do not show any difference between the two threshing methods and others show some with different significance.

Material and Methods
The survey was conducted considering different management aspects for 12 companies in Ancona district as reported in table 1.
Cultivar description is reported in table 2.
The ratio pollen/seed bearing indicates the number of rows of seed bearing line and pollen bearing line the different ratio depends on the capacity of the two lines in giving and receiving pollen. Phytosanitary state is reported in a progressive sequence of numbers from 1 to 4 where 1 means the worst state and 4 absence of disease. Drying is the code for the drying system adopted for drying the inflorescences T is the code for tunnel (with plastic darkening and waterproof cover), TG is the code for big tunnel and C represents the system with agricultural shed.

Table 1: company characterization

Company code	A	B	C	D	E	F	G	H	I	L	M	N
Cultivar	1	2	3	3	2	4	5	5	6	6	6	7
Surface (10^3 m^2)	5	14	7	7	13	15	10	10	15	10	19	5
Harvest date	23/7	12/7	9/7	9/7	15/7	15/7	15/7	17/7	16/7	16/7	12/7	14/7
Threshing date	17/8	5/8	4/8	4/8	9/8	10/8	10/8	11/8	11/8	10/8	10/8	10/8
Yield (kg)	124	87	85	20	230	660	639	639	320	661	268	224

Table 2: description of cultivar tested

Cultivar	Colour	Shape	Type	Downey mildew sensitivity
1	Golden	Round	Hybrid	sensitive
2	Yellow	Round	Hybrid	low sensitive
3	Red	Round	Hybrid	low sensitive
4	Red	Round	Hybrid	low sensitive
5	Yellow	Round	Hybrid	low sensitive
6	Yellow	Round	Hybrid	sensitive
7	White	Flattened	Hybrid	sensitive

Quality parameters considered are: germination; germination energy; abnormal seeds; rotten germs; rotten seeds. A statistical analysis has been conducted comparing different treatments and conditions and the effects on quality parameters. Tests for quality parameters determination have been performed following international standards[4].
The sample tested include 400 seeds for four replicates. The seeds have been kept at 20°C on top of germination paper or between germination paper.
All the test starts in 2016 on December the 12th and ends after 17 days, only two replicates ended after 14 and 19 days instead 17. This limited variability is due to the presence of germination potential after the last counting.
Germination was determined as the ratio between the seeds germinated after the last counting and the total amount of seeds for replicate.
Germination energy was calculated as the ratio between the total amount of seeds for replicate and the sum of products between the number of seeds germinated at each counting time.
Abnormal seeds parameter was defined as the percentage of germinated seeds that have given abnormal germs in essential organs or structures.
Rotten seeds and germs are defined as the percentage of germs or seeds that at the end of the counting had showed mold or marcescence.
The statistical processing of the results was conducted by comparing the total average values with regard to the two threshing methods. The same method has been applied to the confront of mechanical and manual threshing for each company.

Results

From the analysis carried out for the two systems showed in table 3, comparing the average value for germination and germination energy, it is noted that between the two groups of treatments, mechanical or manually threshed, there are clear differences of about 10% in favour of manual threshing for both parameters considered. Another interesting aspect is given by the abnormal seeds parameter: for the mechanically threshed seeds it is clearly higher respect to the manually threshed with differences even higher than 75%.

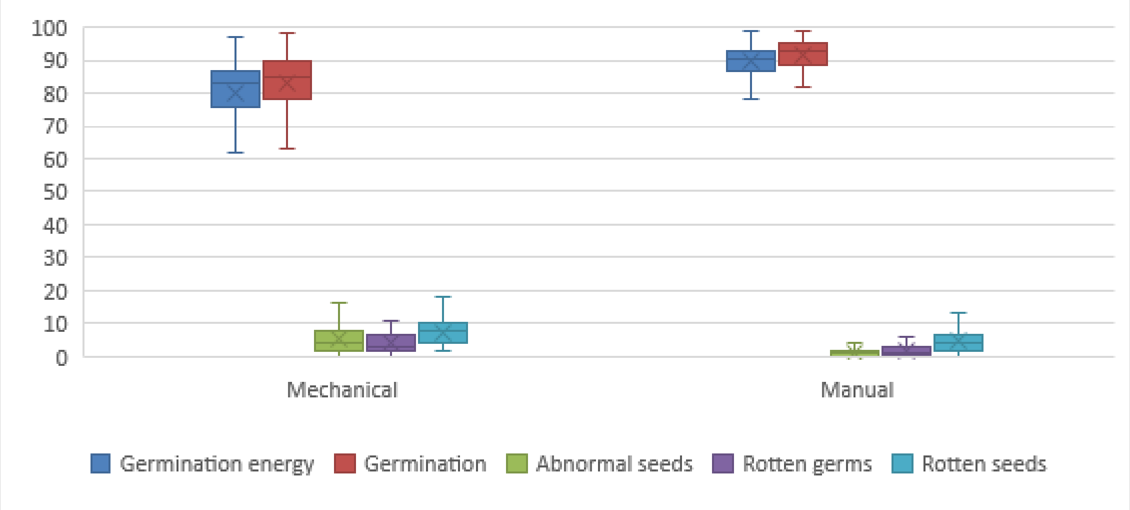

Figure 1: Quality parameter for mechanical and manual threshing

Table 3: mean values and standard deviation for Manual and mechanical threshing of onion seeds and significance of the statistical test

Parameter	Mean value manual threshing	Standard deviation	Mean value mechanical threshing	Standard deviation	Significance
Germination	91.7	±3.5	83.2	±8.8	**
Germination energy	90.0	±3.9	80.2	±10.9	**
Abnormal seeds	1.3	±0.6	5.4	±4.4	**
Rotten germs	1.7	±1.2	3.9	±2.8	*
Rotten seeds	4.9	±3.0	7.5	±3.4	*

** α=0.01 * α=0.05 one tailed test

Conclusions

The germination tests have shown how the manual threshing represents the most valid technique to obtain the best germination standards. On the other hand, it is obvious how many are the possible causes of deterioration of the quality in onion seeds. It is not still clear the role of some aspects in this specific case study, for example the sanitary state or climate and geographical conditions. Further studies could be useful to understand these aspects.

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How to maximise the manure value in a high livestock concentration area: the Life Optimal project

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Keywords: Biogas, Technological innovations, Sustainability

Summary
Livestock farms in the 5 municipalities of Alta Valle Isarco (north-eastern Italy) generate approximately 250000 tons of manure per year which, due to the limits set by the Nitrates Directive (91/676/EEC), cannot be entirely spread over the farms' land. The *Life Optimal* is a project funded by the European LIFE+ program. The general aim of the project is to overcome the problem of nutrients surplus of the area. A 1MW electric centralized biogas plant and the post-processing of digestate (mechanical separation, reverse osmosis, solid fraction drying and pellet production) maximize the value chain of manure: from the production of renewable energy through anaerobic digestion, to the agronomic reutilization of digestate in permanent grasslands, orchards and vineyards.

1. Introduction
The region of Wipptal in South Tyrol is characterized by a very intensive dairy cattle activity. Approximately 400 dairy farmers operate in the area, corresponding to a total of 11000 livestock units (LSU), of which 7000 are dairy cows. The milk is processed by the Milchof Sterzing, a cooperative of 400 farmers, who is merchandising milk, yoghurt and butter all over Italy as premium products.
Due to the national Italian legislation on the protection of ground and surface waters, farmers are facing the problem of nutrients surplus and are looking for new land surfaces for the application of exceeding nutrients. Approximately half of the livestock manures can no longer be applied to farmlands according to the legal restrictions, and alternative exploitation have to be identified (Döhler, H. 2015). Moreover, the Wipptal region is a turistic spot during summer season, this leading to conflicts between livestock activity and mountains goers due to odours emission when manure is applied to grassland. Gun sprayers and splash plate indeed are still the most diffused spreading techniques in the area.
To cope with these problems and with manure surplus, the "Biogas Wipptal" has been founded in 2008, a limited liability company consisting of 67 farmers. Main purpose of the company is to comply with the legal regulations for fertilization to maintain milk production at the actual level. The Life-Optimal project (LIFE12 ENV/IT/000671) aims at demonstrating an integrated approach to manure and nutrients management, by turning the problem of nutrients surplus of a high-density livestock area into a resource for the Wipptal Region.

2. Methods
To reach the project targets a new digestate treatment system (DTS) has been developed and installed at a 1 MWel. centralised anaerobic digestion plant (ADP) having 67 farmers as members and operating in Vipiteno (BZ), Italy.
The concept of the project envisages that all the manure produced by the 67 associated farms is anaerobically digested at the ADP. 50% of digestate is afterwards processed into organic-mineral fertilizer concentrates which are reused in vineyards and orchards of the province. This saves synthetic fertilizers in wine and fruit cultivation, and the exceeding nutrients are exported to outside farm areas.
The organic-mineral fertilizers are produced in a manure processing plant consisting of: anaerobic digestion with electricity and heat generation, cascade mechanical separation, sludge

resistant reverse osmosis cascade, solid fraction drying, pelletizing and packaging of the final product. The purified water from the process (liquid permeate) is discharged to the river adjacent to the plant. The digestate post processing plant was put in operation in May 2017 and is currently being monitored by the DiSAFA- Waste Management Group (Torino University).
The remaining 50% of digestate is spread as it is on the fields (sloped grassland) of the associated farms supplying manure to the ADP. A self-propelled manure spreader prototype with a high precision and a low emission application system has been designed and constructed for this specific purpose.

Fig. 2.1: the Wipptal AD plant (Vipiteno, BZ)

3. Results and discussion

The ADP is fed yearly with 70000 tons of a feeding mixture consisting of dairy farmyard manure and dairy cattle slurry. After anaerobic digestion, 33000 tons of digestate enter the post processing plant constructed with the support of the Life+ Program. The innovative technical solution for the post-processing of manure / digestates lies in a processing cascade which is up to now unique in Europe: solid-liquid separation is performed by a screw press separator and a vibrating sieve without any addition of chemicals (flocculation/coagulation aids etc.). The process is followed by a 3-stage reverse osmosis (RO), which allows 70-85% of the permeate to be discharged as purified water into the nearby receiving water course. The innovation in the process relies in one of the phases of the RO: in a vertical axial column several layers of polymer membranes are stacked; the entire system is subjected to vibration during the separation process so that fouling of the membrane is avoided. The final permeate/concentrate ratio is roughly 75/25 and the permeate properties are complying with the regional discharging water standards.
The solid fraction from screw pressing and vibrating sieve is mixed with the concentrate from the RO phase and is dried afterwards by using the thermal energy produced by the ADP cogeneration unit. After drying, the solid material is further pelletized (approximately 2000 tons per year). Pellets are packaged and put on the market or transported to orchards/vineyards areas where organic matter in the soil is lacking.
Optionally a unit for N stripping from concentrate is available so that a liquid ammonium sulphate fertilizer is produced.

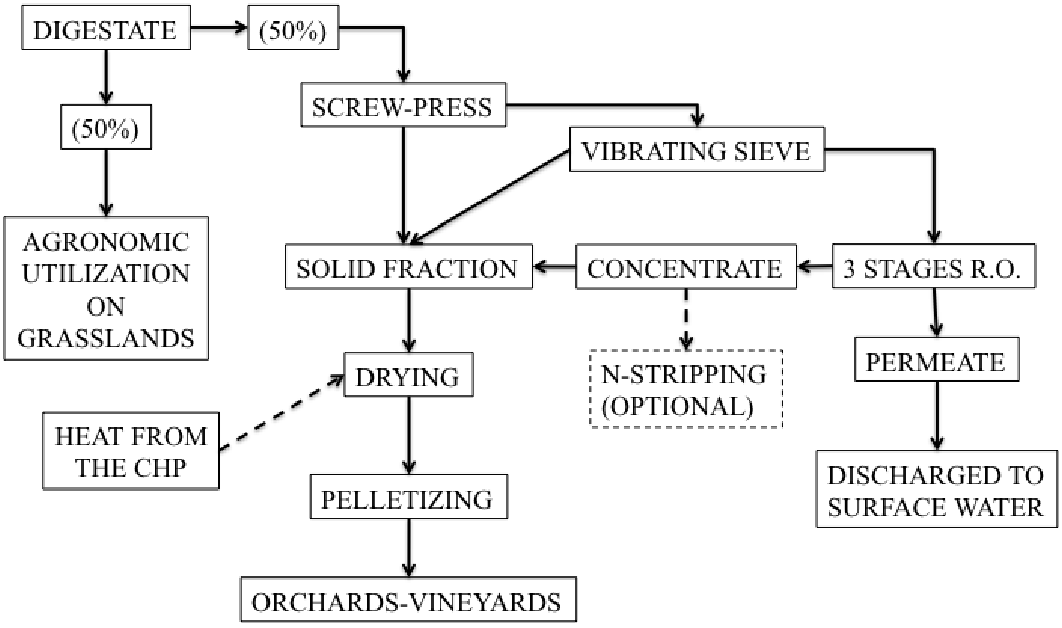

Fig. 3.1: Layout of the digestate post processing plant (R.O: reverse osmosis, CHP: combined heat and power unit)

The remaining 33000 tons of digestate are returned raw to the farms of origin and land applied to grassland by means of a high-precision/low emission slurry spreader. The self-propeller spreader consists of a 4000 litres fiberglass tank, mounted on a Muli-T9 tractor able to operate in slope surfaces. The machinery is equipped with an application rate control system fitted with a Near Infrared Spectroscopy (NIR) unit able to detect the total (TN) and ammonia (TAN) nitrogen, phosphorous (P), potassium (K) and total solids (TS) of digestate in real time during the tank loading. A GPS system enables to trace the spreading operations.

a b

Fig. 3.1: the self-propelled high-precision digestate spreader (a) and the low-emission spreading system

Key data (amount of applied NPK, manure, dominated surface..) are recorded in continuous by the central unit so that at the end of land application a complete report can be downloaded and provided to the farmer. The spreading device consists of 24 trailing hoses fitted with trailing shoes. The latter are spaced 0.25m apart on a 6m wide foldable frame. The system allows to land apply digestate at the required rate, regardless to the machine's forward speed and with reduced ammonia and odour emission.

4. Conclusion

A regional centralized manure processing plant has been constructed in Alto Adige, North Western Italy. Dairy cattle solid and liquid manure is processed by cascade mechanical separation systems and a sludge resistant reverse osmosis cascade, which is at present unique in Europe for this kind of application. Products outputs are electricity, heat, solid and liquid fertilizer concentrates. The plant is now fully operational and is being monitored by the DiSAFA – Waste Management Group. Data about gaseous (ammonia and GHG) losses, separation efficiency of the post treatment system, mass and energy balance of the management chain are expected to be ready by the end of 2018.

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Evaluation anti-radical activity of essential oil and distillate of thymus vulgares, compared with synthetic antioxidant BHT

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Keywords: Anti-radical activity, DPPH Method, Distillate, Thymus vulgares

Summary
Recently, the attention to natural antioxidant compounds with intention to using in the pharmaceutical and food industries has been increased. It is mainly due to increasing unintentional side-effects of synthetic antioxidants. Polyphenols compounds are the major compounds of plants which has been antioxidant activity.

In this research, Anti-radical activity of essential oil and extract of thyme (Thymus vulgares) were determined and compared with synthetic antioxidant BHT (Butyl Hydroxy Toluene). In this study, thyme essential oil were analyzed by GC/MC and its main chemical components were identified. The amount of phenolic compounds in extract of thyme has been evaluated. Anti-radical activity of essential oil and extract of thyme was investigate and also compared with BHT method 2, 2-diphenyl-1-Pycryl Hydrazyl (DPPH). The results showed that the main components of savory essential oil were thymol (60.54%), gamma-terpinene (9.47%), para-cymene (8.54%) and carvacrol (3.33%); and the total phenolic content of the extract was 21.5±0.62 mg Gallic acid per g. In the evaluation of free radical scavenging activity, the highest antioxidant activity was observed at the density of 2% BHT (84% inhibition), 2% essence of thyme essential oil (79% inhibition) and 1.5% of thyme extract (87% inhibition). According to the results, the highest activity was observed of the thyme extract, BHT and thyme essential oil, respectively. Finally, by considering of antioxidant activity of extract, it can be used as natural antioxidants in relevant industries.

1. Introduction

Free radicals are playing a key role in the emergence and persistence of vital. For example, oxygen radicals have a major role in the field of signal transduction, gene expression in cells and regulate the activity of guanylate cycles. Of course, free radicals and other oxidation of biomolecules such as proteins, amino acids, lipids and nucleic acids that it causes cell damage and its death. Active oxygen species are completely certain physical properties, chemical and immunological affect superoxide dismutase which increasing cell oxidative damage (Bektas et al., 2005). Chemicals antioxidants mostly used in the industry include BHT, BHA, TBHQ. These compounds has negative effects and carcinogenic properties on human health which confirmed by some researcher (Dormana et al., 2003). Several studies have been reported on the potential of essential oils of herbs and spices as natural antioxidants. They reported that the addition of various density of thymol and carvacrol in sunflower oil could be reduce the oxidation process (Yanishlieva et al., 1999). The antioxidant effects of phenolic compounds were depend to its concentration. The thymol and carvacrol (both major component of essential oil of thyme) have high antioxidant activity (Dormana et al.,2003). There is an question that, which solution can be more effective as an antioxidant to eliminate free radicals from dental surfaces after bleaching procedures.
Due to the lacks of evidence, the purpose of this study was to evaluate the anti-radical activity of essential oil and extract of thyme (Thymus vulgares) were determined and compared with synthetic antioxidant BHT (Butyl Hydroxy Toluene).

2. Materials and Methods

Thyme essential oil was obtained from the Thyme plant leaves by steam distillation method. Analysis of essential oil compounds is performed by GC/MS. Using of free radical 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) as an antioxidant assay based on electron-transfer that produces a violet solution in ethanol. This free radical was stable at room temperature which reduced in the presence of an antioxidant molecule. It caused to increasing colorless intensive of ethanol solution. The use of the DPPH assay is provides rapid way to evaluate antioxidants by spectrophotometry, so it can be useful to assess various products at the same time.

The percentage of antioxidant activity (AA%) of each substance was assessed by free radical DPPH. The measurement of the DPPH radical scavenging activity was performed according to methodology described by Brand-Williams et al,. 1995. The samples were reacted with the stable DPPH radical in an ethanol solution. The reaction mixture consisted of 0.5 ml of sample, 3 ml of absolute ethanol and 0.3 ml of DPPH radical solution 0.5 mM in ethanol.

for measuring the percentage of inhibition, the concentration of samples (0.25, 0.5, 0.75, 1, 1.25, 1.5, 2%) were analyzes by addeding DPPH.

When DPPH reacts with an antioxidant compound, which can donate hydrogen, it cause to change the sample color from deep violet to light yellow.

The percentage of passage of light through the liquid as a absorbance (Abs) were read at 517 nm after 100 min of reaction by using a UV-VIS spectrophotometer (DU 800; Beckman Coulter, Fullerton, CA , USA). The mixture of ethanol (3.3 mL) and sample (0.5 mL) was used as blank. The control solution was prepared by mixing ethanol (3.5 ml) and DPPH radical solution (0.3 ml) (Mensor et al,. 2001). The inhabitation ratio of free radical was calculated by equation 2.1.

$$AA\% = 100 = \left| \frac{(Abs_{sample} - Abs_{blank}) \times 100}{Abs_{control}} \right| \qquad (2.1)$$

Where, A_{blank} and A_{sample} is absorption ratio of control and sample respectively.

3. Results and Discussion

The results are presented in Table 1. The essential oil compounds showed that the main compounds of Thymus vulgares essential oil were Thymol (60.54%), gamma–terpinene (9.47%), para – cymene (8.54%) and carvacrol (3.33%); and also the total phenolic content of the extract was 21.5±0.62 mg Gallic acid.

Finding results showed in Table 1, confirming the finding reported by Kamkar *et al.*, (2013) in relation with essential oil component. They reported that the most important component of essential of thymus vulgares were thymol(63.14%) para-cymene (9.5%), gamma-terpinene (8.66%), and carvacrol (3.14%). Also Yazdani *et al.*, (2005) reported that the major component of thymus vulgares were thymol (49.04%) para-cymene (7.5%), gamma-terpinene (18.77%), and carvcrol (2.83%).

Table 1. the analysis of Thyme essential oil

Line	**Compound**	**Rate inhibition**	**Percent inhibition**
1	α-Thujene	928	0.85
2	α-pinene	934	0.58
3	Camphene	949	0.52
4	Sabinene	974	0.03
5	1-Octen-3-ol	980	0.23
6	3-Octanone	986	0.06
7	Myrcene	993	1.22
8	3-Octanol	997	0.18

9	α-Phellandrene	1007	0.25
10	δ-3-Carene	1012	0.08
11	α –Terpinene	1018	1.24
12	P-Cymene	1024	8.54
13	Limonene	1033	0.08
14	1,8-Cineole	1034	0.68
15	(E)- β- Ocimene	1048	0.17
16	γ- Terpinene	1046	9.47
17	Cis- Sabinene hydrate	1069	0.84
18	Terpinolene	1089	3.13
19	Linalool	1104	0.09
20	Camphor	1144	0.12
21	Borneol	1166	1.25
22	Terpinene-4-ol	1178	0.22
23	γ- Terpineol	1209	0.25
24	Thymol methyl ether	1236	0.64
25	Carvacrol methyl ether	1244	0.38
26	Thymol	1300	60.54
27	Carvacrol	1314	3.33
28	Eugenol	1360	0.04
29	Isobornyl propinate	1378	0.36
30	β- Bourbonene	1386	0.08

The results of inhibition percentage of BHT are presented in Figure 1. As shows in Fig. 1, the concentration trend decreased with increasing of rate of absorption. Based on the assessment of free radical scavenging activity in Fig 1., the highest antioxidant activity was observed at the concentration of 2% BHT (84%), 2% of thyme essential oil (79%) and 1.5% of thyme extract (87%). According to the result, it appears that the highest activity was observed of the thyme extract, BHT and thyme essential oil, respectively.
Sanchez-Moreno et al, (1999) reported that in high density of extracts, phenol components have a higher restrain ability due to the increasing of number of hydroxyl present in reaction ambient which causes to donation of hydrogen to free radical.

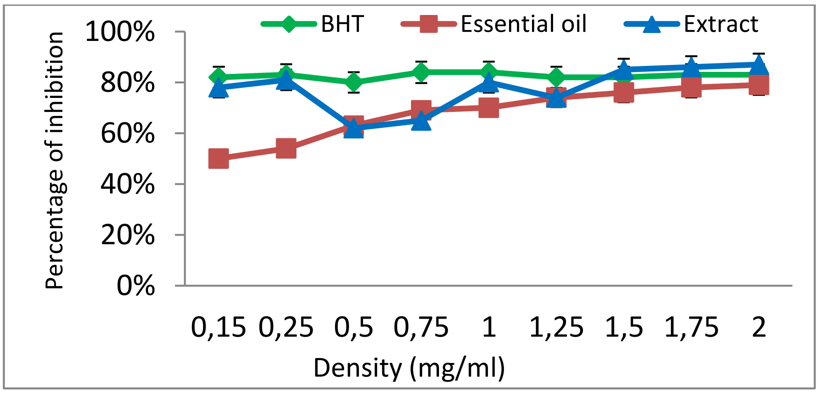

Fig. 1. Percentage of inhibition BHT, essential oil, extracts

Regarding to considerable activity of this study, the extracts have the potential to be used as natural antioxidants in relevant industries.

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Ammonia emissions assessment after buffalo slurry application to bare soil in Mediterranean climate

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Summary
Ammonia emissions assessment from buffalo manure application to the field under Mediterranean climate is proposed, with aim of giving first data for this animal species. A field trial was carried out with concurrent use of two measuring methods: wind tunnel (WT) and Integrated Horizontal flux (IHF). Finally, ammonia emission data measured were compared to those obtained running the statistical regression model ALFAM.
The total ammonia losses are in the order of about 40% and 50% (of applied TAN) for WT and IHF, respectively. Results of comparison with the ALFAM model confirm the reliability of IHF assessments in ammonia emissions compared to WT method.

1. Introduction
Ammonia emissions represent a growing issue for European countries due to the rapid increase in livestock production and next National Emission Ceilings EU Directive adoption, which will limit emissions of NH_3 as well as SO_2, NO_x and NMVOC applicable from 2020 and 2030.
Recent researches are devoted to the individuation of standard methods for reliable assessment, consequently many European countries are now building national emissions inventory. The main issue is a lack of data about ammonia losses from buffalo manure, under Mediterranean climate. Buffalo is reared mostly in South Italy, and even if well studied (Infascelli et al., 2010; Pindozzi et al. 2013), there are not researches about ammonia emissions. Besides measurement method itself, meteorological conditions influence emissions too. Wind tunnel (WT) and Integrated Horizontal flux (IHF) are the most used methods for NH_3 assessment while ALFAM model (Søgaard, et al. 2002), is often used to compare ammonia losses estimated with those obtained with experimental trials, in order to discuss the effectiveness of the results (Minoli et al., 2015).

2. Materials and Methods
On July 2016 a field trial combining the use of wind tunnel (WT) with Integrated Horizontal flux (IHF) was performed in a farm situated in Acerra (40°57'57.5"N, 14°25'34.9"E). Climate is Mediterranean according to Emberger's index, while soil is sandy loam texture according to the USDA Textural Classification System, with a pH of 7.4, an organic matter content of 2.9 % and cation exchange of 0.4 mS cm^{-1}. Micrometeorological data were monitored during the test, by the near weather regional station 200 m far from the plot.
Slurry fertilization was provided on bare soil by splash plate spreader for IHF circular plot and by hand on WT covered surface. Field trial characteristics and buffalo manure properties are reported in Table 2.1.

Table 2.1: Experiment set-up

Method	Duration	Application			Manure properties		
		Technique	Rate (kg tot N ha^{-1})	Area (m^2)	TAN (mg l^{-1})	DM (%)	TKN (mg l^{-1})
IHF WT	4 days	Splash plate Manual	400	1256 0.32	700	8.335	3200

2.1 Ammonia losses assessment

Ammonia emission measurements were carried out sampling at the same time step with two diferent NH_3 concentration devices, depending on the method. Specifically, in the case of Integrated Horizontal Flux method (IHF) by Wood et al. (2000), glass tubes (Schjoerring et al., 1992), previously treated with a solution of oxalic acid and acetone, were employed. These samplers were positioned in a pair at 4 and 3 heights of rotating masts, in order to catch the main wind direction, placed in the centre of fertilized plot and 80 m far at the backgroud, respectively. The main principle of the method is to calculate the vertical NH_3 flux from the emitting area, equating to horizontal flux measuring ammonia concentration in the air at differtent heights above the surface.

Wind tunnel (Scotto di Perta et al., 2016), consisting of a particular chamber placed on a rectangular fertilized surface, that allows to simulate the wind action on the surface, by means of a fan. WT is equipped of two sampling points at the inlet and at the outlet sections. Acid traps were used to trap NH_3 volatilized. They were furnished with sulphuric acid solution, flow meter and suction pump. Acid solutions were replaced every 2 hours for the first two days and every three to four hours for the remaining two days. The concentration of NH_3 trapped both in oxalic and sulphuric solutions were measured spectrometrically using the FIAstar 5000 system (FOSS, Denmark) in the laboratory.

2.2 The ALFAM model

The ALFAM model is the result of a statistical analysis of NH_3 emissions data, collected in seven European countries (Denmark, Italy, the Netherlands, Norway, Sweden, Switzerland and UK) over the years. At the base of the model there is the kinetic of Michaelis-Menten-type:

$$\mathbf{N(t)= N_{max}} \frac{\boldsymbol{t}}{\boldsymbol{t+K_m}} \qquad (1)$$

Where N(t) is the cumulative NH_3 volatilization over time (t); N_{max} is the total NH_3 loss when time approaches infinity and K_m is time interval when N(t) reaches $0.5N_{max}$.

The cumulative NH_3 emission is estimated according to a set of parameters affecting NH_3 volatilization, reported in Table 2.2. The model was run assuming a similarity between cattle and buffalo manure

Table 2.2: Input of ALFAM model

Method	Soil moisture	Temperature (°C)	Wind speed ($m\ s^{-1}$)	DM (%)	TKN ($g\ kg^{-1}$)	Application Rate ($t\ ha^{-1}$)
IHF WT	dry	25.17	1.19 0.3	8.33	0.7	127

3. Results and Discussion

Mean environmental conditions recorded during the trial are shown in Table 3.1.

Table 3.1: Mean meteorological conditions, in the blankets min and max are reported

Air Temperature (°C)	Wind speed ($m\ s^{-1}$)	Air Humidity (%)	Soil moisture (%)
25.17(16.4-32.2)	1.19 (0-3.8)	70.33 (40-98)	5.16 (4.8-5.5)

Cumulative ammonia emission obtained after 4 days of measurements are reported in Table 3.2.

Table 3.2: Total NH_3 losses measured with IHF and WT

Method	kg N ha^{-1}	of TAN applied
IHF	46.8	52
WT	34.1	38

In the present study, the highest ammonia emission rates occurred in the first hours after fertilization and decreased substantially after 24 h , achieving 61% and 67 % of the total ammonia loss for IHF and WT, respectively. This was due to manure hydrolysis process occurring before application (Ferrara, 2010), usually on the floors of animal house within 24 h of deposition (Sommer et al., 2013) and for this reason the ammonia emission process proved to be faster. Moreover cumulative ammonia emission curves related to both methods (Figure 1a) are well described by a Michaelis-Menten type curve. They could be modelled as a first-order reaction (Sommer et al., 1994), fitting the Eq. 1 to the measured ammonia emission data.

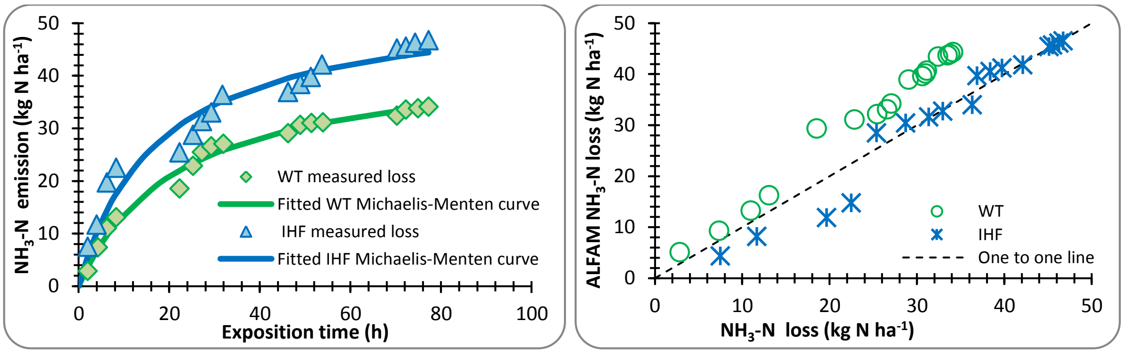

Figure 1: Comparison between measured and fitted NH_3 (a), measured and predicted NH_3 (b)

Table 3.3 reported the statistical indexes evaluated. The ALFAM model was in particularly good agreement with IHF results for buffalo manure application to the field, considering the modification to the method and the different nature of fertilizer that was approximate to the cattle slurry. In the same time, ALFAM model seemed to over predict the ammonia loss related to the wind tunnel (Figure 1b).

Table 3.3: Statistical indexes: coefficient of determination (R^2),relative root mean square error (RRMSE), model efficiency (E), coefficient of residual mass (CRM)

Relations	R^2	Slope	Intercept	RRMSE	E	CRM
IHF fitted/IHF measured	0.951	1.024	-1.189	8.459	0.964	-0.012
WT fitted/WT measured	0.986	0.995	0.006	4.843	0.985	-0.005
ALFAM_IHF/IHF measured	0.963	0.844	5.811	9.797	0.951	-0.026
ALFAM_WT/WT measured	0.986	0.768	-0.177	33.816	0.288	0.238

These results could be explained considering the variety of wind tunnel applications existing in literature (Scotto di Perta et al., 2016) and the difficulty in comparing emission data related to each of them (Saha et al., 2009), because the results could vary according to the geometries of the devices.

4. Conclusion

The total ammonia losses is in the order of about 40% and 50% (of applied TAN) for WT and IHF, respectively. Cumulative NH_3 emissions are well described by a Michaelis-Menten type curve.The good accordance between the NH_3 emissions obtained with IHF method and those resulted from the predictive ALFAM model confirms the possibility to use the first one to assess the ammonia volatilized into the field, since it is totally comparable to the results recorded from other European countries.

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Performance of a hot-foam machine for the herbicide-free weeding of the vineyard

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Summary

The complete elimination of the herbicides use is a key factor in the vineyard, even more in case of biological management. In this view, for the area under the row, the machines performing the mechanical weeding are characterized by a low travelling speed; on the other hand, those with flails can damage significantly the vine stock, increasing the possibility of pathogens attack. The flame weeding is an alternative solution, but this is quite costly and a possible high fire risk has to be taken into account if the grass growth is important. An other possibility provides the use of steam, in order to destroy the internal structure of the weeds. A new solution is represented by the use of hot-foam, in order to transmit the heat to the weeds, maintaining it for the longest time possible, consuming a reduced amount of energy in comparison with the flame-weeding and the steam techniques.

A hot-foam machine for the herbicide-free weeding of the vineyard was manufactured to be fitted in front of the tractor, in order to produce a foam that is deposited on the upper part of the weeds. The hot air contained inside of the bubbles then collapse the internal structure of the vegetation. The machine includes a fan-burner group for the production of hot air, blowed into a device producing the foam, to be deposited in strip under the row. Because the machine tools are not working between the plants, the working speed can be comparable to that typically adopted for the chemical weeding.

The tests showed the production of foam strips of approx 40 cm wide and 20-25 cm high, at a temperature of more than 75 °C recorded at the machine outlet. The effect of the weeding appears significant after 3 days, although complete killing of the upper part of the weeds occurs after 7-14 days, mainly depending on the species and amount treated.

1. Introduction

Directive 2009/128/EC (transposed into Italy by Leg. Decree No. 150-14.08.12, and commonly referred to as the "*National Action Plan for the Sustainable Use of Plant Protection Products*"), as well as subsequent local guidelines, provide for very stringent limits on the use of weeding chemicals in urban areas, especially in those of vulnerable groups. Their use is allowed only with the integration of methods assuring a low impact on human health. In the agricultural sector, and especially in viticulture, the organic cultivation is increasingly adopted. As a consequence, the weeds control has to be more frequently implemented with techniques alternative to the chemical ones (Balsari et al., 1999). The spontaneous vegetation can be controlled by means of mechanical techniques (periodic shredding or mowing, at least 5 per year), or eliminated through mechanical, chemical or physical techniques (Bajwa et al., 2015). The control is often difficult, for the high frequency and for the poor efficiency of this task (Harker and O'Donovan 2013). In field cultivation as well as in fruit- and viti-culture, mechanical solutions are likely to damage the shallow roots and suffer from poor working capacity, although the low labour productivity could be solved by the adoption of automated robots (Saber et al., 2013).

A recent solution involves the use of water blade of a very high pressure (up to 100 MPa), which is thrown violently on the weeds causing their destruction, while at the same time the first soil layer is tilled. This represents an undoubted eco-friendly mode, but the machines are still at the prototype stage, and at present cannot guarantee long autonomy, since in order to be able to work effectively about 1500-2000 l/ha of water is needed. However, the popular chemical techniques for weeding are sufficiently cheap and characterized by a high working capacity. In recent decades chemicals have spread widely and were distributed with increasingly advanced spraying machines (Shaner and Beckie, 2014), equipped with low-drift nozzles, and sometimes also equipped by shields (Otto et al., 2016). The fitting of optical sensors allows the selective distribution only where the spontaneous vegetation is grown, thus limiting the environmental pollution (Balsari et al., 2005). Among the most eco-sustainable and less impacting techniques, the use of heat is an interesting solution, in order to obtain the "boiling" of the plant cells, resulting in collapse and death (Vincent et al., 2013). The most well-known of these (and probably even the cheapest) is certainly the weed-flaming, but it suffer for causing fire triggers on dry vegetation (Martelloni et al., 2016). Hot water (Hansson and Ascard, 2002) or steam (Martelloni et al. 2016) can then be taken into account as possible alternatives, as well as infrared radiation. In any case, energy demand, and therefore costs, increase considerably. In addition, where water is used, the problem of its limited transport further reduces the machine's working capacity. A further promising solution involves the use of hot foam, exploiting in particular the insulating effect of bubbles generated, with a significant reduction in energy requirements compared to steam or hot water.

2. Materials and Methods

Fig. 1 - The prototype of the hot-foam machine.

A machine producing and distributing hot-foam on the weeds growing under the vineyard rows has been manufactured and tested in different operating conditions, using several types of surfactants (both naturally biodegradable or not) (**fig. 1**). The main goals were the optimization of the weeding efficiency and a working capacity comparable with the traditional mechanical techniques. The foam was devoted to: a) produce an amount sufficient to cover the entire area under the row (width of about 0.4-0.5 m); b) assure a temperature of the air inside of the bubbles sufficiently high for obtaining a good weeding effect; c) guarantee a long time duration of the foam; d) maintain a travelling speed and adopt a water tank volume able to assure a working capacity as high as possible. The machine is basically composed by a 300 l tank containing the water and the surfactant, a pump to transport the mixture, a diesel fuel burner to heat and a fan to blow the hot air flow and a device to produce and distributing the hot foam on both the sides of the vineyard rows. Except the mixture tank (fitted on the rear 3-point hitch), all the other parts of the machine are fitted in front of the tractor, in order to assure for the driver the best control of the task.

The hot-foam machine was tested using both conventional and naturally biodegradable surfactants, being the last intended for legal use in organic agriculture. Moreover, as an alternative, the water-surfactant mixture was used at ambient temperature or previously heated. Further parameters were taken into account: a) the concentration of the surfactant in the water; b) the mesh of the net used to generate the bubbles; c) the amount of the air flow (i.e. the fan speed); d) the expansion ratio, intended as the ratio between the volume of the mixture and that of the correspondent foam produced; e) the time duration of the foam, i.e. the heat transmission efficiency to the vegetation.

LCA approach

The environmental benefits arising from the substitution of conventional weed management (involving herbicides applications) or, in organic viticulture, from the intensive mechanical control could be evaluated though the Life Cycle Assessment (LCA) approach. Of course, the use of the hot-foam machine is responsible for non-negligible adverse environmental effects, involving the consumption of additional fuel for the heating of the mixture of water and surfactant and, above all, the release of the foam into the environment. On this scenario, the key point of the LCA study is related to the application of the surfactants, in particular to their production and their emissions in the environment. Once the most suitable surfactant (100% naturally biodegradable or not) will be identified, a specific assessment of its environmental impact will be carried out, taking into account its physic-chemical features as well as the application dose (kg/ha).

3. Results and Discussion

Tab. 1 shows the main technical specifications and performance of the surfactants.

Table 1 - Main technical specifications and performance of the investigated surfactants.

Surfactant make and type	Naturally biodegradable	Concentration in water, % (v/v)	Mixture temp., °C	Mesh net	Fan speed, rev/min	Expansion ratio	Duration of the foam
Salvarani, ST Agrifoam C5	no	1.5	26	500	2860	1:117	high
			67		2000	1:210	
Salvarani HQ			26		2460	1:181	
			60		2000	1:180	
Salvarani, ST Agrifoam C5			26	400	2090	1:148	
			66			1:95	
Salvarani, HQ			26		2000	1:111	
			64			1:102	
Salvarani, ST Agrifoam C5			27	300	2000	1:129	
			65			1:49	
			27		2090	1:102	
			70			1:35	
Salvarani, HQ			27		2000	1:95	
			65			1:65	
SDK 2		3.0	54	500	2000	1:120	medium
ZetaDueVu			52			1:132	medium-high
		1.5	60		1750	1:128	
Soc.AGr. Le Erbe, Brillor	yes	5.0	65		2000	1:81	low
		10.0	64			1:97	

Fig. 2

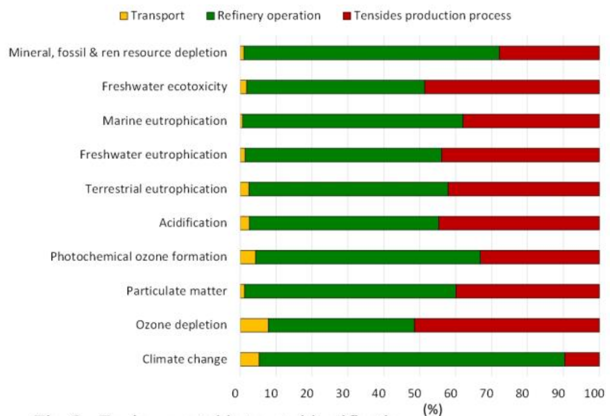

Fig. 3 - Environmental hotspots identification.

The machine was able to produce foam strips of a width of approx 0.4 m and a max height of 0.20-0.25 m, at a temperature of about 75 °C recorded at the machine outlet. To obtain a sufficient amount of foam, the travelling speed was settled at about 0.4 m/s (1.5 km/h) at a tractor engine speed of 157 rad/s (1500 rev/min).

The best results, in terms of expansion ratio and above all duration of the foam, were obtained with a foam marker already available on the market, using a water-surfactant mixture both heated or at ambient temperature. The effect of the weeding appears significant after 3 days, although the complete killing of the upper part of the weeds occurs after 7-14 days, mainly depending on the species and amount treated (**fig.** 2).

Concerning the LCA, **tab. 2** reports the environmental impact related to the production of 1 kg of a surfactant coming from vegetable ingredients (palm oil, cottonseed, coconut) while in **fig. 3** the environmental hotspots are identified.

Table 2 - Environmental impact for 1 kg of surfactant.

Impact Category	Unit	Score
Climate change	kg CO_2 eq	1.732
Ozone depletion	mg CFC-11 eq	0.211
Particulate matter	g PM2.5 eq	4.805
Photochemical ozone formation	g NMVOC eq	13.741
Acidification	mole H+ eq	0.024
Terrestrial eutrophication	mole N eq	0.085
Freshwater eutrophication	g P eq	0.843
Marine eutrophication	g N eq	26.839
Freshwater ecotoxicity	CTUe	33.85
Mineral, fossil & ren resource depletion	g Sb eq	0.463

4. Conclusion

The machine showed a remarkable efficiency in producing a good quality foam, altough the working capacity is at the moment significantly lower than that of the traditional mechanical weeding, so requiring a significant increase of the foam amount. An other key factor for the success of this environmentally sustainable tecnique is the finding of a foam 100% naturally biodegradable, showing at the same time a long duration, in order to maximize the heat transmission to the weeds, for optimizing the killing effect on the vegetation.

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Effects of long-term of different management scenario on energy consumption for durum wheat cultivation in Sicily

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Keywords: Sustainable agriculture, Energy consumption, Durum Wheat

Summary
Aim of this paper is to evaluate the effects of the long-term use of three tillage techniques (conventional tillage, CT; minimum tillage, MT; and no-tillage, NT) for wheat production in Sicily on energy consumption and on wheat yield for the different combinations of machines and techniques distinguishing the experimental years. The hypotheses differ in terms of tillage intensity, depth and time required. Due to the interaction between tillage systems and experiment year fifteen scenarios were compared. Considering the average values of the three theses during the 5 years of testing, the results demonstrate NT requires less or equal Inputs than CT and MT. This is due for both direct energy costs of fuel and especially indirect costs, linked to use of the machines. In general, NT thesis showed a better efficiency and timeliness because mean work capacities were always higher than other theses, but on the average, the yields of the CT and MT theses are greater.

1. Introduction
The durum wheat cultivation represents a driving force for the agricultural economy of Sicily, particularly for the non-irrigated inland areas. But the increase in the cost of technical means and the fall in prices of the wheat risks penalizing heavily grain cultivation and reducing the business income.

The minimum tillage and no-tillage for durum wheat cultivation could represent a solution able to reduce costs of working and also an opportunity to contribute to soil conservation and its quality, to reduce oxidation of organic matter as well as consumption of fuels and to mitigate the effects of GHG (Ali et al., 2015, 2017; Castellini and Ventrella, 2012; De Sanctis et al., 2012; De Vita et al., 2007; Grahmann et al., 2014; Hernanz et al., 2002; Khaledian et al., 2012; Montemurro and Maiorana, 2014; Moussa-Machraoui et al., 2010; Mrabet, 2011; Nassi et al., 2011; Peruzzi, 2005; Peruzzi et al., 2003; Tellez-Rio et al., 2017).

This paper aims to contribute to the assessment of environmental impacts in durum wheat cultivation in the central eastern area of Sicily, which is representative of the extensive cultivation of winter wheat by means of an energy consumption analysis. The data refer to an experimentation that takes place in 5 years and provides the alternation of different tillage for the seed-bed preparation in order to reproduce what occurs in the examined production context. Because the energy consumption studies of durum wheat cultivation in Sicily are absent in literature, in order to support the regional agricultural political choices, primary purpose is to assess the performances of three different cultivation practices for the seedbed preparation: conventional tillage, minimum tillage and no tillage.

2. Materials and Methods
The experiment was carried out in a representative flat land area extended about 1 ha (Catania province of Sicily) divided into 6 adjacent lots of 15 m wide and 120 m long and cultivated with *Triticum turgidum* L. var. durum. The site has a Mediterranean climate and the machines and techniques applied during the tests were alternated in accordance with those commonly adopted for the durum wheat cultivation in the territory where the tests were carried out.

Conventional tillage (CT) represents an intensive method including ploughing and deep harrowing. Minimum tillage (MT) represents a method with a reduction in the number of tillage and the tillage depth, and with the elimination of ploughing. No tillage (NT) is a method involved a pre-sowing weed control with a glyphosate based product and a direct sowing without tillage. The sowing was carried out between December and January, with a common 3 m wide seed-drill (16 coulters), in the IT and MT lots, and with a 2.5 m wide seed-drill machine (13 coulters), suitable for direct sowing, in the NT lots. The same pre-sowing fertilizing with 200 kg ha^{-1} of diammonium phosphate was carried out in all the lots. After sowing, when the plants emerged, top fertilizing with 200 kg ha^{-1} of ammonium nitrate and weed control using 400 l ha^{-1}of herbicides were carried out in the same way in all the lots. The harvesting was performed with a small combine harvester, 1 m wide, specially designed for harvesting of cereals only in experimental lots.

Figure 2.1: The seed-drill machines used in the experimental trials

In order to assess the performance of the machines during the work, standardized methods were adopted. Diesel fuel consumption of the tractors was calculated through a direct measurement by using the "top-up" method on the field.
Total Inputs were calculated using the energy equivalent values for the work duration of machinery in the different management scenario, the fuel consumption and the quantities of fertilizer and herbicide.
The Output was calculated by multiplying the amount of wheat production and its corresponding energy equivalent value and by multiplying the amount of by-product (straw) and its corresponding energy equivalent value.
Based on energy input and output calculations, the net energy gain, energy efficiency, energy productivity, energy profitability and energy intensity were either calculated for each scenario.

3. Results and Discussion

As shown in figure 3.1, the average values of the 5-years trials demonstrate that NT requires less or equal Inputs than CT and MT. The direct energy due to the use of fuel is much lower in NT as well as the energy required due to the use of the machines (Figure 3.2). But, the use of herbicides is greater in NT thesis than CT and MT, thus reducing the benefit of this technique in terms of energy savings.
On the average, the yields of the CT and MT thesis are greater (about 2.2 t ha^{-1}) than NT thesis (about 1.8 t ha^{-1}) and thus Output average values in the NT are lesser than the other two for whom values are higher especially for CT thesis.

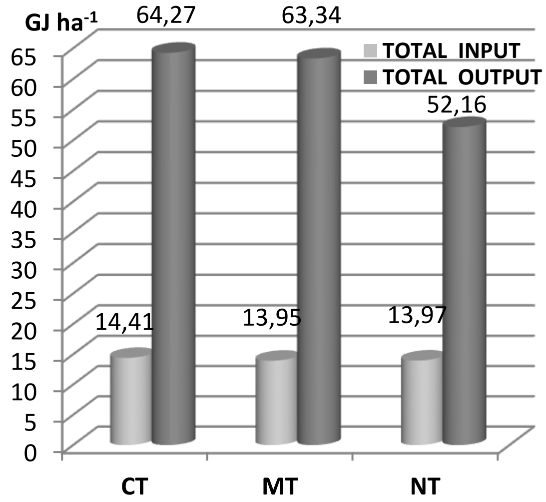

Figure 3.1: Total Input and Output in the three different management systems

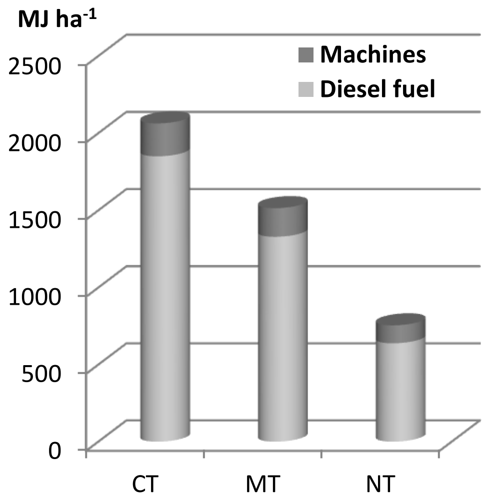

Figure 3.2: Energy Input of diesel and machines

Energy ratio (O/I) is more efficient for CT thesis (4.46) and MT thesis (4.54) than NT (3.73). But also the other indicators are less favourable for NT thesis.

4. Conclusion

The results of these 5-years experiment show that thanks to the minor use of the machines NT thesis saved on the use of diesel but it requires a greater use of herbicides and yields are often inferior respect to other management system.
In our context, minimum tillage reduces the use of the machines, but also leads to high durum wheat production.
Further analysis will be conducted to assess the environmental impact.

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Numerical simulation of natural airflows in greenhouse: definition of optimized CFD models in a case study

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Keywords: modelling, CFD, greenhouse, microclimate

Summary
Control and management of the climatic conditions in greenhouses are the subject of numerous studies and researches, with the aim of continuous improvement of production performance, in correlation to a growing attention to the issue of environmental and economic sustainability. An indirect method of study involves the use of computational fluid dynamics (CFD), which is used in this study to evaluate the internal airflows in a glass greenhouse. The analysis were performed using 2D and 3D models, using Autodesk and Fluent. The results showed a good agreement between the two software and, in particular, similar air movements in the span, with increasing external wind velocities. The ventilation was always characterized by an important inhomogeneity of airflows in all the sections studied. The simulations have proved to be a valuable tool for the analysis and evaluation of the internal fluid dynamics.

1. Introduction

The heterogeneity of the microclimate variables is common inside a greenhouse. Their distribution can cause a non-uniform production and quality of the plants, but also creates issues with pests and diseases. For these reasons, control and management of the climatic conditions in greenhouses are the subject of numerous studies and researches (Piscia et al., 2012), with the aim of continuous improvement of production performance, in correlation to a growing attention to the issue of environmental and economic sustainability. Several studies focus on the control of parameters, such as temperature, humidity, concentration of oxygen and carbon dioxide, in which ventilation can play a key role. Natural ventilation is often chosen as ventilation system since it is the most economic method available, but is highly dependent on external conditions, determined by numerous factors and their mutual influences (Teitel et al., 2008). In particular, wind is one of the main external agent influencing the natural ventilation of a greenhouse, as its velocity and direction may modify the indoor air flows and the homogenisation of the indoor conditions (Mistriotis et al., 1997).. From an operative point of view, the efficiency of natural ventilation depends on the disposition of vents and on opening timing of these during the day. In fact, Bartzanas et al. (Bartzanas et al., 2004) underlined that the optimal timing could be effective in reducing the indoor temperatures and the type of opening (roll up or side opening) and could directly affect the air flow. Moreover, Boulard et al. (Boulard et al., 2002) characterized the air flow obtained by only side openings or roof vents or both, in Mediterranean climate.

Not only the wind but also the solar radiation can affect the growing conditions of plants. The radiation raises internal temperatures and can damage directly the leaves, especially in summer, during the hottest hours. The most used technique to lower temperature and protect crops is the use of internal or external shading screens, combined with an optimized ventilation and a cooling system (Munoz et al., 1999).

Studies of internal distributed climate induced by ventilation include experimental analyses, which have pointed out the impact of vent configurations on airflow pattern, particularly when the wind is the main driving force. However, the development of computational fluid dynamics (CFDs) has provided the opportunity to simulate the climate inside greenhouses for known vent

configurations, and to test a wide range of geometries with different vent combinations under different climatic conditions (Bournet and Boulard, 2010).
This work aims to the definition of models that allow the CFD simulation and analysis of the main parameters affecting the internal microclimate of a greenhouse, according to different configurations of the building envelope and different external conditions.

2. Materials and Methods

In this work, a teaching and experimental three-span greenhouse of the University of Bologna, located in Imola, has been chosen as case study. In particular, the research has focused on one of the three spans, showed in figure 2.1. The main purpose has been to study the ventilation and the fluid dynamics in the structure. Primarily, a 2D analysis of the central vertical cross section of the cultivation area, with constant wind speed as input, has been conducted. These analysis have been performed by means of two different software, FLUENT (2D and 3D) and Autodesk CFD (3D), in order to evaluate the differences and similarities in the assessment of speed profiles. Due to space constraints, the first approach has been described in detail, while the second one has been briefly summarized. The reliability of both models has been proved through a validation process which has not been described hereafter for brevity's sake.

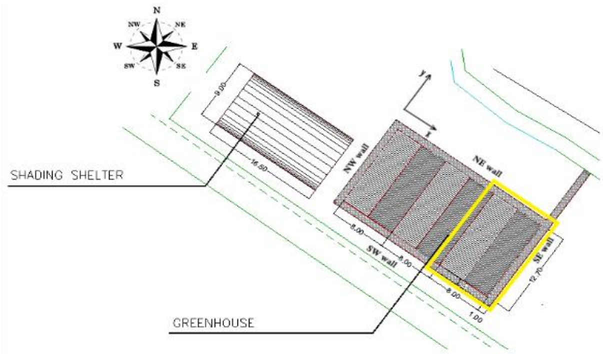

Figure 2.1: Top view of the greenhouse. In yellow is underlined the particular span of the study

From the 2D model, a more complex 3D model has been created, validated with an experimental measurements campaign. This model has been used for simulations in FLUENT, according to different configurations and different input speed profiles, in order to be able to investigate the air movements and the critical issues in indoor ventilation, under different wind velocities. The simulations were performed with a user defined function (UDF, eq. 2.1) for the wind profile:

$$U(z) = \frac{u^*}{k} \log\left(\frac{z + z_0}{z}\right) \tag{2.1}$$

where U(z) is the average wind speed at the height z above the ground, z_0 is the surface roughness, u* is the friction velocity and k (0.42) is the von Karman's constant.
FLUENT simulations has been carried out with a neutral boundary layer, together with the standard k-ε turbulence model. The computational domain is a parallelepiped with dimensions 72 m by 50.7 m in the horizontal plane and 22 m in the vertical direction. The greenhouse was designed adherent to the reality with a separation wall dividing the spans in two, the front and back. The back of the first span was a zone used for the research activities where three cultivation benches were placed. These were modelled as parallelepipeds, distant 1 m from the back wall, 1.49 m from the separation wall and elevated 0.65 m from the floor. First, a grid convergence study was performed. The meshes for the study were created finer inside the greenhouse than in the outside of greenhouse domain. In particular, the characteristics of the meshes are presented in the table below (Table 2.1).

Table 2.1: Meshes sizes and number of elements

Mesh	Internal dimensions	Outside dimensions	Number of cells
1	0.1 m	0.2 to 1 m	3×10^6
2	0.2 m	0.3 to 1 m	1×10^6
3	0.3 m	0.4 to 1 m	6×10^5
4	0.4 m	0.5 to 1 m	4×10^5
5	0.5 m	0.6 to 1 m	2×10^5

All the simulations were conducted with the same initial conditions: outside temperature of 9 °C, floor temperature of 22 °C and a logarithmic wind profile with friction velocity of 1 m/s. The test permitted to estimate the independency of the results from the mesh and, in this way, to choose the size of the mesh in such a way that it is possible to obtain valid results and reduce computational time. The figure 2.2 shows the results of the test, which permitted to identify the mesh 2 as the one for the subsequent simulations.

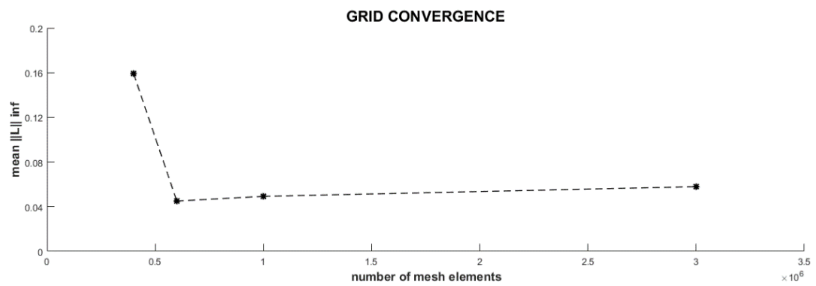

Figure 2.2: Representation of the results obtained from the convergence study

Then simulations were performed with wind profile with velocity progressively higher from 1 m/s to 8 m/s.
Mesh independency was verified with Autodesk CFD for the 3D FEM model through the mesh adaptation tool, leading to the adoption of a mixed mesh with elements of 0.2 m inside the building and 1 m outside, with volume increasing rate of 1.35 in the transition zones. Mesh independency was achieved with $7.523\cdot10^6$ elements at a rate of 95.18% for pressure and 99.97% for velocity. (Benni et al., 2017).

3. Results and Discussion

In order to evaluate globally the air movements, three different sections of the greenhouse were considered and analyzed: the middle section, one section two meters to the front and other one two meters to the back. These sections were characterized by similar airflows. In specific, the Figure 3.1 shows the comparison between the middle sections of the simulations with the lowest and the fastest wind velocity.

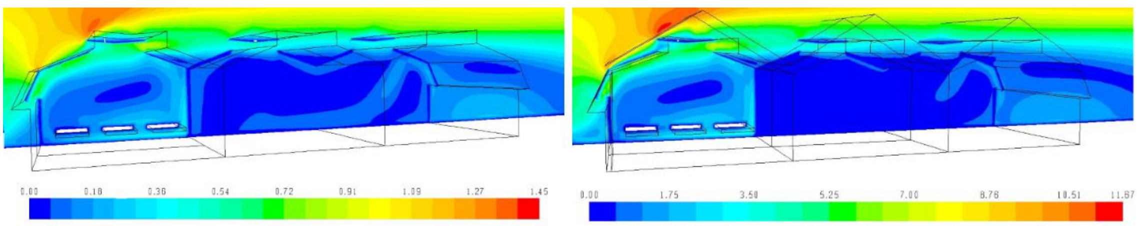

Figure 3.1: Comparison of middle sections with lowest (left) and fastest (right) wind velocities.

The mains differences were related to the magnitude of the air velocities, due to the dependence from the external wind profile. In fact, all the cases studied were characterized by a inhomogeneity of the internal ventilation of the span.

Simulations with Autodesk CFD provided a circular airflow pattern around a center placed at the height of the wall inlet in the south-eastern part of the span. The comparisons between the results obtained through 3D models with the two codes provided a substantial agreement of the velocity profile, particularly in the inlet zones, characterized by the highest velocities.

4. Conclusion

The simulations have proved to be a valuable tool for the analysis and evaluation of the internal fluid dynamics. Moreover, they have provided quantitative elements allowing to assess the opportunity of constructive or managerial adaptations of the greenhouse, in relation to the needs of the various agronomic activities, as well as to identify other specific needs of experimental insights.

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Microclimate measurements and evapotranspiration modeling in high-tunnel greenhouses and screenhouses in semi-arid regions

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Keywords: Temperature, Radiation, Air velocity, Evapotranspiration, Penman-Monteith

Summary
The area of crops grown in protected environments is constantly increasing worldwide. Two types of high-tunnel structures are common: A greenhouse covered by a plastic roof and a screenhouse covered by a porous screen. In the agricultural practice, most growers do not consider the difference in cover type in their irrigation management. The objective of this research was to study the effect of roof cover type, either plastic or porous screen, on microclimate and Penman-Monteith evapotranspiration (ET), to improve irrigation management in semi-arid regions. A field study was carried out during spring 2016 in two otherwise identical high-tunnels in which a pepper crop was grown. One was covered by a plastic sheet (hereafter denoted as the greenhouse) and the other by a 17-mesh screen (screenhouse). In both houses, microclimate variables were measured simultaneously above the canopy. Evapotranspiration was estimated using 8 different Penman-Monteith models, differing either in the resistance terms, or in the type of microclimatic data used, i.e. internal or external. Results showed that air temperature during daytime was higher in the greenhouse. Linear regressions between internal and external climatic conditions resulted with R^2 values between 0.51 and 0.97. Higher R^2 values were obtained for the screenhouse because internal microclimate interacted with the outside more than in the greenhouse. Mean daily evapotranspiration for the eight Penman-Monteith models tested was 2.12 – 2.74 and 1.66 – 2.41 mm day^{-1} for the greenhouse and screenhouse, respectively.

1. Introduction

In recent years, the area of protected cultivation in greenhouses and screenhouses is constantly increasing worldwide. For example, in Israel the area of vegetables, fruit trees and ornamentals cultivated under screens is more than 12,000 ha. A common type of such houses is high-tunnels that are covered by either a porous screen or a plastic film. The effects of the cover on microclimate are divers and mainly depend on the cover characteristics (material, color, porosity, roof shape) and on the crop type. All literature studies on screenhouses reported that the screen reduced radiation and wind speed, in comparison to an open crop; however, findings regarding the effects on temperature and humidity are ambiguous (Tanny 2013; Haijun et al. 2015; Kittas et al. 2012).

There is well-established knowledge on irrigation requirements of crops grown in open field (Allen et al. 1998). These requirements are usually based on reference evapotranspiration, extracted either from meteorological data or pan evaporation, which is then adapted to the crop status through empirical constants. On the other hand, irrigation of protected crops is much less documented, and currently limited for few crops in certain types of structures and climatic regions (Möller et al. 2004; Moratiel & Martínez-Cob 2012; Kitta et al. 2014).

Crop irrigation requirements are determined by several factors: crop type, microclimate, soil type and water quality. Cultivation under screens or plastic films modifies crop microclimate and previous studies have shown that such modification can increase the water use efficiency (Tanny 2013). For example, for a pepper crop cultivated in a large insect-proof screenhouse (Möller et al. 2004) results showed that actual crop water use was lower by about 50% than irrigation requirements for an open pepper crop. In a screen-covered table-grape vineyard (Pirkner et al. 2014), actual evapotranspiration was measured and compared with several estimates based on the Penman-Monteith model. Results showed significantly lower evapotranspiration under the screen compared to the value calculated for an open vineyard.

In irrigation management, most growers do not consider the effect of different cover type on crop water demand. The objective of this research was to study the effect of roof cover type, either plastic or porous screen, on microclimate and Penman-Monteith evapotranspiration (ET), in order to improve irrigation management.

2. Materials and Methods

A field study was conducted in spring 2016 in two otherwise identical high-tunnels in which a pepper crop was grown. Each tunnel was 45 m long, 10 m wide and 3 m in height. One roof was a plastic sheet (hereafter denoted as the greenhouse, GH) and the other a 17-mesh screen (screenhouse, SC), see Fig 2.1a. In both houses, micro-meteorological variables were measured above the canopy, see Fig 2.1b. Air velocity was measured by an ultrasonic 3D anemometer (model 81000, R. M. YOUNG, USA). Air temperature and humidity were measured by a combined sensor (model HMP45, Campbell Scientific, USA), solar radiation by a pyranometer (model CMP3, Kipp & Zonen, The Netherlands) and net radiation by a net radiometer (model Q7.1, REBS, USA). A nearby meteorological station measured external conditions of wind speed, air temperature and humidity and solar radiation.

Evapotranspiration was estimated using 8 different Penman-Monteith models, differing either in the resistance terms, or in the type of microclimatic data used, i.e. internal or external. Table 2.1 presents the various models.

(a) (b)

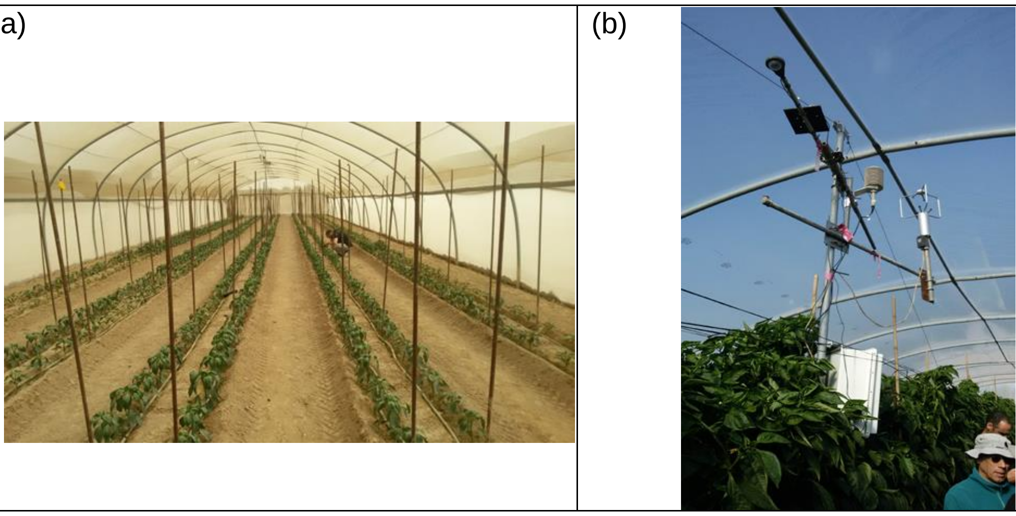

Figure 2.1: (a) The screenhouse after pepper plantation. (b) Micrometeorological sensors installed in the screenhouse above the pepper crop.

Table 2.1: The different Penman-Monteith models used in the present analysis

Model Name	**Model characteristics**	**Literature Reference**
ET for pepper plants	PM model with specific resitances for pepper plants	(Allen et al. 1998; Möller et al. 2004)
ET-FAO56 (outside, daily)	Reference evapotranspiration	(Allen et al. 1998)
ET-FAO56 (outside, hourly)	Reference evapotranspiration	(Allen et al. 1998)
ET-FAO56 (inside, hourly)	Reference evapotranspiration	(Allen et al. 1998)
ETscr	PM modified for screenhouses	(Möller et al. 2004)
ETgr	PM modified for greenhouses	(Fuchs 1993)
ETpt	PM under equilibrium	(Priestley & Taylor 1972)
ETrb	PM with boundary-layer resistance	(Pirkner et al. 2014)

3. Results and Discussion

Table 3.1 presents relations between external and internal meteorological variables for the two structures during the months of February and March 2016.

Table 3.1: Relations between internal and external conditions in the two houses

Relations in-out (Out is X-axis)	**Slope**	**Y-axis Intercept**	**R^2**	**No. Of data points**
Radiation GH (Wm^{-2})	0.44	0.15	0.89	21030
Radiation SC (Wm^{-2})	0.5	0.66	0.915	21030
Wind speed GH (ms^{-1})	0.08	0.033	0.51	21030
Wind speed SC (ms^{-1})	0.259	-0.0016	0.66	21030
Temperature GH (°C)	1.44	-6.81	0.76	21030
Temperature SC (°C)	1.09	-1.33	0.97	21030
RH GH (%)	0.98	0.96	0.67	10727
RH SC (%)	1.11	-21.94	0.84	10727

Results show that wind speed and radiation in the screenhouse are larger than in the greenhouse. Maximum air temperature, during daytime, was higher in the greenhouse, while minimum relative humidity during daytime was only slightly higher in the greenhouse than in the screenhouse. Table 3.1 shows that for all variables higher R^2 values were obtained for the screenhouse than the greenhouse because internal screenhouse microclimate interacted with the outside more than in the greenhouse.

Table 3.2 presents ET values calculated by the various Penman-Monteith models during 12 days. The results show that in models based on internal conditions, ET in the greenhouse is higher than in the screenhouse, presumably due to the higher air temperature. Mean daily evapotranspiration for the eight Penman-Monteith models tested was 2.12 – 2.74 and 1.66 – 2.41 mm day^{-1} for the greenhouse and screenhouse respectively.

Table 3.2: Penman-Monteith model estimations of ET in the two houses (STD is standard deviation)

Model	**Greenhouse**			**Screenhouse**		
	mm day^{-1}		**STD**	**mm day^{-1}**		**STD**
ET_{FAO56} out Daily	2.12	±	0.46	2.12	±	0.46
ET_{FAO56} out Hourly	2.41	±	0.66	2.41	±	0.66
ET_{FAO56} in Hourly	2.34	±	0.73	1.70	±	0.49
ET scr	2.74	±	0.90	2.13	±	0.72
PM in (for Pepper)	2.28	±	0.76	2.24	±	0.68
ET gr	2.59	±	0.87	N/A		N/A
ET pt	2.59	±	1.00	1.66	±	0.59
ET rb	2.38	±	0.78	2.28	±	0.66

4. Conclusions

Microclimatic variables were measured and Penman-Monteith ET was calculated in two high tunnels, one covered by a porous screen (screenhouse) and the other by a plastic film (greenhouse). Radiation and wind speed were higher whereas temperature was lower in the screenhouse than the greenhouse. Evapotranspiration based on internal climatic conditions was larger in the greenhouse than the screenhouse. Results may assist growers in accurate irrigation management.

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Design and management of dairy cow barns in Lombardy

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Keywords: barn design, welfare, management

Summary
As is well known, design and management of barns can significantly affect productivity and welfare of dairy cows. Although guidelines have been defined and are available to technicians and farmers, the effective application of this guidance is not straightforward.
The aims of this research were to: i) better understand the characteristics of barns and their management in practical farms in Lombardy; ii) highlight the need for better information and iii) identify deficiencies that must be filled to improve the performances of the herds. Therefore an assessment of the compliance of practical farms with design criteria and management guidelines was conducted on 38 freestall barns in Lombardy (provinces of Milano, Lodi and Cremona). The main structural parameters, layout and management were investigated in relation to animal welfare and herd performances. Each farm was visited twice (in spring and in summer 2016). During the visits, data on cow activity and microclimatic condition also were collected.
The results show a relevant number of farms with suboptimal conditions. For example, 20% of the barns had an inadequate number of stalls both for feeding and resting. The availability of drinking troughs was adequate only in 22% of the barns. Also the results on structural aspects highlight some critical points: for instance only 25% of the farms had a roof slope that can be considered optimal for good natural ventilation. The survey highlighted how criteria for the correct design of stalls for dairy cattle in order to ensure animal welfare and sustain the productivity are not always followed, and that many farmers exhibited only limited attention to these aspects affecting cow welfare.

1. Introduction
Dairy cow barns are a production tool and must ensure the well-being of the cows so that they can be fully productive and reproductive. This concept is universally known and accepted, but under operating conditions we often encounter situations in which the principles of good design of structures, spaces and equipment are not always respected.
The structure of the barn has a fundamental function in ensuring the optimum microclimatic conditions for cows. It must attenuate the temperature peaks in the warm hours of the day and ensure shadow on the barn, preventing areas being exposed to direct sunlight and ensuring good ventilation (CIGR, 2014).
The effects of heat stress are well known and might be mitigated by cooling systems (Porto et al., 2017), but a correct design of the barn is a fundamental prerequisite (Barbari et al., 2012). Several studies have highlighted how stress affects cow behaviour, reducing the resting time of cows and as a consequence, reducing the milk yields (Bava et al., 2012; Porto et al., 2015).
The aim of this research was to better understand the characteristics of the barns and their management in practical farms in Lombardy and to highlight the need for better information and the deficiencies that must be corrected to improve the performances of the herd. Therefore, the compliance of practical farms with design criteria and management guidelines was assessed.
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2. Materials and Methods
The assessment was conducted on 38 freestall barns in Lombardy (provinces of Milano, Lodi and Cremona). The main structural parameters (materials, size, height, roof slope, openings, type of floor), layout (layout of cubicles, passageways, drinking facilities), and management (feeding strategy, milking) were investigated in relation to animal welfare and herd performances.

Functional assessments were performed twice: the first time in a period with mild temperatures (April, May); the second time in the summer during higher temperatures to evaluate possible heat stress of the animals. During the visits, data on cow activity (number of cows standing, resting, feeding two hours after the milking) and microclimatic condition (temperature humidity index and air velocity) also were collected. The characteristics of each farm were compared to existing guidelines using a classification scheme for the different parameters.
The barns were selected among those having resting areas with cubicles and a traditional milking parlor. The survey was not aimed to obtain a statistical representation of the situation in Lombardy but rather to provide a picture of the productive realities operating today in this region.
In each barn, the characteristics of the structure, the size and type of equipment, and the size of the corridors and passages for animals were recorded. In addition, after two hours from the end of the milking, the number of breaths per minute and other animal behaviour indexes (such as the number of bovine lying and feeding) were evaluated visually. These measurements were made on a group of animal selected, where possible, in the central phase of lactation.

3. Results and Discussion

The average size of the monitored barns was 200 head in production, while the monitored groups represented half the total herd size (Table 3.1). Variability in the number of head in the different farms was notable, as were differences in the daily milk yield (average of 31 kg per head with a maximum of 42 kg). However, most farms yielded 25–35 kg per head per day. The values of somatic cells and bacterial counts were generally good although some of the farms had a significant possibility of improvement.
Although most of the barns followed existing structural guidelines, a relevant number had suboptimal conditions. With regard to the roof height at the gutter, 72% of the structures surveyed were adequate, but slightly more than 25% had a height below 3.5 m with possible limitation of the air inlet, especially in summer conditions. Furthermore, the slope of the roof was very often not well designed. In fact, about 75% of the structures had inadequate slopes (<30%) and around 20% of the examined barns had a roof with insufficient slope to ensure good ventilation (Figure 3.1).

Table 3.1: Average number of head, milk yield, somatic cell count and bacterial count in the 38 farms surveyed.

	Average	Standard Deviation	Minimum	Maximum
Total number of cows	200	129	45	530
Number of cows of the surveyed group	104	47	34	215
Milk yield (kg/head/day)	31	4	23	42
Somatic cell count (number)	217,387	67,336	72,000	430,000
Total Bacterial Count (UFC/ml)	21,614	38,876	6,000	249,500

The openings at the top of roofs play an essential role in the natural ventilation of the barn. Although this is a widely known aspect, less than half of the barns had a proper width of opening at the top. This can create negative conditions both in winter (by increasing moisture values) and in summer (because the hot and humid air is not moved away from the area where the animals live).
Conversely, the presence of good insulation was frequent and only 25% of the structures examined were without some kind on insulation. Finally, only one-third of the barns were properly oriented with the main axis in the east-west direction, considered optimal. The others were oriented north-south (36%) or in other directions. These data confirm the lack of attention to design criteria at the time of building, when contingent aspects of available space or continuity with other buildings prevailed.

The examined barns generally had 2 or 3 cubicle rows, though with some exceptions. The internal corridors were well sized in almost all cases, but in 30% of the stables there was at least one dead-end passageway. Generally, these derived from the presence of gates for the subdivision of animals into groups. So, in many cases, these flaws could easily be eliminated by appropriately managing the spaces and improving cow traffic.

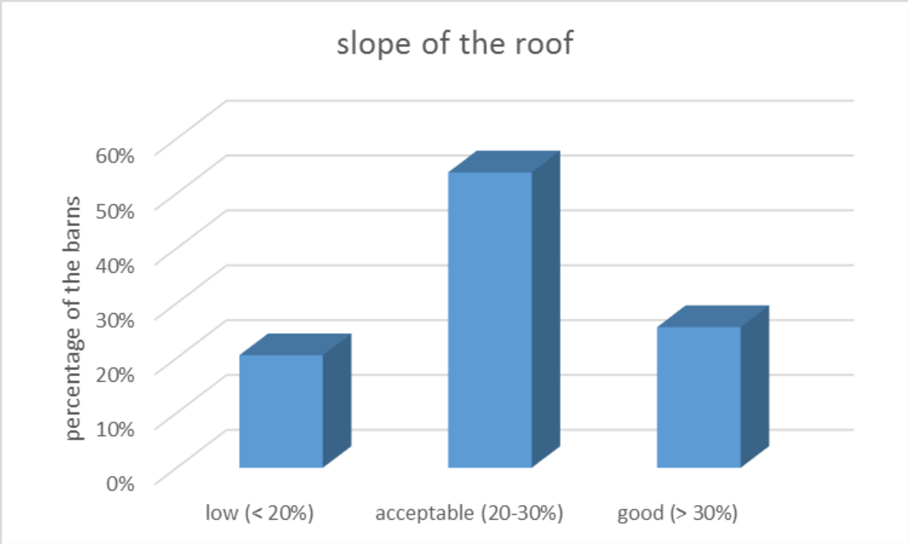

Figure 3.1: The slope of the roof is one of the key elements to ensure good natural ventilation, but only 25% of the examined stables had adequate roof slope.

The width of the passageways across the rows and their number was adequate in 80–85% of cases, highlighting how only in some cases, especially for the oldest stables, focus has been on reducing the overall size of the stall without considering the limitations of animal traffic in the housing area. This conclusion is also confirmed by the width of the feeding area, which was inadequate in 18% of the barns.
The availability of places in the manger and in rest areas was unexpectedly low. In fact, only half of the barns can be considered optimal for these two aspects and almost 20% of the barns were definitely inadequate (Figure 3.2). This result is perhaps more likely to be attributed to an increase in the number of head over time than to a poor initial design.
The availability of drinking facilities both in the housing area and at the exit of the milking parlor was strikingly inadequate. More than half of the barns tested did not meet the minimum guidelines for this equipment.

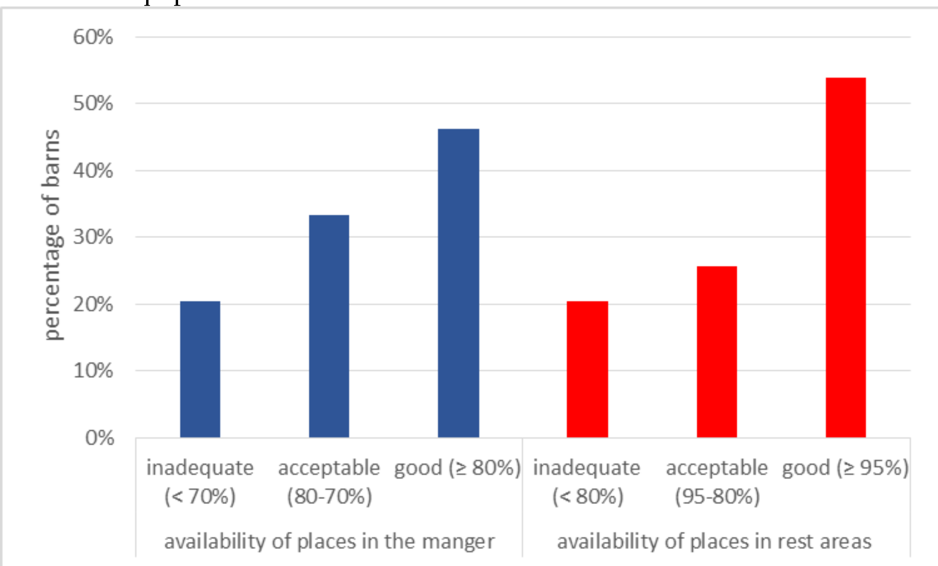

Figure 3.2: Appropriate availability of manger and stalls in rest areas ensures that the cow can lay down and have free access to food in full freedom. In 20% of the examined farms the availability of places was considered insufficient.

4. Conclusions

The survey highlighted that criteria for the proper design of dairy farms for dairy cows to ensure animal welfare and support productivity are not always respected in practice. In some cases, the shortcomings are linked to structural problems, which certainly are not easy to solve. However, non-structural deficiencies might be easily rectified at low cost, and in many cases, with existing farm resources.

The results obtained, which need to be integrated with animal behavioral and micro-environmental conditions, not reported here, suggest, however, a limited sensitivity and knowledge of the design criteria for cow welfare among farmers.

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Indoor environmental conditions and energy consumption of a plastic multi-span greenhouse: numerical simulations vs. monitoring

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Keywords: energy modelling, dynamic simulation, multi-span greenhouse

Summary

The present work deals with the simulation and calibration of an energy model of a 3 hectares plastic multi-span greenhouse in Piemonte. Dynamic energy simulations were performed by means of the EnergyPlus software tool. The energy model of the greenhouse was calibrated against monitoring data of the 2014 year, which were retrieved from the Building Automation System (BAS) of the greenhouse. At the end of the process, the simulation results matched with the real data gathered on field. The calibrated energy model allowed possible retrofitting solutions to be evaluated in term of energy performance increasing and satisfaction of the environmental requirements for plants' growth.

1. Introduction

The present work aims at carrying out reliable simulation results considering all the complex physical processes influencing the thermal behaviour of a large greenhouse. Indeed, a dynamic energy simulation software is generally designed for traditional buildings and an additional attention must be paid when modelling the greenhouse complex environment. On the one hand, the low thermal inertia of greenhouse envelope and internal components, coupled with high solar heat loads, generate dynamics that are faster than those of traditional buildings. On the other hand, the physiological process related to evapotranspiration of plants is a particular internal latent heat load that affects both the thermal and the moisture balance (Ponce et al., 2015).

2. Materials: description of the case study

The present work deals with one of the larger greenhouse in Piemonte designated for the hydroponic cultivation of tomatoes throughout the year. The cultivated area considered was a greenhouse with a total heated surface of 7130 m^2, composed of a multi-span steel structure of 9.6 m of width. The greenhouse envelope cover is made by a double plastic film of ethylene vinyl acetate (EVA), with a 5 cm intermediate air gap to increase the thermal resistance. The greenhouse was equipped with a BAS that monitors the entire production process and regulated the greenhouse internal air temperature, carbon dioxide concentration and relative humidity. The control of these parameters influences both the energy consumption of the structure and the plant growth (Van Straten et al., 2010). In the considered case study, the control of solar radiation was performed by means of the application of an external film of calcium carbonate, which was sprayed at the beginning of the Summer season to reduce the solar load. This film gradually flushes away with the rain. Furthermore, the greenhouse used the natural ventilation, regulated by means of an automated opening system of skylights and vents, as a primary source of free-cooling. During the cold season, the greenhouse environment is heated by an active water based system. This heating system is twofold: a primary pipe rail heating is placed near the soil (and the rails are used to guide a cart for the workers) and a vegetation pipe heating is placed vertically near the plants. The thermal energy was delivered by a boiler in open buffer heating system (supplied by natural gas and with a storage tank of 5000 l). The heating system schematics is shown in Figure 1. During 2014, the cultivation was done from February to December, while in January the maintenance of the systems and the plantation of new plants were performed. The greenhouse heating season typically last from the half of November to the end of April of the following year. During the heating season carbon fertilisation is provided handling the boiler exhaust gases with a catalytic converter. During the remaining part of the year a liquid carbon dioxide tank is used for this purpose. Every 2 minutes the BAS monitors all the main variables of the greenhouse (e.g., internal environmental parameters, external weather, energy and water consumption, etc.). These data were used for the calibration of the numerical simulations.

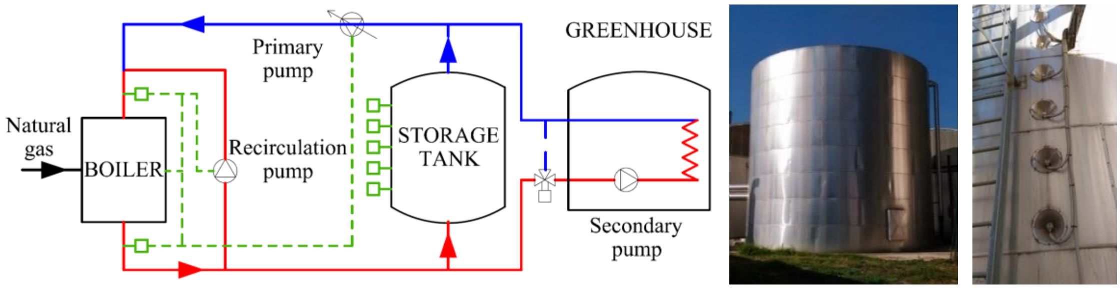

Figure 1: Schematic of the boiler in open buffer heating system of the greenhouse. Green dashed lines represent the control logics of the primary pumps (left). Storage tank and its thermocouples (right)

3. Methods

Firstly, a geometrical model of the entire greenhouse and the external shadings affecting the solar gains were developed in Google SketchUp. Then, thermal zones and material thermal properties, obtained by technical datasheets (e.g. thermal conductivity and capacity, solar and visible transmission) were assigned through the OpenStudio simulation tool. Eventually, into EnergyPlus, additional information about the heat exchange with the ground and the control system were also introduced and HVAC system parameters and hourly schedules of the control system were defined. Weather conditions affecting the structure were defined from the data monitored by the greenhouse external weather station. An internal source of vapour was used to represent plants evapotranspiration, and its hourly schedule was retrieved from the plant physiological model of Stanghellini (1987), that considers the evapotranspiration as a function of the environmental parameters of the greenhouse microclimate.
Simulations were performed to obtain a trial and error calibration procedure that allows the gap between real data and results of energy simulation to be reduced (Fabrizio and Monetti, 2015). The calibration procedure consisted in the comparison between simulated results and monitored data of the following three parameters: the design heating load, the monthly energy consumptions, and the internal temperature trends at hourly time step. The first step of the procedure consisted in properly setting the parameters affecting the heat exchanges towards the ground. Secondly, the radiative heat exchange properties of the transparent film of the cover were adjusted. Afterwards, the calibration was focused on the parameters concerning the air change rate (e.g. leakage through the greenhouse envelope and natural ventilation through windows opening). These are in general the more stochastic values that affect the heat and mass balance of a structure. Fifteen different combinations of such parameters were considered, and the resulting simulated energy consumption and internal temperature trends were compared with respective real data.
After the calibration of the energy model, possible energy retrofit measures were simulated. The goals of these retrofit measures were both the improvement of the internal microclimate conditions for enhancing tomatoes growth and the reduction of energy consumption of the greenhouse. The internal environmental condition needed for crop ideal growth were estimated from the literature, assuming an internal air temperature ranging between 12 °C and 29 °C, a carbon dioxide concentration between 800 - 1200 ppm and a relative humidity between 50 % and 80 %. To generalise the obtained results, the retrofit scenarios were tested using weather data gathered from the International Weather for Energy Calculation (IWEC) weather file of Turin.
Three different scenarios of possible energy retrofit measures were investigated. (i) The first retrofit measure consisted in substituting the external film of calcium carbonate with a movable

external screen for shading, operating during the warm season. This allowed the solar radiation load to be properly controlled, therefore limiting the temperature rise inside the greenhouse. (ii) The second measure was an internal thermal screen that reduced the heated volume of the greenhouse during the cold season. Furthermore, this internal screen allowed the heat radiation loss toward the sky during night time to be also reduced, thus to maintain a steadier internal temperature and to save energy at the same time. (iii) The third retrofit measure was the adoption of a slab with additional thermal insulation in order to reduce the thermal losses toward the ground. All the simulations referred to each retrofit measure were performed with a parametrical approach that evaluated various combinations of material features (e.g., different thickness or conductivity of the insulation layer in the slab, different level of shading).

4. Results and Discussion

The combination of parameters that allowed the simulation results to best fit the monitored data undertook the ground thermal conductivity equal to 2.5 W/(mK), and the solar transmittance at normal incidence of the EVA film equal to 95 %. Furthermore, the threshold temperature values for natural ventilation activation was set equal to 14 °C and the air change per hour to 0.6 1/h. The resulting design heat load was 1.02 MW, a value that matched with the 1.21 MW of maximum power deliverable by the actually installed boiler. The calibrated simulation model estimated a yearly energy consumption of 194 kWh/m^{2}year. This result was comparable with the actual energy use of the greenhouse retrieved from the natural gas energy consumption, that was equal to 180 kWh/m^{2}year (difference of 7.6%). Figure 2 (left) shows the comparison between the real and the simulated monthly energy consumptions. From this figure, it is possible to infer how the largest amount of the whole difference between real and estimated energy consumption is attributable to the consumptions of the month of December, when the reliability of the monitored data was affected by some missing values. The simulated internal air temperature showed an hourly trend that matched with the real data with a RMSE of 10.6 % and a NMBE of 0.57 %, amply below the maximum threshold values indicated by ASHRAE (2014) – respectively 30 % and 10 %. Figure 2 (right) shows the comparison between the real and the simulated hourly temperature trends for a 10-days period of time.

Results of the simulated scenarios concerning possible measures of energy savings were particularly interesting. Indeed, they highlighted how effective energy savings were achievable with relatively simple technical solutions. Firstly, the scenario (i) simulating the additional external screen that controls the solar radiation showed that the hours in which the internal temperature exceeded 29 °C can be reduced of 40 % by means of an external shading with 80 % of reflectance. Simulations referred to the greenhouse with the internal thermal screen (ii) are function of the reflectance of the indoor thermal screen cover. With 96 % of reflectance, it was estimated a potential reduction of 7.7 % of the energy consumption during the heating period. The retrofit solution concerning the slab with additional thermal insulation (iii) showed a possible reduction of the energy demand for the heating period up to 12 % by means of the adoption of an additional insulation layer that reduced the slab conductivity to 0.28 W/(m^{2}K).

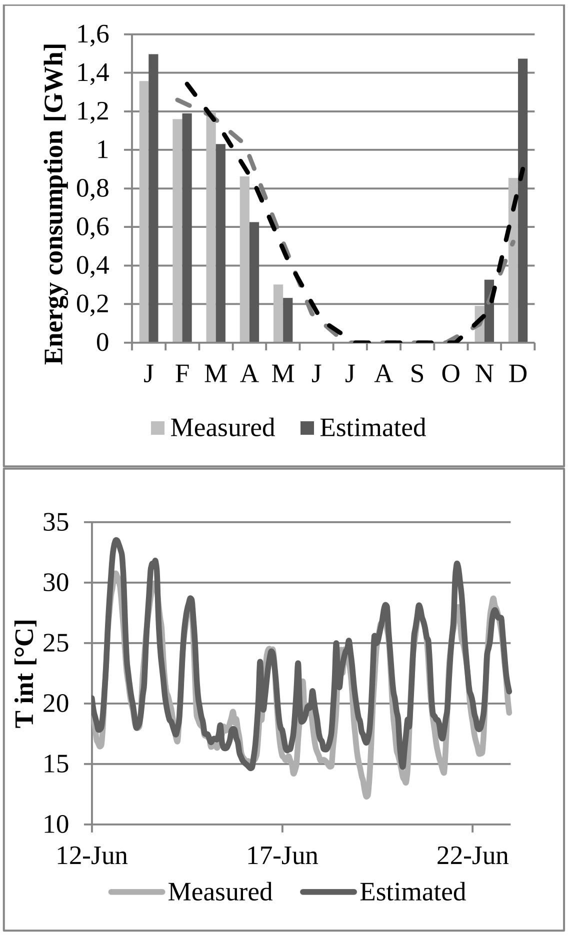

Figure 2: (left) monthly energy consumptions (bars) and associated rolling average (dashed line). (right) Representative hourly profiles of internal air temperatures related to the period over the Summer solstice.

5. Conclusion

The present work dealt with numerical energy simulations of an heated greenhouse. A specific calibration aiming at reducing the mismatch between real data and simulation results was herewith presented. Results are amply below the threshold value indicated by ASHRAE to define if simulation models are reliable. Thus, the obtained energy model allowed possible retrofitting solutions to be evaluated in terms of potential improving of the environmental requirements and energy savings.

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Viewpoints and visibility analysis: a case study on the UNESCO site of Langhe-Roero and Monferrato (Piemonte Region)

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Keywords: Visibility analysis, Landscape analysis, UNESCO sites

Summary
The present work is based on the coupling between the visibility analysis based on viewsheds/cumulative viewsheds (binary maps) and the study conducted at a regional level that identifies points that can be considered and that should be preserved.
Visual landscape assessment methods can now exploit the resources that public administrations shares within the open data normative requirements. This implies a further valorisation of the investments done though the creation and update of geographical data.
The scope of this work is not to obtain a static map, but to set out an interactive tool that, based on visibility analyses, can be used to measure the landscape sensitivity of sites. The area named "Vineyard Landscape of Piedmont: Langhe-Roero and Monferrato ", listed as the 50th Italian site in the World Heritage UNESCO list, was identified as a case study, since it is a cultural landscape of exceptional and universal value.
The information provided by this application may be used into the regulatory framework for all the authorization process of new developments in preserved areas.
The objective is to provide technicians and local administrators tools based on objective data for the conservation, preservation and valorization of the landscape on one side, and for the development of economic activities that can promote a sustainable development of such peculiar locations.

1. Introduction

It is well established the fact that new developments impact on the viewing conditions of a landscape. Visibility analyses for the landscape settings have widely been used, especially in rural and forest areas, in order to determine through viewsheds to which extent a portion of a landscape is/can be seen from another point.
At the same time, the application of such analyses within the regulatory framework of new developments is not an easy task since it is difficult to determine which are the "viewing points" from which visibility analyses should be performed.
Most of the visibility analyses that are currently developed can be defined as "static" and can lead to the two following main drawbacks:

- on the one hand, the simple fact that a land unit "is seen by" (or "can be seen from", for the reversibility of optical paths) a large number of viewpoints is not in itself particularly significant. A certain land unit can be seen from points with different features, while some viewpoints, like the 6 ones selected by the local administrations as panoramic points have a different value. In other words, the identification of the landscape sensitivity based on only quantitative metrics (larger or smaller visibility) can be seen as a too limited approach.
- on the other hand, many researchers have designed and implemented applications and tools for the landscape values estimation, and nowadays technologies are sufficiently developed to implement analyses based non only on the visibility between points, but also on the classification of the land units and weighting of portions of visible land as a function of qualitative perceptive indexes and metrics. For example, a portion of territory which is already

in some way "disturbed" by elements that somehow mark it and compromise its landscape value, may not be so heavily damaged by new developments that do not involve a particular degradation and, at the same time, guarantee economic activities necessary for the economy development of the territories.
Studies that allow such analyzes are currently being developed by the Authors, even though at this moment they are not yet completed.
Instead of immediate use, it is possible to create dedicated GIS tools for dynamic visibility analysis, so that results can be discussed directly in decision-making processes (building commissions, landscape commissions, etc...). Contrarily to the first landscape planning tools that were almost exclusively conservative plans, today a new concept of planning tools, which include transformation, innovation, and therefore necessity of tools is being developed. There is therefore the necessity to integrate the analysis of visibility within the discussion and the analysis, by considering different points of view, realistically taking into account not all "possible" visuals, but only those visuals that are to be privileged, those that are significantly relevant and contains realistic visual simulation of what is proposed.

2. Materials

The PPR (*Piano Paesaggistico Regionale*) of Piedmont identifies 154 landscape viewpoints at a regional level (Figure 1).

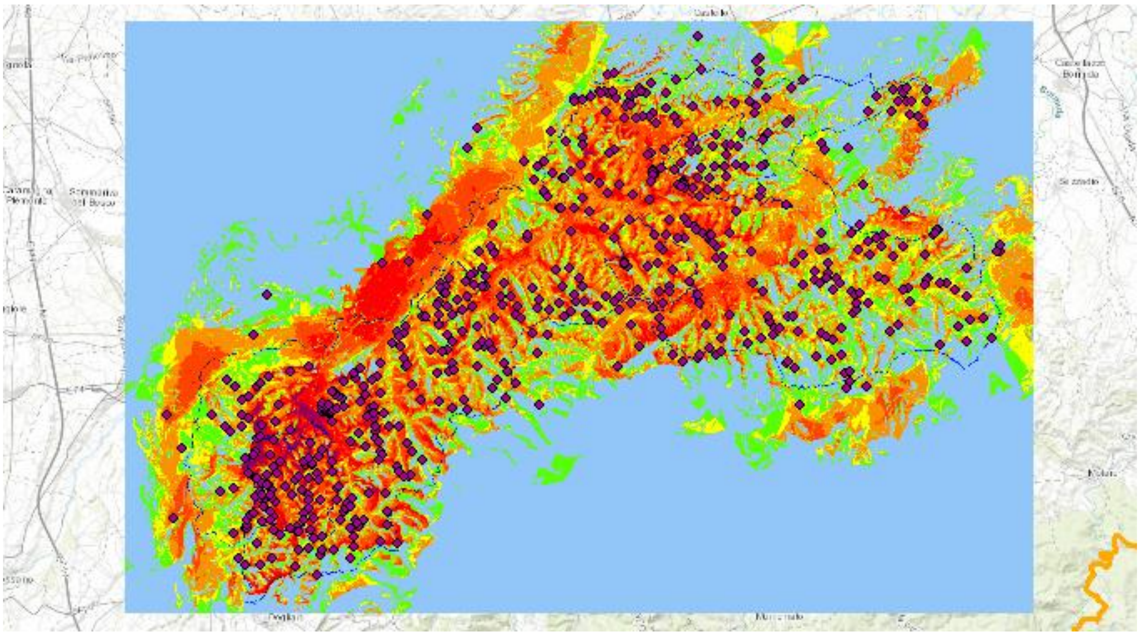

Figure 1: Visual sensitivity map of the Langhe-Roero UNESCO site. Each viewpoint is indicated by the purple dot. Red land units are the ones with the maximum visibility of the viewpoints.

On the UNESCO site of Langhe-Roero and Monferrato, in accordance with local mayors, 730 viewpoints were identified. Viewpoints were identified in accordance with the criteria of the Guidelines of PPR, through inspection visits by municipalities, aggregations of municipalities and provinces, so that they have a distribution as homogeneous as possible. As a consequence, a visual sensitivity map was developed (DGR 26-2131 of 21 September 2015). The visual sensitivity classes of the map indicate the number of viewpoints from which it is possible to observe each land unit (25mx25m).
The interest in the viewpoints for the landscape preservation and management is also demonstrated by the fact that a program agreement between Piedmont Region and six municipalities in the UNESCO site for the creation of a network of panoramic views to strengthen the economic and tourist development of the areas involved was signed on April 3rd

2017. This network of viewpoints is seen as a further element of tourist attraction dedicated to the beautiful landscape of Langhe-Roero and Monferrato. For this development, 1,448,600 euros were allocated. Selected areas will be managed, and possibly rebuilt, to have common elements that recognize the network of viewpoints into a sort of path equipped also with multimedia devices.

4. Results and Discussion

On the UNESCO site visibility analyses can be generated from databases, recent and homogeneous, already conforming to the specifications of DM 10/11/2011. These are:

- Level 4 DTM;
- Region 2010 and AGEA 2013 Orthophotos;
- former CRT data bases;
- regional LiDAR data.

Using these data, visualization tools like the reported in Figure 2 can be generated.

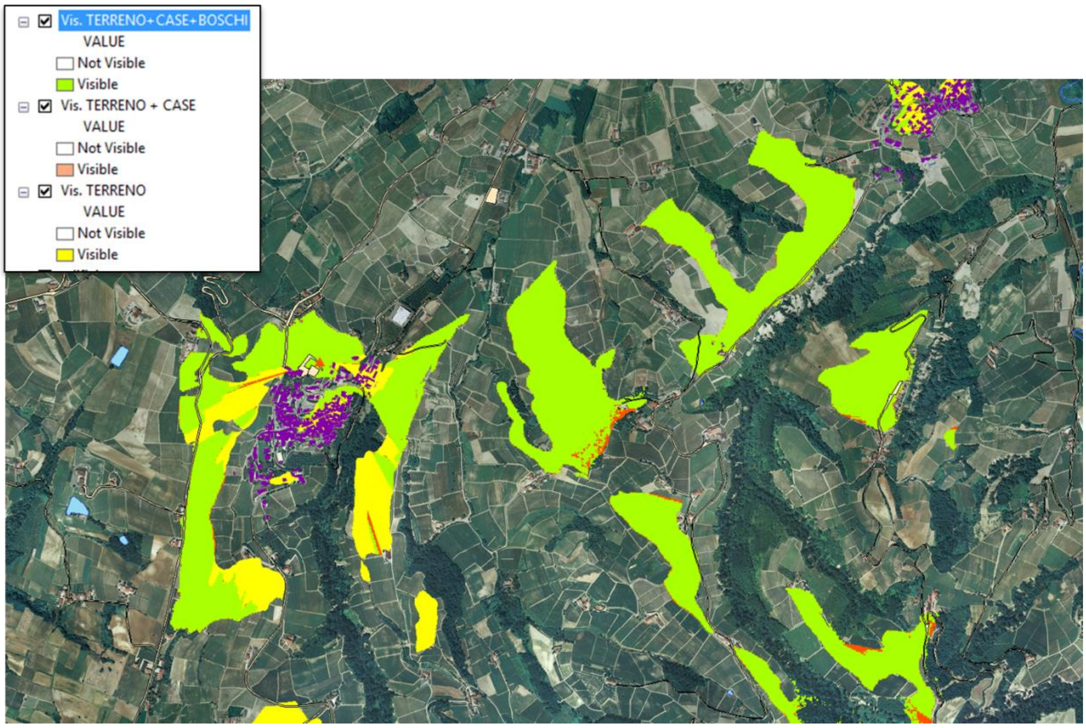

Figure 2: Visibility analysis considering the DTM, the buildings and the forests.

In order to better model the buildings, it may be useful to provide the territory under consideration with photogrammetric captures made with the increasingly common digital oblique aerial cameras (commercially known as Pictometry, MIDAS, ...).

At this time, they are not so widespread, but there are already several productions in Italy, namely:

◦ municipalities with a population of more than 40,000 inhabitants (CGR, 2007-13)
◦ all urban centers of Sardinia;
◦ the coast of Calabria.

With such cameras, it is possible to see not only the roof of buildings, but also the facades of the buildings. These may be also used to extract extrinsic properties of the building (for the probable reform of Italian cadastre). With such cameras, it is possible to generate ad hoc data bases for the generation of 3DML models to enhance dynamic visibility analyses.

Figure 3: MIDAS oblique aerial camera.

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Heat stress of dairy cows subjected to different cooling systems

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Keywords: Livestock buildings, Cooling systems, Heat stress

Summary
This paper presents the results of a research study which had the objective of investigating the effect of a sprinkler system coupled with forced ventilation on the heat stress of dairy cows bred in a free stall barn without paddock.
To this aim, an experiment was carried out inside a free-stall dairy house equipped with two different cooling systems: a fogging system associated with forced ventilation in the resting area and a sprinkler system associated with forced ventilation in the feeding alley. The experiment regarded two adjacent boxes of the barn and was constituted by three different trials carried out in the following periods: 27th June – 7th July (P1), 25th July – 4th August (P2), 24th August – 3rd September (P3). The experimental protocol of each trial required that in one box the two cooling systems were always activated following an established timetable, whereas in the other box the sprinkler system associated with forced ventilation was always deactivated.
Climatic parameters were measured inside each box of the barn and outside. Then, THI index was calculated. Rectal temperature and respiration rate of a sample of dairy cows were monitored each day during the three periods considered (P1, P2 and P3).
During the experiment, the cows of each box were subjected to mild or moderate heat stress. Although the sprinklers do not influence the microclimatic conditions, their use contributed to relieve heat stress as attested by a worsening of the physiological conditions of the cows that were bred in the box with the sprinkler system deactivated.

1. Introduction

Among the causes that influence cow welfare, heat stress induced by microclimatic conditions is one of the most relevant. For mitigating cow heat stress, different kinds of cooling systems are used and among them, sprinklers for the direct wetting of the animal body coupled with forced ventilation have positive influence on both cow physiology, behaviour and cow lactation performance (Avendaño-Reyes et al., 2010; Berman, 2010; Porto et al., 2017).
The benefits induced by sprinklers systems were investigated by several research studies through experiments carried out in geographical area often characterised by hot dry climate, whereas analogous studies in zones characterised by hot humid climate, such as those of the Mediterranean basin, are rather less frequent (Honig et al., 2012; Calegari et al., 2012). The functional area where cooling is carried out could influence cow heat stress relief. In some research studies, the herd is cooled in the holding pen before the milking time (Avendaño-Reyes et al., 2010; Honig et al., 2012). In other cases, the cooling is carried out in the feeding alley and in the resting area. In this situation, if animals have free access to a paddock (Frazzi et al., 2000; Calegari et al., 2012), heat stress due to high levels of relative humidity could also be reduced by leaving the barn when microclimate becomes uncomfortable.
On this basis, this paper investigates if cow heat stress induced by hot humid climate could be mitigated by using a sprinkler system coupled with forced ventilation installed in the feeding lane of a free-stall barn without access to a paddock and equipped with a fogging system associated with forced ventilation installed in the resting area and.

2. Materials and Methods

The experiment was carried out inside a free-stall dairy house located in Pettineo/Pozzilli (37°01'N, 14°32'E) in the province of Ragusa (Italy), at the altitude of 234 m above the sea

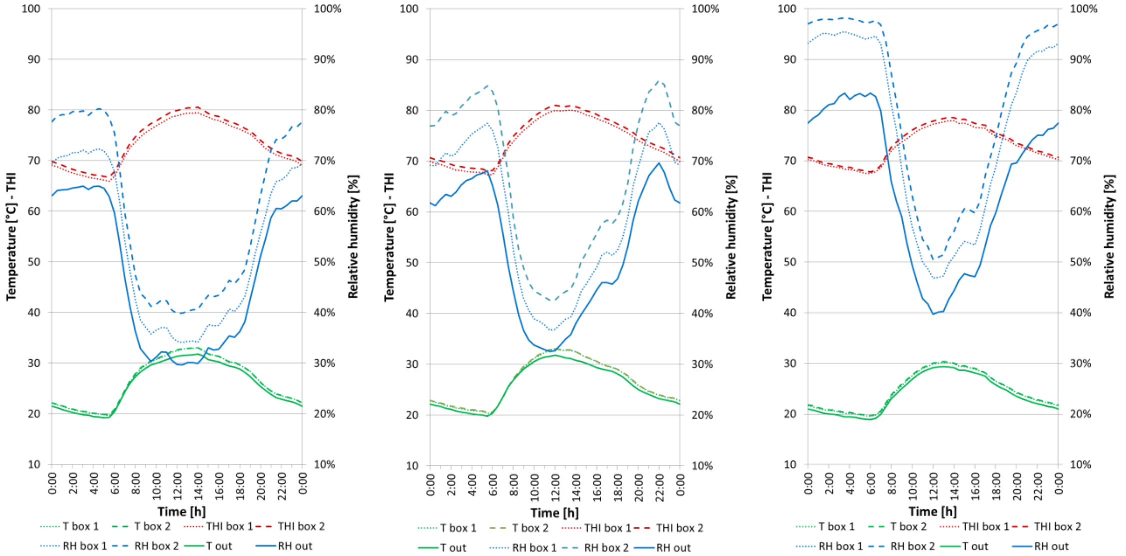
level. The barn was closed on the side along the feeding alley and opened on the other three sides. The experiment was carried out in two adjacent pens separated by transverse passages: one with a resting area consisting of 26 cubicles housing 19 Friesian cows (box 1) and the other one with a resting area consisting of 16 cubicles housing 15 Friesian cows (box 2). The cubicles were bedded with sand.
The free-stall barn was equipped with two different cooling systems. A fogging system associated with forced ventilation was installed in the resting area and a sprinkler system associated with forced ventilation was installed in the feeding alley.
The trial started on 27th June 2016 and ended on 3rd September 2016. The experimental protocol was structured as follows: in box 1 (treatment group) the two cooling systems were always activated following an established timetable, whereas in box 2 (control group) the sprinkler system associated with forced ventilation was deactivated in the following periods: 27th June – 7th July (P1), 25th July – 4th August (P2), 24th August – 3rd September (P3).
Rectal temperature and respiration rate of 6 cows in box 1 and 5 cows in box 2 were monitored at about 14:30 of each day during the three periods considered (P1, P2 and P3). During the measurements, each cow was blocked in the feeding rack. The respiratory rate was measured by counting the breaths per minute with the aid of a digital timer, the rectal temperature was recorded using a digital thermometer.
Cows were fed ad libitum and feed was delivered at 8:00. The feeding area was cleaned once a day between 8:30-9:30 using a scraper driven by tractor. Cow milking occurred twice daily between 5:00-6:00 and 17:30-18:30.
Air temperature and relative humidity were measured outdoor at the ridge line of the roof. Inside the barn, air temperature and relative humidity were measured at the height of 2.00 m above the floor, using four probes in box 1 and two probes in box 2. All the sensors were connected to a data-logger that read the measurements every 5 seconds and recorded the corresponding average values every 5 minutes. The THI index was calculated by the following (Yousef, 1985):

$$THI = T_{db} + 0.36\,T_{dp} + 41.2 \qquad (1)$$

where T_{db} [°C] is the dry-bulb temperature and T_{dp} [°C] is the dew-point temperature.

3. Results and Discussion

As the cows were free to move within each box, they were subject to microclimatic conditions that are better represented by the average values of the respective probes. Therefore, measurements of the four probes inside box 1 and of the two probes inside box 2 were averaged. Figure 3.1 reports the mean daily values of air temperature and relative humidity outside the dairy house and inside the two boxes with the respective calculated THI indices, in the three periods considered. Period P2 was characterized by the most severe climatic conditions, with the same mean air temperature of period P1 (25.8°C) and an higher mean value of air relative humidity (52.4% vs. 46.8%), whereas period P3 was characterized by a mean air temperature of about 2°C lower than P1 and P2, although with the highest mean value of air relative humidity (64.9%).



P1 P2 P3

Figure 3.1: Mean daily values of air temperature and relative humidity measured outside the dairy house and inside the two boxes with the related THI indices, in the periods P1, P2 and P3.

The results inside the barn show that, in both groups, air temperature in P3 was lower than in P1 and P2, and that air relative humidity increased during the experiment from P1 to P3. Consequently, in both boxes THI value in P2 was a little higher than in P1 and P3. The comparison between the microclimatic conditions in the two boxes within each period shows that air temperature was almost the same, whereas relative humidity was always higher in box 2. As a consequence, the highest THI mean values occurred in box 2 during all the three periods and they ranged from 73.3 in P1 to 74.7 in P2.

Summarizing the previous results, during the three trials the cows of both groups were subjected to mean climatic conditions corresponding to mild or moderate heat stress. However, during daytime, air temperature and relative humidity reached values corresponding to a severe heat stress, as it is shown by the maximum THI values that were higher than or very close to 80 (figure 3.1).

The results of the measurements of the physiological parameters in the monitored cows show that in both groups the highest mean values of respiration rate and rectal temperature occurred in period P1. This evidence, which is not in perfect agreement with the results of THI values, can be explained considering that in P1 the cows were subjected to a fast and a remarkable rise of air temperature compared to the days immediately preceding the start of the trial. Differently, in P2 the cows have had more time to adapt to a condition of thermal stress. In the treatment group the value of respiration rate was 56.4 in P1, while during P2 and P3 it was respectively equal to 51.6 and 49.4, that are very close to the highest value of the ideal range (26-50; Merck Veterinary Manual, 2012a). These results are very close to that obtained in Calegari et al. (2012) and indicated a more favourable condition for heat dissipation in the box with the sprinkler system. On the contrary, in the control group, the mean values of the respiration rate were considerably higher than the ideal range during all the three periods of the experiment, as it ranged from 64.5 in P3 to 70.1 in P1.

In the treatment group, despite the heat stress conditions, rectal temperature was within the ideal value (38-39.3°C; Merck Veterinary Manual, 2012b) in all the three periods. In the control group, rectal temperature was higher than the upper limit of the ideal range (39.4°C) only in P1, indicating mild heat stress. As reported by other studies (Khongdee et al., 2006; Calegari et al., 2012) rectal temperature values might have benefited by the mitigating effect of the cooling system installed in the cubicles area.

4. Conclusion

The effects of heat stress on lactating dairy cows were investigated when a cooling system consisting of sprinklers and fans was installed in the feeding alley. The results show that the sprinkler system did not influence the microclimatic conditions as the barn was completely open on three sides. This condition determined that the two groups of cows were exposed to the same mild or moderate heat stress, although during the day time THI reaches values higher than 80.
The results show that the sprinkler system installed in the feeding lane made it possible to mitigate heat stress on dairy cows in hot wet climate. Specifically, the system especially influenced the respiration rate that, in the treatment group, kept itself inside or very close to the ideal values, while in the control group was up to 20 breath/min higher than the maximum suggested value. The sprinkler system had more limited effects on rectal temperature that, however, in the treatment group was lower than in the control group in all the three periods of the experiment.

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Micro-climatic effect of plastic nets for crop protection in greenhouse

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Keywords: crop shading, plastic nets, radiometric characteristics, photo-selective properties, micro-climatic effect

Summary
Excessive levels of solar radiation may negatively influence crop growth, with sunburns or other possible crop damages, while increasing the internal greenhouse temperature above levels that are tolerable for plants and workers. In order to control hot air temperature inside a greenhouse, one of the most common solutions traditionally employed by growers in Southern Europe is whitening the external side of its cladding material, by painting it with liquid calcium carbonate. More recently, the use of plastic shading nets is progressively affirming, thanks to their cheaper price and some improved technical characteristics that enable them to act as a "passive" tool for controlling internal microclimate and produce suitable environmental conditions. A comparative analysis between a plastic net and a traditional whitening technique, aimed to critically assess the efficacy of the two different shading methods to modify and control the internal microclimate inside a plastic-covered greenhouse, is presented in this paper. A trial was carried out in Pontecagnano (Southern Italy), where one small-scale tunnel was shaded with a plastic net characterized by 60% of shade effect, while another identical small-scale tunnel was whitened with liquid calcium carbonate on the external side of the cladding plastic film. The radiometrical characteristics both of the plastic net and the whitened film were determined in the laboratory of the SAFE School of the University of Basilicata (Italy). The results obtained through these experimental trails enabled a comparative analysis of the performances of the two tested shading methods, confirming the relationship among the shading conditions and the transmittance in the solar range, highlighting the role that a correct solution may play on the final results in terms of crop protection from high temperatures and sunburns.

1. Introduction

Excessive levels of solar radiation may determine negative effects on the crop growth. Plants that are not adapted to intense sunlight can develop heat stress. Most of these negative effects may be avoided, mostly in the case of crop protection under greenhouse, when suitable shading devices are employed (Castronuovo et al., 2015).

To control hot indoor air temperature, one of the most common traditional solutions utilized by growers in Southern Europe is the summer shading of the greenhouse against excessive solar radiation through the application of calcium hydroxide (*i.e.*, slaked lime) or other chemicals on the cover of the greenhouse (so-called, *whitening*, *i.e.*, white shading paint). Whitening can be achieved by spraying the exterior cover surface with an aqueous solution of hydrated Calcium oxide ($Ca(OH)_2$). Whitening the greenhouse roof is inexpensive and has positive effects on both microclimate and crop behaviour, being considered an efficient mean for alleviating large heat loads during summer that, at the end of the summer season, is naturally washed away by autumn rains.

More recently, the use of plastic shading nets is progressively affirming, thanks to a cheaper price and improved photo-selective properties (Sica et al., 2008). Plastic nets are usually characterized by a shading factor, ranging from 10% to 90%, which represents the capacity of the net to reduce the incoming solar radiation, related to the average value of the transmissivity of the net in the solar wavelength band from 380 nm to 760 nm (Schettini et al., 2012). A plastic net, due to its influence on the main microclimatic parameters (temperature, relative humidity, carbon dioxide concentration, solar radiation, *etc.*), could play a fundamental role on creating more favourable environmental conditions during the crop growth (Picuno & Abdel-Ghany, 2016; Abdel-Ghany et al., 2016). On the other hand, plastic covers play a crucial role not only

towards the internal environment, influencing the crop growth, but also towards the external surrounding landscape, strongly affecting the visual aspect of the rural land (Picuno et al., 2011; Statuto et al., 2016).
With the aim to critically assess the efficacy of these two different shading methods to modify and control the internal microclimate inside a plastic-covered greenhouse, in this paper the results of a comparative analysis between a plastic net and a traditional whitening technique are presented.

2. Materials and Methods

Two small tunnels (fig. 2.1) reproduced in scale were realized in an experimental area located in Pontecagnano (Southern Italy) during summer 2016. These experimental small-scale tunnels, both covered with an EVA plastic film, were left without any cultivation. One of them was whitened with an aqueous solution of 20% hydrated Calcium oxide ($Ca(OH)_2$) – *i.e.*, a dose of 0.2 kg l^{-1} – while the second one was externally covered with a 60% plastic shading net adhering to the film. Air temperature and relative humidity inside each tunnel were measured by relevant probes (CS500-L modified version of Vaisala's 50Y Humitter, Campbell Scientific Inc. Utah, USA). Data were recorded into a CR10x data-logger (Campbell Scientific Inc. Utah, USA).

Figure 2.1: Trial small-scale tunnel covered with a 60% shading net adhering to the EVA film (left) and with the same EVA film whitened with Calcium Oxide (right).

The radiometrical characteristics in the UV-VIS-NIR wavelength [200 – 2.500 nm] of both the EVA film + 60% shading plastic net and the whitened plastic film were determined in the Laboratory of Material Tests of the SAFE School of the University of Basilicata (Italy) through a Jasco V-570 spectro-radiometer.

3. Results and Discussion

The results of the spectro-radiometrical analysis over the tested materials are reported in Table 3.1, in terms of the main characteristics measured in different significant ranges within the solar spectrum. Figure 3.1 shows the diagrams of solar transmittance and reflectance of the two tested methods, together with that one of the EVA film without any shading effect.

Table 3.1: Results of the spectro-radiometrical analysis on the tested shading methods.

Range	Wavelength	**EVA film + 60% Shading Net**		**Whitened Film**	
	nm	τ [%]	ρ [%]	τ [%]	ρ [%]
Solar	200 - 2500	45.19	27.82	41.09	51.73
PAR	400 - 700	28.90	47.46	31.81	59.99

Solar IR	700 - 2500	52.15	26.75	46.79	51.38
UV	280 - 380	6.75	6.66	2.77	45.50
UVA	320 - 380	6.78	6.91	4.48	49.74
UVB	280 - 320	6.71	6.25	0.15	39.14

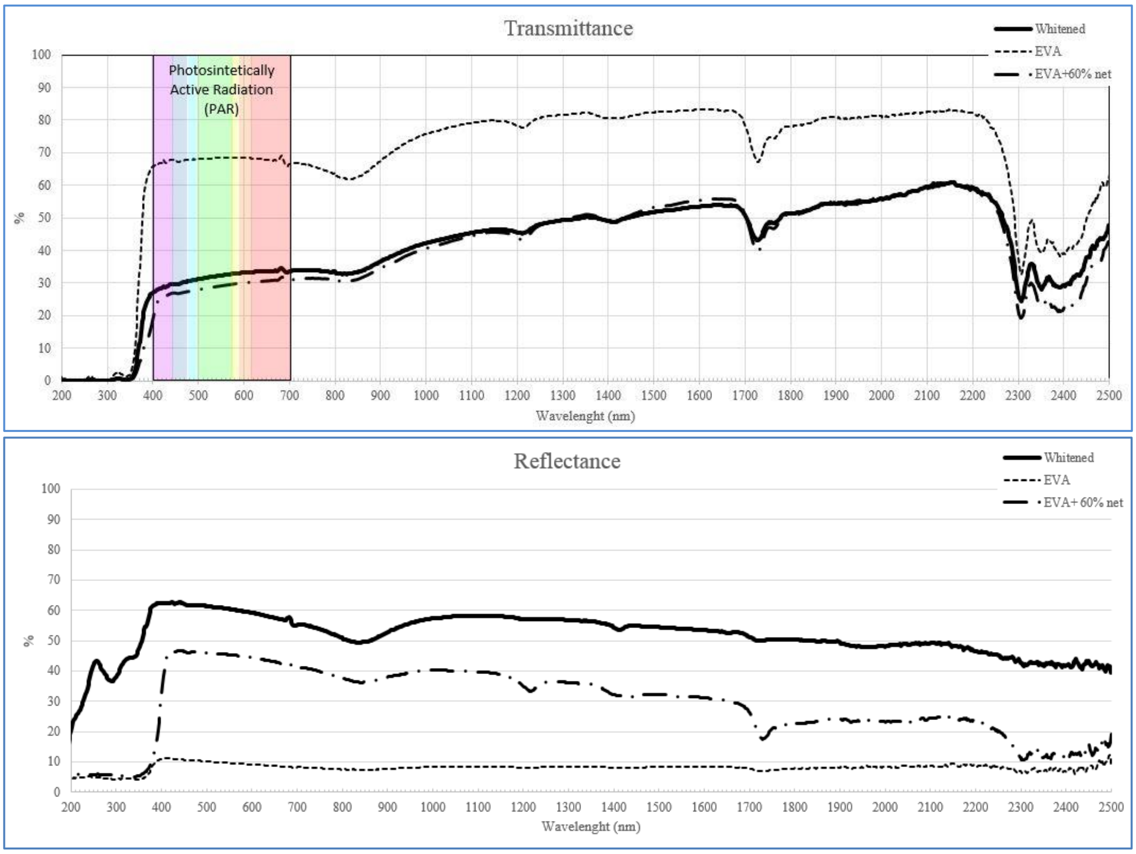

Figure 3.1: Transmittance τ and reflectance ρ low of the film + 60% shading net, the whitened film and the EVA film.

From the results of the spectro-radiometrical analysis performed in the solar range, it would be firstly deduced that the shading effect declared by the plastic net producer seems sufficiently close to the value that was detected.

The very small difference in the radiometrical characteristics of the two shading methods did not seem to have any significant influence on the thermodynamic behaviour within the two different small-scale tunnels during the testing period. The temperatures that were measured inside the two small tunnels during the testing period were indeed almost similar (fig. 3.2), showing very little differences mostly during daytime (about 1°C higher in the whitened tunnel), so confirming that the two tested methods produce almost similar effects toward the internal microclimate. Anyhow, their different reflectance asks for further analysis on the effect on the surrounding landscape.

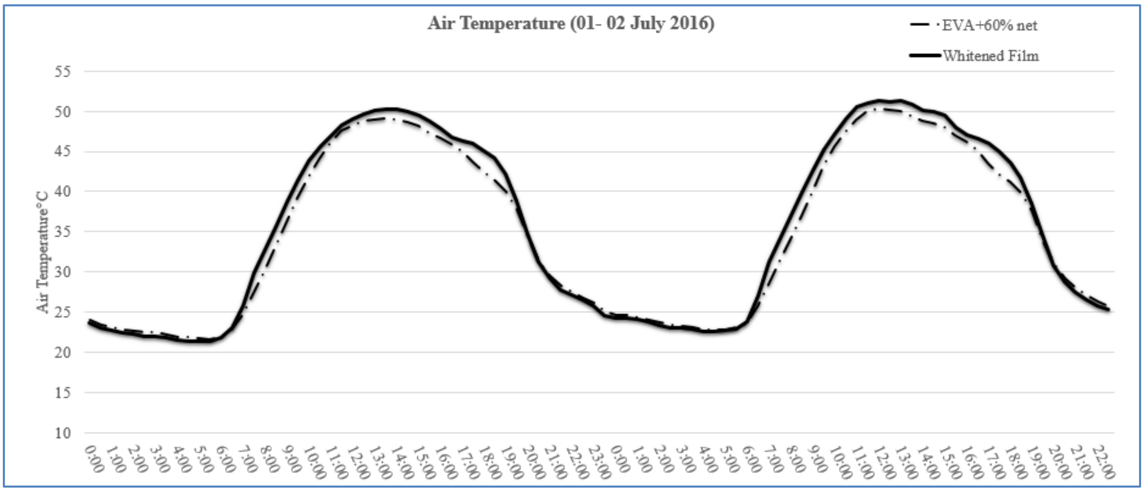

Figure 3.2: Air temperature inside differently shaded trial greenhouses.

4. Conclusions

Both shading traditional techniques – *e.g.*, whitening – and new materials, as plastic nets, deserve a more deep analysis of their performances in shading a greenhouse, protecting the internal cultivation while influencing the surrounding environment. Further studies are therefore necessary for examining how to improve the selective filtering effect of both these techniques, enhancing agronomic production while reducing their impact on the visual quality of the rural landscape as well.

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Testing of net based protection systems of olive trees against the vector of *Xylella fastidiosa*

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Keywords: insect net, integrated pest management, nursery

Summary
A net protection system- specific for in field cultivations and for nurseries of olive trees and plant production- against the vector of *Xylella fastidiosa* Wells et al. was studied. Mesh size, kind of fabric, threads typologies were taken into account for the design optimization of the net. In absence of studies concerning the response of *Philaenus spumarius* L. to colors, transparent wires and white strips were chosen in the tests. Experimental nets were produced in SACHIM factory in Putignano, Italy. Six nets with different kind of fabric and mesh size were tested. Preliminarily, nets were tested in laboratory, afterwards, an experimental apparatus (net-box) for in field test was built. Based on these first results, the net which better fulfilled the required performance was the monowire knitted one with the wider mesh (2.4mm) tested.

1. Introduction

In 2010, olive trees on the west coast of Salento Peninsula, Italy, began to decline and die with a condition of unknown etiology called "Olive quick decline syndrome" (Nigro et al. 2014). Saponari et al. (2013) showed all symptomatic trees tested were positive for *Xilella fastidiosa* Wells et al. This was the first widespread detection of the bacterium in Europe and a quarantine around the infected area was imposed (European Food Safety Authority [EFSA], 2013). *X. fastidiosa* is transmitted by the meadow spittlebug, *Philaenus spumarius* L. (Saponari et al., 2014) from infected to uninfected olive trees (Cornara et al., 2016).
Unfortunately, quarantine was not able to limit the diffusion of the bacterium and, by 2013, the affected area had grown to almost the entire Salento Peninsula.
In Apulia Region, olive trees cultivations are almost 370.000ha, the economic value of the yearly olive production is almost of 492M€ (Bucci & Zambelli, 2012). But olive trees are not only a very important sector in the economy of the Apulia Region, the landscape of olive trees cultivations is considered as a symbol of the Region, a part of its cultural, traditional and historical identity. Centennial trees, very common in the southern of Puglia are considered as monuments and are an important attraction for tourists.
For this reason, addressing the research is crucial not only to study olive tree species resistant or immune to *X. fastidiosa*, but also how to preserve existing trees. Another aspect related to the epidemic of the bacterium is the protection of nursery, in order to guarantee a production "*Xylella free*" to local and foreign markets, not only of olive trees.
At present, it seems that the only way to preserve plants from the *X. fastidiosa* is to physically avoid the contact with its vector, the *P. spumarius.*
Hence, aim of this research was to study a net protection system- for in field cultivations and nurseries- specifically designed against the vector of *X. fastidiosa.*

The main required performance is to avoid adults of *P. spumarius* passing through the net. In fact, they are the only stage able to fly and therefore much more movable then the juveniles who usually leave on herbaceous plants. In addition, the immature stages lose the capability to transmit the bacterium during moults. Moreover, it is strategic to choose the net with a mesh as wider as possible in order to minimize the visual impact of the in field installed nets and to reduce the wind loads on the supporting structures. In addition, as the color is a key factor for the choice of a protection net system, researches are going on in order investigate the response of *P. spumarius* to them. As well as keeping the permeability to air as high as possible to minimize the impact of the net on growth conditions such as temperature and air humidity.

2. Materials and Methods

In *P. spumarius*, adult length ranges from 5.3 to 6.0 mm for males and from 5.4 to 6.9 mm for females length of the body (Germain, 2016). Accordingly, three different maximum linear length of the mesh of the experimental nets were studied: d_1=1.2mm, d_2=1.8mm, d_3=2.4mm.

The porosity (Φ), defined as the ratio between the surface of empties (Se) and the area of the net (St) (2.1), plays an important role in the evaluation of the air permeability of the net and, consequently, of wind loads on the structure (Castellano et al., 2016).

$$\Phi = Se/St \qquad (2.1)$$

Table 2.1: Construction characteristics of tested nets. Flat woven net (F), knitted nets made by strips and wires (KS) and only by wires (KW), (d) is the maximum linear dimension of the mesh (mm). d is the maximum linear dimension of the mesh.

Tested Net	d (mm)	Porosity (%)	Warp diameter (mm)	Weft diameter (mm)
F- d1	1.2	58.11	0.28	0.28
F- d2	1.8	64.62	0.28	0.28
F- d3	2.4	71.60	0.28	0.28
KS- d1	1.2	6.27	0.26	Strips (90μm thickness)
KS- d2	1.8	18.00	0.26	Strips (60μm thickness)
KW- d3	2.4	42.96	0.23	0.23

Three experimental nets with two different kinds of texture were chosen: i) flat woven net (F) with wires thermally stabilized in order to avoid the slope of a wire on the other; ii) knitted nets made by strips and wires (KS); iii) only by wires (KW) (Fig. 2.1). Wires had circular section and made of high-density polyethylene (HDPE). In absence of studies concerning the response of *P. spumarius* to colors, transparent wires and white strips were chosen for the tests. Experimental nets were produced in SACHIM factory in Putignano.

(a) (b) (c)

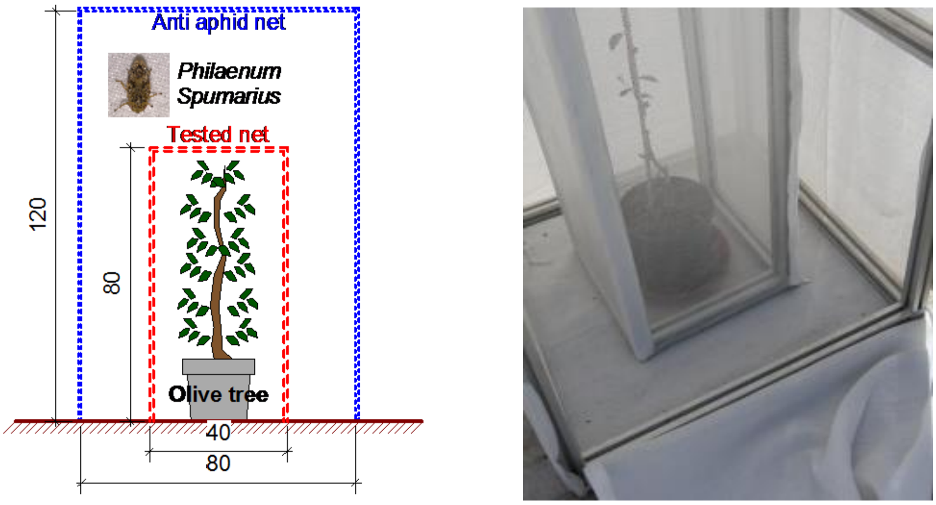
Figure 2.1: Pictures of tested nets: F- flat woven (a); KS- knitted nets made by strips and wires (b); KW- knitted nets made only by wires (c)

Preliminarily, nets were tested in laboratory by means of a device made of two glass cylindrical jars divided by the net to be tested. Ten one-day old adult insects were released in the upper jar

(Ø 15 cm x 20 cm) whereas two-week-old fava bean plants (n = 5) were positioned in the lower jar (Ø 15 cm x 25 cm) with the apical shoots at least 3 cm below the net to avoid insect feeding. To prevent insects escape, the upper jar was closed with non-woven fabric. Six replicates were performed for each net.

Afterwards, an experimental apparatus (net-box) for in field test was built. A young plant of olive tree was put in a steel frame (40x40cm base, 80cm height) covered with the experimental nets. The frame with the plant was placed in a larger one (80x80cm base; 120cm height) covered by an anti-aphid net (Fig. 2.2) where 25 *P. spumarius* adults were released. Since the insects were not supplied with water or food it was expected they would be strongly motivated to reach the olive tree in the inner box trying to pass through the test net. Two repetitions were performed for each net.

Tests were carried out during the months of April and May 2017 at the experimental field of the University of Bari in Valenzano (BA).



(a) (b)

Figure 2.2: Net-box used for in field test: construction scheme (a) and picture (b). Units are cm, the insect in the picture is not on scale.

3. Results and Discussion

In all the tests, 100% of *P. spumarius* adults were not able to pass through the experimental nets. It was observed (Fig. 2.2 b) that the insects died after few hours (6-24h) in field tests, while the survival period was lightly longer in laboratory trials. This was probably due to the absence of any food source.

While flat woven nets showed the damage of some thermal connections and the consequent sliding of wires, knitted nets did not show any damage.

4. Conclusion

Based on these first results it was possible to state that the net which better fulfilled the required performances, that were no insect intrusion, low visual impact and less resistance to wind loads, was the monowire knitted net with the wider mesh: d_3=2.4mm (KW-d3).

The nets shall be installed at the vents of structures of nursery in the greenhouses or as fences both for open field nursery and fields with olive tree cultivations. In order to reduce the visual impact and to increase the life of the netting system- considering the life cycle of the *P. spumarius*- it is possible to consider that in some cases the net could be removed during the period of the year when the insects do not fly (approximately from November to March).

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Evaluation of rain permeability of agricultural nets: first experimental results

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Keywords: porosity, HDPE nets, rain test bench

Summary

A system made of technical textiles able to protect cultivations from the damages of rain fall and to let air to pass through, could increase the reliability of predictions for the harvesting of many fruits such as cherries. To this purpose a test device was designed and set up at Sachim srl to simulate and measure the rain permeability of agricultural nets at different inclinations, in terms of water amount reduction passing through the net when exposed to rain. The rain permeability index of the net was defined as the ratio between the water sprayed by the nozzles and the water gathered into the container under the net sample. Nets with different geometrical characteristics such as porosity, texture, kind of threads were tested; the effect of the net inclination was investigated, as well as the real contribution to the rain permeability decrease of a double layers textile scheme.

First results allowed to understand the influence of the main parameters to the rain permeability of the nets. The porosity, defined as the ratio between the surface of empties and the area of the net, seemed not to play a significant role as was observed when air permeability tests were performed. The mesh size, the inclination of the net and the use of the double layers scheme of the protection system were found to give the most significant change to the rain permeability behaviour of the nets. Studies have also been carried out to overcome the present limits of single layer protection textiles in order to reach an advantageous as well as predictable low permeability to rain.

1. Introduction

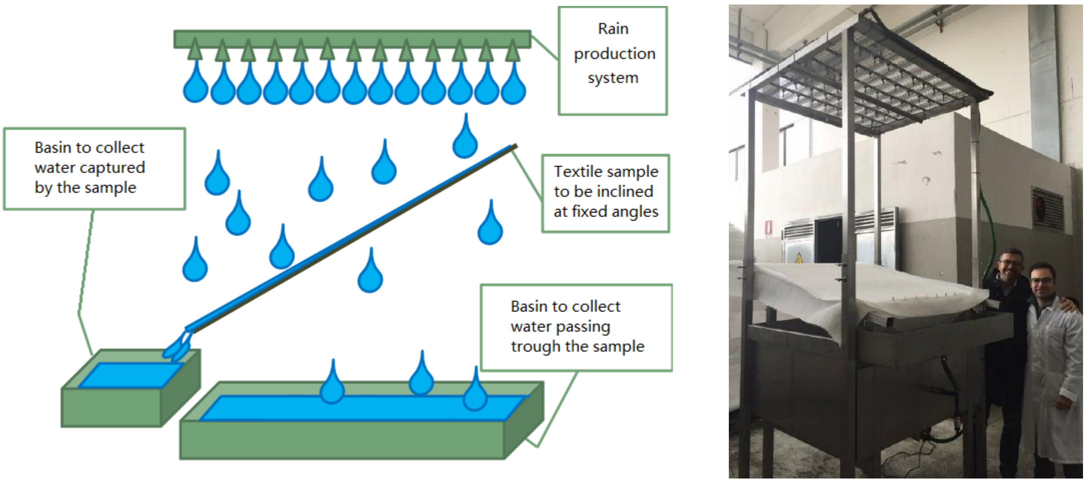
Some orchards (cherry, kiwi, peach, plum, soft fruits) and vegetable crops such as spinaches are adversely affected by heavy rainfall.

Two methods of rain cracking protection are usually employed: chemical treatments and impermeable covers such plastic films. Chemical treatments are used in order reduce the osmotic potential inside the fruits, but the effect of this treatment varies and when precipitation levels are large, the percentage reduction in cracking is very small. Chemical treatments affect the taste of the fruit as well. Plastic covers protect fruits from rainfall, but they increase the temperature and relative humidity and modify the solar radiation passing through the film. Rain covers were tested by Blanke and Blamer, 2008, on cherries trees. Several early ripening varieties were tested. Flowering under covers advanced bloom by 6-13 days and ripening by 12-19 days. Fruit under covers were found to be slightly smaller and softer than the uncovered control. Covered cherries also showed an increase in sugar and acid but there was no effect on color. Impermeable coverings, moreover, induce severe wind loads on supporting structures.

In order to avoid the use of chemical treatments and to reduce the negative effects of impermeable coverings of cultivations, the use of plastic nets as rain protection system was investigated in this research. Nets with different geometrical characteristics such as porosity, texture, kind of threads were tested; the effect of the net inclination was investigated, as well as the real contribution to the rain permeability decrease of a double layers textile scheme.

2. Materials and Methods

A specific device was built up in the Sachim R&D lab (Fig. 2.1). The rain simulator test bench was made of several nozzles spraying water, a steel frame supporting the net samples wet by the simulated rain at different angles (0 ÷45°), a container where the water passing through the net was gathered, and a purposely designed measuring system. The rain permeability index (Πr) for different inclination of the net was defined as the ratio between the water sprayed by the nozzles and the water gathered into the container under the net sample.



(a) (b)

Figure 2.1: Rain test bench: construction scheme (a) and picture (b).

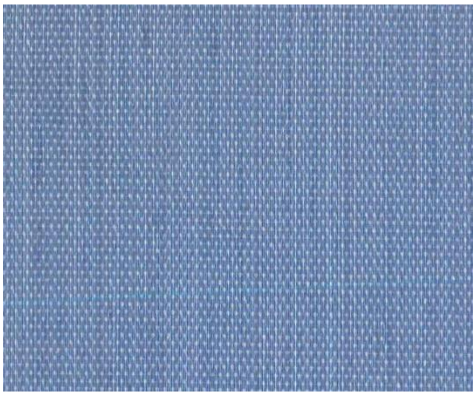


Figure 2.2: Picture of tested net, commercial name 3532BT.

First results refer to a net sample of HDPE mono wire flat woven net produced by Sachim (commercial name 3532BT) (Fig. 2.2).
Three inclination of the sample- 10%, 20%, 30%- were tested, with a 60mm/h rainfall intensity (RI). Due to the shape of the hole of the net the net was tested in two different position of the hole with respect to the slope of the sample.

3. Results and Discussion

The porosity, defined as the ratio between the surface of empties and the area of the net, seemed not to play a significant role as was observed when air permeability tests were performed (Tab. 3.1). The mesh size, the inclination of the net and the use of the double layers scheme of the protection system were found to give the most significant change to the rain permeability behaviour of the nets. The orientation of the rectangular hole with respect to the slope of the panel is not significant when the inclination is low (10%), at higher values (30%) it increases differences in rain permeability passing from $\Phi r(30°)=28\%$ to $\Phi r(30°)=36\%$. When a second layer is installed, the system becomes almost not permeable, with rain permeability practically equal to zero at all the inclinations .

Table 3.1:Geometric characteristics of tested net and results. Πr rain permeability index, RI rainfall intensity

Net	Layers	d (cm)	Mesh (mm)	Porosity	Πr(10°)	Πr(20°)	Πr(30°)	RI /(mm/h)
3532BT-L	1	-	0.033x1.039	7 %	33 %	30 %	36 %	60
3532BT-L	2	3	0.033x1.039	4 %	0 %	3 %	0 %	60
3532BT-T	1	-	1.039x0.033	7 %	33 %	32 %	28 %	60

4. Conclusion

First results allowed to understand the influence of the main parameters to the rain permeability of the nets. The porosity seemed not to play a significant role as was observed when air permeability tests were performed. The mesh size, the inclination of the net and the use of the double layers scheme of the protection system were found to give the most significant change to the rain permeability behaviour of the nets.

Further studies will be carried out in order to overcome the limits of present single layers configurations and to deepen the influence of geometric characteristics of the netting system on the rain permeability with respect to the parameters which describe the rainfall: intensity, size and shape of the drops, velocity and energy of rain drops.

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Experimental cultivation of peppers in low energy demand greenhouses. An interdisciplinary study.

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Keywords: solar radiation, greenhouse, infrared radiation, photovoltaics, crop quality.

Summary
Energy demand of greenhouses is an important factor for their economics and photovoltaics (PV) can be considered an alternative solution to cover their electrical and heating needs. On the other hand, Infrared radiation (IR) heating systems possess the advantage of high directional control and focused compensation of energy losses, appropriate for creating local temperature conditions in open or thermally unprotected spaces resulting in an overall reduction of heat losses and consequently heating energy needs. The objective of this research is to develop a low energy demand greenhouse by using IR heating and the cover of remaining energy needs by the installation of fixed PV panels on the greenhouse's roof. Also, to investigate the effect of PV panels induced partial shading on growth parameters and physiological characteristics of plants. Experimental results are presented from a full cultivation period inside two greenhouses under the weather conditions in South-West of Peloponnese, Greece. Two identical, small scale experimental greenhouses of same dimensions, placed side by side were implemented with and without fixed PV panels correspondingly. Pepper (*California Wonder* L.) is used as the test crop for a three (3) months period. The results are presented in this paper, include electrical energy output, greenhouse inside space lighting and temperature and plant growing. Results were compared to classical cultivation. The design and energy performance of the above PV installation modes is analyzed and results are presented.

1. Introduction

Greenhouses are intensive cultivation units, which require optimum combination of lighting, heating, cooling and ventilation. In climatic conditions of Mediterranean countries both heating and artificial lighting in winter is needed, as well as cooling and lighting control for the summer. These conditions make more complex the control of internal space conditions and difficult to find a cost-effective solution.

IR heating systems can efficiently maintain favorable environmental conditions at the plant canopy, which promote the uniform, quantitative, and qualitative growth of plants and suppress plant pest and diseases. Implementation of IR heating in a production scale greenhouse has indicated energy savings in the range 40–50% and has contributed to improved product quality (Kavga et al, 2015).

PV panels are suggested to be mounted on the roof of greenhouses and cover energy needs of greenhouses. Optimal PV installation is needed due to the solar radiation that passes through cover is reduced. This reduction may be charged to the adequate plant lighting. In Tripanagnostopoulos et al, 2017 detailed study for using PV panels on greenhouse roof has given interesting results regarding, mainly, electricity production. The combination of IR heating and PV panels on greenhouse roofs results in a low energy demand greenhouse and could be used for a wider application of them. In this study, the application of PV on greenhouse's roof is suggested to be studied regarding their effect to plant growing. The results

+ In memory of Professor Yiannis Tripanagnostopoulos from the tested low energy demand greenhouses and the effect of shading and of the energy gain are presented.

2. Materials and Methods

Two identical small-scale experimental greenhouses located in western Greece were used as the test bed of the two installation options with and without PV correspondingly. The greenhouses have east-west orientation, where the solar system was facing south. The experimental greenhouses were equipped with an IR heating system consisting of four lamps with blownbulb reflectors (1 kW total power, 50° beam angle) placed at the greenhouse corners and an elevation of 1 m above the plants. Two polycrystalline silicon (pc-Si) PV covering in total 0.8 m^2 were mounted on the roof of the one greenhouse. A horizontal pyranometer was mounted parallel to PV plane, to measure the incoming solar radiation on it. Finally, by measuring the output in electricity, the produced electrical power was calculated.
Interior microclimatic parameters monitored in both greenhouses were the temperature at the canopy, inside the greenhouses and at the inside and outside surface of the greenhouse glazing cover and of PV panel, as well as the relative humidity and radiation fluxes (incoming solar radiation, PAR and incoming solar energy on PV surface). The environmental conditions including temperature, wind speed, relative humidity, sky temperature and rain were monitored on a meteorological mast close to the greenhouses. The experiment was performed for three months operation period of both configurations.
Pepper cultivated on the soil, was used as the test crop. In each greenhouse 16 young pepper plants were planted, forming four rows of four plants each and planting distances were 36 cm x 24cm. A drip irrigation system was applied. The supply of each drip emitter was 2lit/h. The irrigation dose during the experiment was 3.6 lit per plant. Fertilizing of the plants was done with water-soluble fertilizers. During the cultivation, 120 gr N, 280 gr P, 160 gr K, 12gr Mg and 18gr Ca were administered on each greenhouse.

Figure 2.1: The experimental setup with the cultivation

3. Results and Discussion

Investigation concerning the accumulated energy results of incoming and transmitted solar energy to greenhouses, PV input and output as well as the effect of shading produced by the PV to the plants grown has been performed.

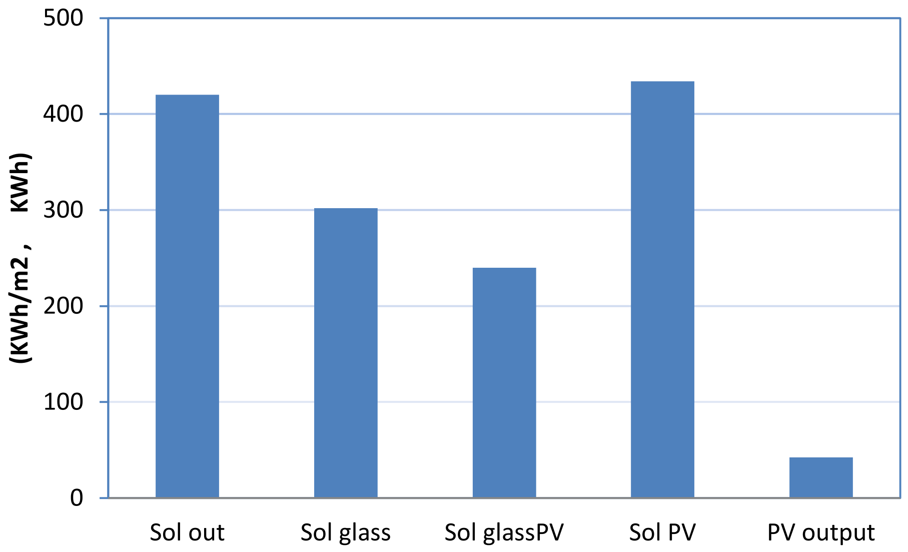

Figure 3.1: Accumulated energy results of incoming and transmitted solar energy to greenhouses and PV input and output for the testing period

As depicted in fig 3.1 the values of the transmitted solar radiation are lower than the incoming ones because of the reflection and absorption from the greenhouse's glass cover. The total radiation that the pyranometer on the greenhouse roof with the same slope of PV panels (Sol PV) recorded was 434.11 $kWhm^{-2}$ and the total output electrical energy of the two PV panels (PV output) was 42.37 kWh (or 52.96 $kWhm^{-2}$). Based on the totally recorded data for the incoming solar radiation on PV panels and the output electricity, the PV system has produced electrical energy with efficiency of about 12,2%.

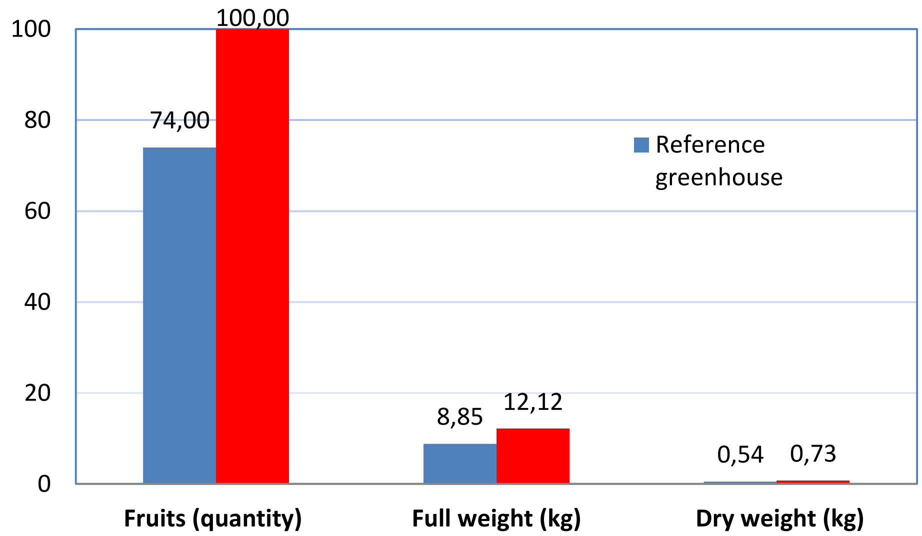

Figure 3.2: Total values of basic fruits grow indicators I

In Figure 3.2 the results for the quantity of fruits, the full and dry weight are presented. Specifically, the results give a figure of increased fruit production in the PV greenhouse against the reference greenhouse.

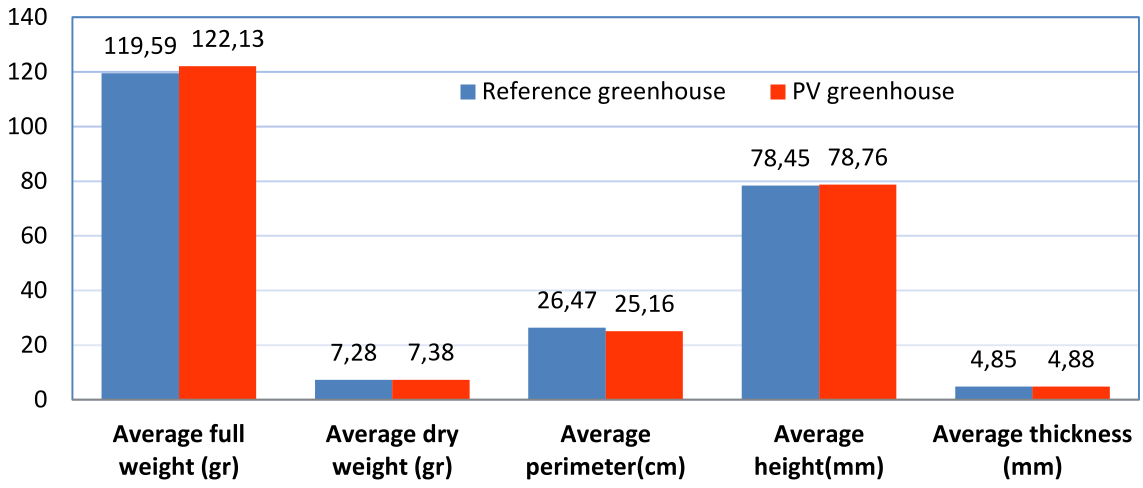

Figure 3.3: Average values of fruits grow indicators II

In Figure 3.3 the results regarding the average of full and dry weight and the average of perimeter height and thickness of fruits are shown. From these results it is noticed that the values of the fruits of PV greenhouse, compared to those of the fruits of the reference greenhouse are almost the same.

Discussing these results the shaded greenhouse produced a larger number of fruits and as a natural consequence the weight of the fruits obtained from this greenhouse was higher than the reference greenhouse. On the other hand, observing the quality characteristics of the fruits of the two greenhouses, namely their average weight, their height, their perimeter and their thickness, we see that there are virtually no differences and that uniform fruits were produced.

4. Conclusion

An installation of PV panels on a greenhouse roof was studied regarding the effect on the transmitted solar radiation into greenhouse space, the electricity output and the effect on plant growing.

For a low covering ratio of greenhouse roof 20% by photovoltaics, a considerable energy contribution to the greenhouse's demand is achieved without significant effect on plant growing, under the mild weather conditions of south-west Greece.

Considering the results, it's observed that shading has positively influenced the productivity of the PV greenhouse, with no impact on the quality characteristics of the fruit.

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TOPIC 8

SAFETY, HEALTH, ERGONOMICS, MANAGEMENT AND STANDARDIZATION FOR AGRICULTURE AND FORESTRY MACHINES, EQUIPMENT AND STRUCTURES

The Italian sprayers inspection situation after the expiry of the deadline set by the National Action Plan and the Directive 2009/128/EC

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Keywords: sprayers inspection, Directive 2009/128/EC, National Action Plan, workshop, licensed inspectors

Summary
In Italy the sprayers in use functional inspection activity is performed by more than 200 workshops and by more than 600 licensed inspectors that work throughout the National territory.
In the last few years, the number of workshops and inspectors grew up significantly, but the number of the sprayers inspected was not sufficient to comply with the deadline established by the EU Directive 128/2009/EC (26th November 2016).
The aim of this work is to present a report of the Italian current situation of the sprayers in use functional inspection activity and to analyze some of the possible causes of the limited number of sprayers inspected up to now.

1. Introduction
The number of sprayers in use in Italy is one of the largest in Europe, as it represents the 20-25% of the entire European fleet (Wehmann, 2016).
Even if in Italy there isn't yet an official national register of the sprayers in use (this is one of the objectives of the National Action Plan - clause. A.3.10), it is estimated that more than 500000 Pesticide Equipment (PAE) operate on the national territory.
Before the entry into force of 128/2009/EC Directive, the functional inspection of the sprayers in use was generally made on a voluntary basis, except for the farms joining the Regional rural development plans for which the inspections were mandatory.
Despite of the sprayers inspection activity has begun several years ago (first sprayer in use functional inspections were carried out in 1980; Balsari et al., 2004), only in the last ten years and especially after the introduction of the compulsory inspection (Legislative Decree n° 150/2012 for the transposition of the Directive 128 and the National Action Plan), it has consistently increased (Figure 1), also thanks the important work carried out by ENAMA (National Board for Agricultural Mechanisation) and its Technical Working Group for the national coordination of the sprayers inspections (Balsari et al, 2010).

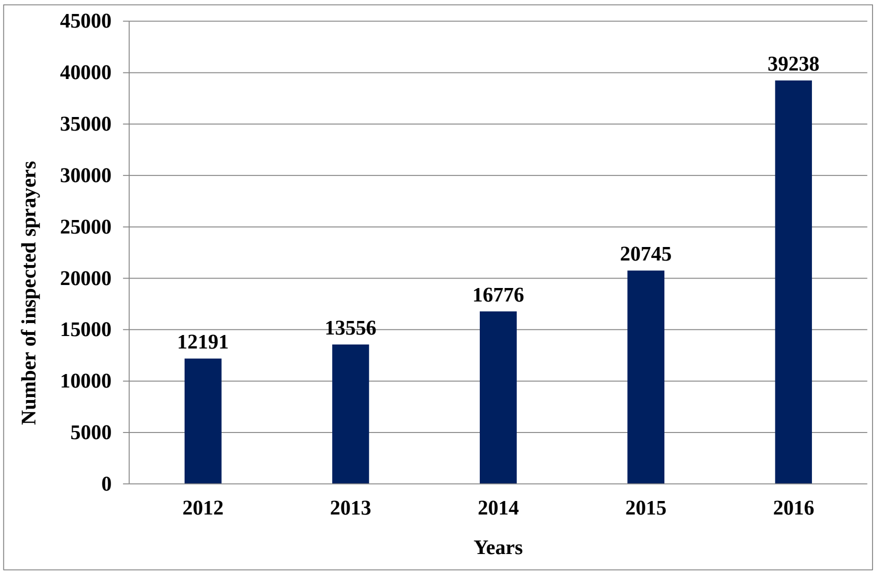

Figure 1: Number of sprayers inspections carried out annually in Italy from 2012 to 2016

This work, started 17 years ago and still ongoing today, includes some different activities that are intended to promote the development, dissemination and harmonization of the sprayers functional inspection activities in all the Italian Regions and Autonomous Provinces. These activities mainly consist of: a technical support to the Regions; training courses for the sprayers inspectors and workshop control Authorities; Stakeholder information of the importance and advantage of the sprayers functional inspection activities; the creation and the periodic updating of a web site with all the authorized inspectors and workshops divided by Regions and with the main references of them.

2. Materials and Methods

An enquiry about the numbers of sprayers in use already inspected and the main reason of the obstacle found in making the mandatory inspection was realized through a questionnaire sent to the Responsible persons for sprayers inspections in all the Italian Regions and Autonomous Provinces.

In detail to analyze the current situation of the sprayers inspection activity and its evolution in the last few years, the following information were requested:

a) the number of sprayers inspections carried out annually from 2012 (issuing year of the Legislative Decree n.°150 for the transposition of the Directive 128) to 2016 (expiry deadline for the inspections established by the Directive);

b) the increase of the workshops and the licensed inspectors number from 2012 to 2016;

c) the percentage of inspections carried out in each Region at 26th November 2016 compared to the total sprayers that should have been checked.

3. Results and Discussion

The increase of the workshops and of the licensed inspectors number from 2012 to 2016 is reported in Figure 2, while the percentage of sprayers functional inspection carried out in each Region after the 26th November 2016 compared to the total sprayers numbers that should have been checked is shown in Figure 3.

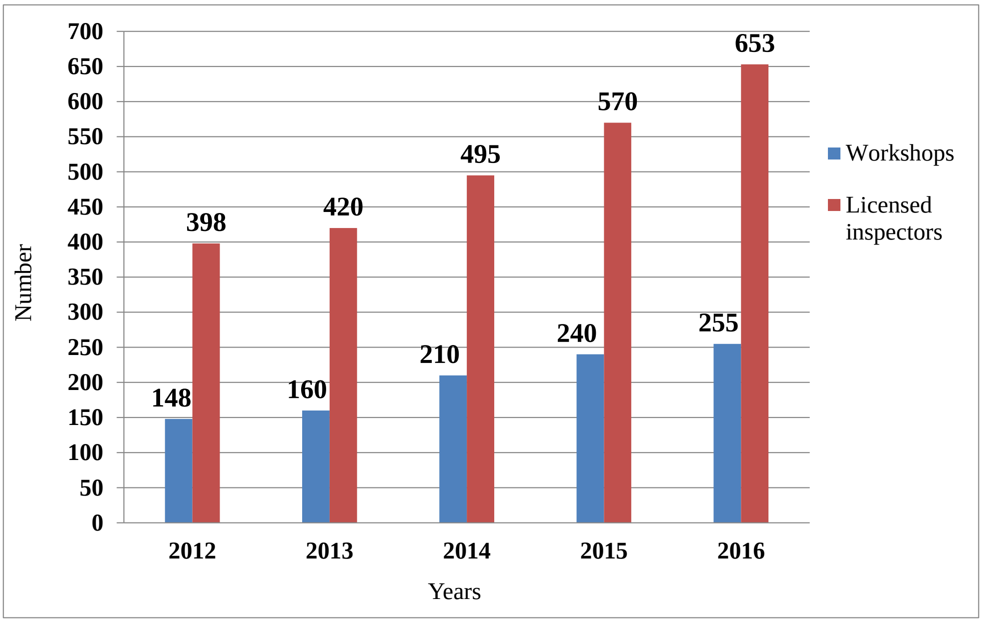

Figure 2: Number of authorized workshops and licensed inspectors from 2012 to 2016.

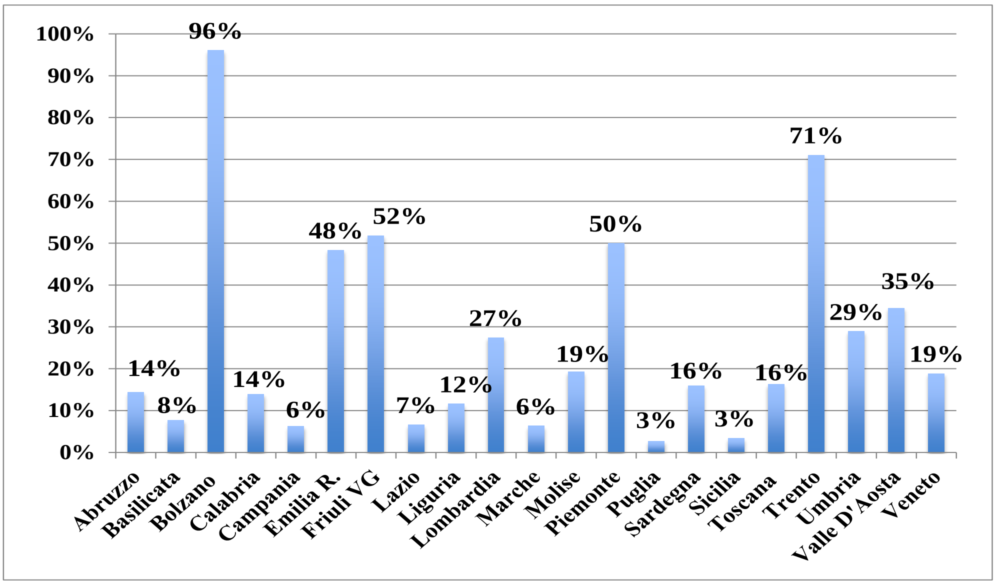

Figure 3: Percentage of inspections carried out in Italy at 26th November 2016 compared to the total number sprayers that should have been checked.

Analyzing these two figures it can be noted that since 2012 (the year of transposition of the Directive in Italy) the number of workshops and licensed inspectors and the number of sprayers inspections carried out annually at national level have been subjected to fairly steady and gradual growth.

Especially after 2014 (NAP publication year) these two data have increased significantly till to reach in 2016, a number of workshops and licensed inspectors equal to 653 and 255 technicians, and a number of yearly controls of 39200.

Despite this increase, by examining the data regarding the total number of inspections carried out within the deadline provided by the Directive and the NAP, the percentage of sprayers inspected with respect to the total number of PAE in use is extremely low (about 20%).

This aspect of inspection activity appears more evident when evaluating the data reported in the third graph, where the percentages of inspections carried out in the individual regions are indicated in relation to the total number of machines to be controlled.
It is also evident that the sprayers inspection activities done in Italy up to 2016 have a high heterogeneity across the different Regions due to the actual different level of development and dissemination of this activity across the territory.
Among the main causes that have affect and hinder the growth and development of the inspection activity, the following have been identified as more important:

- The lack of information of farmers and sprayers owners regarding the introduction of the compulsory inspections and the inspections deadlines;
- The not sufficient number of workshops and licensed inspectors and their uneven distribution on the territory (especially in those regions where the inspection service has been activated recently);
- The difficulties in the organization and planning of the inspection activity both at regional and at national level;
- The lack of a national responsible body;
- The delay of a regional legislation concerning the inspection activity;
- The lack of an official national register of the sprayers in use.

4. Conclusion

Thanks to the data and the information collected it has been possible to realize a general framework of the national sprayers in use functional inspection activity.
The National situation seems not at all in line with those of others EU Countries and not yet able to fulfill the Directive and the NAP requirements.
Among the main causes of this delay, those related to the limited information of the farmers and sprayers owners and to the lack of an official national register of the sprayers in use shall be underlined.

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A review of the methods used for the assessment of seed dressed dust drift

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Keywords: pesticides, particulate matter, maize, honeybees, neonicotinoids

Summary
This paper summarizes the methods and techniques we have employed during the last years to evaluate the seed dressed dust drift. Since the year 2010, CREA-IT has been involved in researches about the role of pneumatic precision drills in the phenomenon of dust drift coming from the abrasion of dressed maize seed. In the paper, both field and static experiments are reviewed.

1. Introduction

The seed dressing (or coating) is a common technique to protect seeds and early stages of plant growth against pests and diseases. The seed dressing, in comparison with other technique (i.e. whole-soil applications with sprays or granular pesticide application) allows control with a reduced dose of chemical. The seed treatments show the advantage to deliver the active ingredient directly on the target (the seed) ideally without any pesticide losses in the environment. A disadvantage of this technique is that a certain amount of pesticides can be released by means of the abrasion dust produced during storage, manipulation and sowing of dressed seeds.

The four neonicotinoids imidacloprid, clothianidin, thiamethoxam, thiacloprid, plus the fipronil (belonging to the phenylpyrazole chemical family), employed for maize seed dressing (Elbert et al., 2008), have been largely investigated about their potential toxicity to honey bees and other pollinating insects (Tison et al., 2016; Iwasa et al., 2004; Goulson, 2013).

Since the year 2010, CREA-IT has been involved in researches about the role of pneumatic precision drills in the phenomenon of dust drift coming from the abrasion of dressed seed. The objective of the paper is to review methods we have employed to carry out these studies.

2. Materials and Methods

The methods employed in our studies can be divided in field and static (with the machine in stationary position) trials. The determination of dust expelled and drifted by the drill has been carried out by means of air sampling (with both active and passive samplers) and by passive samplers to assess ground deposition. Air sampling entails the use of: (1) air pumps operating at medium and low volume, equipped with various membrane filters (Teflon, cellulose-nitrate); (2) multistage impactor; (3) passive MWAC samplers (Gossens et al., 2000). The determination of residues at ground level has been carried out by means of Petri dishes filled with an aqueous solution of acetonitrile. Depending on the employed sampler, the collected content was analysed in different ways. Membrane filters can be both weighted and analysed to determine the content of chemical species. Moreover, filters can be observed at light microscope to obtain information on size and morphology of particulate matter.

Figure 2.1: Arrangement of sampling in the wind tunnel. (1) Fan generating the air flow. (2) Tested drill. (3) Sampling area with Petri dishes and (4) air pump samplers.

Regarding the test at fixed point, part of the experiments has been carried out in a sort of wind tunnel that we arranged in our laboratories (fig. 2.1). The results of the experiments in the wind tunnel were also validated with respect to field findings (Biocca et al., 2015). In addition to the studies aimed at assessing the dust drift, we have carried out static tests to evaluate the performance of various drill configurations in terms of quantity of emitted dust. For this purpose, we mounted on the tested drill a sampling pipe consisting of a straight, 2 m long pipe, that normalizes the air velocity. The sampling pipe receives the air expelled by the drill by means of the deflector pipes installed at the fan air outlet. The air sampling was made by means of probes properly inserted into the sampling pipe (Biocca et al., 2017).
Regarding the field studies (fig. 2.2), we have carried out trials in small and large plots, and we developed an original placement of samplers to determine the drift in uncontrolled environment conditions (Pochi et al., 2015b).

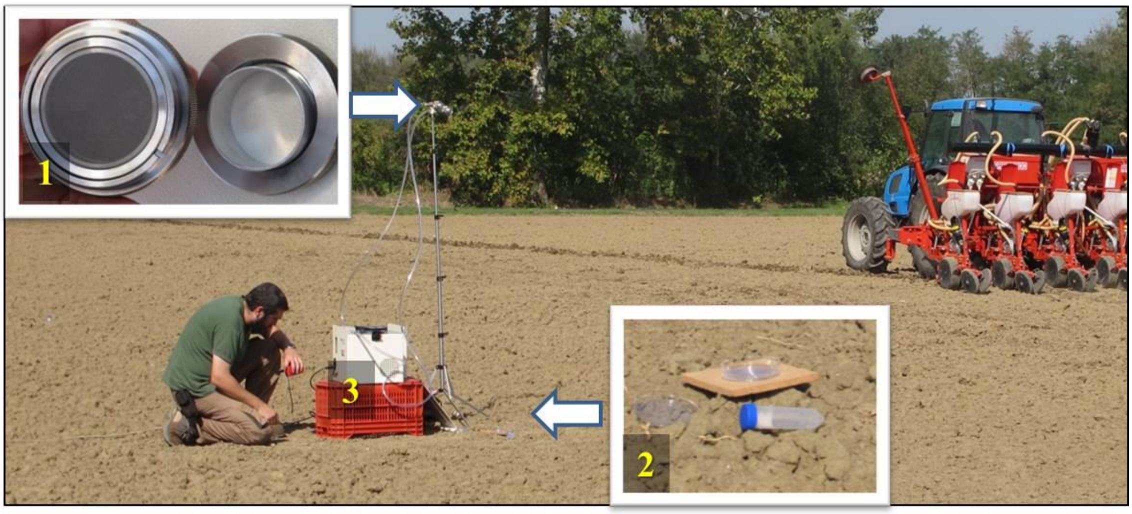

Figure 2.2: Sampling in the field – first line of sampling at 5 meters from the field edge. (1) Detail of the head sampling, with the filter holder. (2) Detail of a Petri dish. (3) Air pump.

Figure 2.3: Sampling of the operator exposure with personal samplers placed: (1) inside the tractor cab; (2) on the operator; (3) on the tractor, close to the cab door.

3. Results and Discussion

The methods employed in our studies were useful to determine the quantity of dust released by drills sowing dressed seeds. The results were employed: (1) to determine threshold levels of hazard for honeybees (Pochi et al., 2012); (2) to test new and modified model of drills capable of reduce the dust drift (Biocca et al. 2011; Pochi et al., 2013; Pochi et al., 2015a; Pochi et al., 2015b); (3) to determine size, morphology and other characteristics of the abraded particles (Pochi et al., 2015a; Biocca et al., 2017); (4) to assess the operator exposure to dust during sowing operations (fig. 2.3) (Biocca et al., 2013). Moreover, our findings have contributed to better describe the dust drift, that shows a different behavior if measured at ground level (dust deposition) or sampled in the air (air concentration) (fig. 3.1).

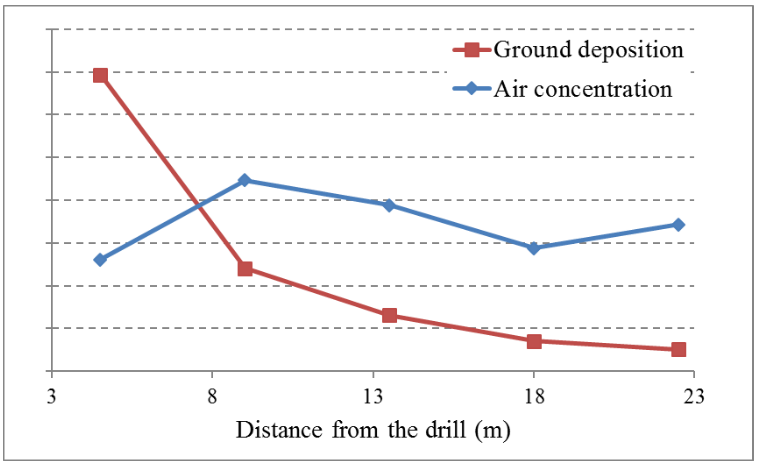

Figure 3.1: Drift curves of thiamethoxam when measured in terms of ground residues or air concentration. Scale is arbitrary.

4. Conclusion

To assess the quantity of dust containing insecticides that can be released into the environment during the sowing operations, we have employed several methods and we have developed facilities and systems to assess dust drift. These methods were used to evaluate different seed drills and prototypes capable of effectively reduce dust drift.

This paper, as others on the same subject (Foqué et al., 2017) can contribute to the definition of standardized control protocols for the risk assessment caused by the dust drift

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Safety of manure spreaders: proposal of a solution against risks due to contact, entanglement, dragging, cutting and crushing

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Keywords: Manure spreader, Safety, Agricultural machine, Declutching

Summary
This study concerns the prevention and protection from safety risks during work inside the loading hopper of the manure spreader when the working bodies of the same are in motion. This situation often occurs during cleaning operations of the machine and exposes workers to serious or fatal injuries.
Technical standards for this type of machine not always proved effective in the protection of workers. Therefore the present study intends to evaluate regulatory deficiencies trying to propose adequate solutions to resolve them.
The present work describes a motion decoupling device controlled by motion sensors applied on the axles of the wheels of the manure spreader.
This solution has been tested at the INAIL research center of Monte Porzio Catone (Italy) on a prototype developed by Ren Mark (Ren Mark Snc di Fontana e Genitoni - San Polo D'Enza, Italy).
The research results show the technological feasibility of the device with a certain impact, however, on the overall cost of the machine. Incidence that can be significant for smaller trailers and almost negligible for the larger ones. The results also may be useful for the definition of new technical standards or to update existing ones.

Acknowledgement
Project realized with the financial support of INAIL.

1. Introduction
A manure spreader is an agricultural machine used to distribute manure over a field as a fertilizer. It consists of a towed or carried trailer with a rotating mechanism driven by the tractor's power take off (PTO). Self-propelled trailers are also on the market.
The use of manure spreader involves several risks for workers: contact, entanglement, dragging, cutting, crushing and so on. One of the main risks is that occurring during work inside the loading hopper of the manure spreader when the working bodies of the same are in motion (e.g.: during cleaning phases of the machine).
A possible solution for this kind of risk could be the automatic stopping of mechanical transmission to working bodies when the wheels of the machine are stopped.
Technical standards for this type of machine not always proved effective in the protection of workers. Recently, a revision of the EN 690 standard has been approved by CEN: this involves the insertion of a motion sensor on the wheel axles that controls a light or acoustic warning signal when the wheels are stopped.
The present study intends to evaluate regulatory deficiencies trying to propose adequate solutions to resolve them.

2. Materials and Methods
This study was made possible thanks to the collaboration of Ren Mark Snc (San Polo D'Enza - Italy) a manufacturer of manure spreaders.

Following brainstorming and bibliography analysis, various possible solutions have been analyzed in order to identify solutions that can eliminate or reduce the risk of contact with moving bodies during cleaning and maintenance.
For each of these, SWOT analysis revealed the various intrinsic strengths and weaknesses and extrinsic opportunities and threats.
In particular, several solutions have been developed and analyzed to make the manure spreader "self-cleaning" by means of built-in or external devices, trying to prevent operators from entering the wagon when the working bodies are in motion.
The solution that seems to minimize the risk is the use of mechatronic systems able to ensure decoupling from the motion transmitting organs when the wheels are stationary.
Thus, we proceeded with the design, construction and testing of a prototype decoupler. The decoupler is potentially applicable to different types of manure spreaders, and is characterized by an electromechanical actuation controlled by the tractor's voltage: in case of power failure the transmission to the chassis would be interrupted.
An additional solution, already tested in Italy on a prototype by INAIL, consists in the automatic segregation of the working bodies when the machine is in a stationary position. Under these conditions, the protection can only be removed using a hold-to-run control located in a safe area and allowing the complete visibility of the danger zone. This solution appears relatively easy to apply in the case of wagons already equipped with a rear bulkhead segregating spreading devices.

3. Results and Discussion

Figure 3.1 shows the device scheme. The system is equipped with a hydraulic drive clutch with built-in pump and oil tank. The choice of a "all in one" system is useful for its adaptability to different models of manure spreaders.

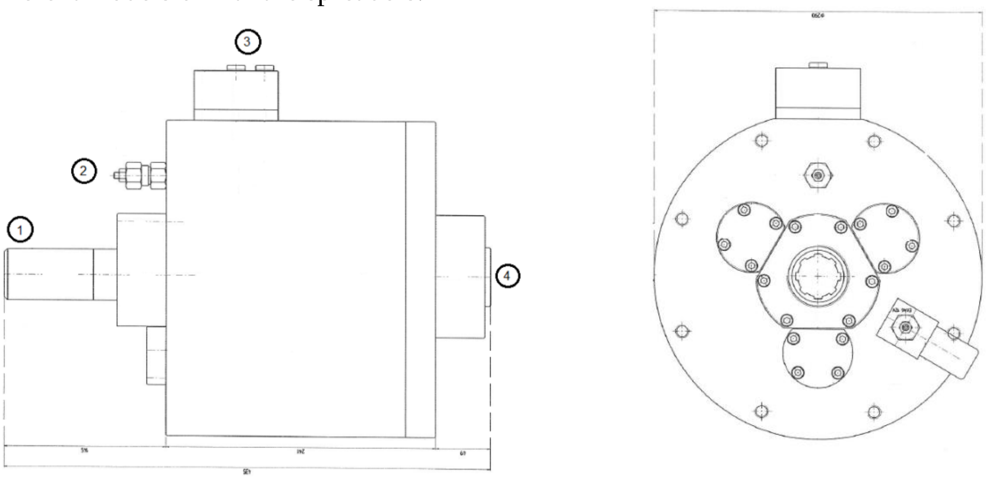

Figure 3.1: Device scheme. 1. PTO cardan shaft attachment; 2. main valve; 3. electric control; 4. connection to the wagon.

Figure 3.2 shows the general scheme of the system with the positioning of the sensors.
Wheel motion detection is achieved thanks to the magnetic proximity sensor that detects the passage of the metal surface of 5 nuts, installed on the wheel drum.

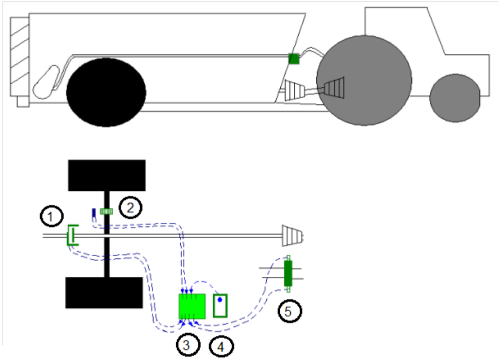

Figure 3.2: Complete device diagram. 1. clutch; 2. sensor; 3. PLC; 4. hold-to-run control; 5. hydraulic distributor (tank, max valve and pump: integrated in the device).

Workers often need to spread the material and activate the spreader rollers when the machine is in a static position. To overcome this need, a hold-to-run command can be used: it consists of a button (or lever) to be held down. This safety-related command must be located in a safe area so as to prevent any accidents that may occur if it is located close to the moving zones of the machine. For the same reason, it must be positioned in a zone allowing full visibility of the hazardous area.
In order to control all components and to ensure the stop and reset of the operating elements of the machine, a programmable logic controller (PLC) is installed. This has the following input signals: analog signals from the angular speed detector (with 2 inputs - signals to determine if the wagon is moving or not and if the PTO is moving or not); signal deriving from the hold-to-run control (1 input). At the output, the PLC will provide: signals for clutch control, 12V electrical power out and ground discharge (2 outputs); signals for the hydraulic distributor (to the pump for the above described device).
The decoupler was tested in February 2017 at the INAIL research center in Monte Porzio Catone (Italy) where it was installed on a rear-end manure spreader RenMark model RP 140. The test results show an average stopping time of the rear rotors of 12 seconds (± 1 s) from the moment when the wheels are stopped. It should be noted that the stopping time is resettable by PLC.
A video showing the test is available at https://youtu.be/w5vDZhzcvZY.

4. Conclusion

The present study attempted to address a problem found on manure spreader wagons, in particular the risk for workers involved in cleaning or maintenance operations inside the trailer when the working bodies are in motion.
The ability to automatically stop the motion of the working bodies when the wagon wheels are in a stationary position, would drastically reduce the risk, although human access inside the wagon is not prevented (the risk would remain, for example, in the very remote case of operations carried out inside a wagon moving on the field or on the road).
For this purpose a PLC controlled decoupling device has been developed. The device is installable on the most common manure spreader wagon models on the market.
This work shows how the device can be installed, possibly, on wagons already on the market or in service. The size of a "all in one" device such as the one proposed in this research (total length of about 440 mm, with a diameter of about 290 mm) would allow installation on different models, without involving large Mechanical-structural changes.
The prototype uses a hydraulic drive with its own circuit, thus disconnected from the tractor hydraulic system. It is also designed to ensure decoupling in the absence of 12V power supply.
The market costs that will affect the purchase prices of the machines remain to be considered in detail. In the specific case, the net cost of design and construction is around € 8,000, but

obviously the cost would be much reduced in the case of industrial production of the device. Estimates made by this and other research groups reveal costs between € 2665 and € 4380.
Finally, with regard to manure spreader models connected to the tractor's three-point linkage, specific sensors should be studied to command decoupling in the event of a stationary situation of the machine in the field.

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Different dust (PM_{10} and fine particulate matter) resuspension time in piggeries following animal activity

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Keywords: dust, PM_{10} and $PM_{0.25}$, animal activity, pig facilities.

Summary
The aim of this study was to evaluate the contribution of animal activity to dust concentration in finishing pig facilities. The study was addressed to estimate the lag time occurring from maximum level of activity and peaks of particulate matter (PM_{10} and fine particles) in the barn, and to evaluate dust deposition times for the different PM size categories.
For this purpose, two finishing rooms, with around 360 animals were used. A Grimm Portable Laser Aerosol Spectrometer Model Mini-LAS 11-R was used to evaluate dust particles ranging from 0.25 µm to 30 µm, in mass and count, in the facilities. The instrument was placed in the middle of the pen in a protective shell, at a height of 50 cm, at the respiratory apparatus level of pigs. Measurements were performed continuously for 3 d every two weeks during the three months of the finishing phase.
As demonstrated in previous works, data showed that, there is a lag time between the beginning of increased animal activity (at visual observation) and PM_{10} peaks: the peaks were registered eighteen minutes after the beginning of feed release.
During feed assumption, PM_{10} reached the peak of concentration, up to 1400 µg/m3 during the driest day. Usually, the PM_{10} concentration lowered to 80 µg/m^3, in around 15 minutes. $PM_{0.25}$ showed a peak directly in correspondence with the beginning of animal activity (around 7 µg/m^3, 43700 particles, in count).The concentration remained high during the positioning of pigs on the floor to rest, lowering to reach a linear "rest trend" only around 90 minutes after the feeding time.
These results take importance for the risk induced by environmental pollution in animal facilities for workers and veterinarians, since, during vaccination time and inspection, animals reach a great level of activity.

1. Introduction

Level of pollutants in animal confinements vary remarkably during the day and during the season of the year, according to a wide series of parameters as ventilation rate (Wang et al., 2000), relative humidity, climatic conditions, air distribution (Maghirang et al., 1994), feeding type (Costa et al., 2007). Animals' activity (Takai, 1992; Pedersen, 1993) can also rise dust concentration through the suspension or the re-suspension of dust particles. In many studies on dust in pig barns, the strong relationship between animal activity and dust concentration has been highlighted (Takai, 1992; Pedersen and Pedersen, 1995; Haeussermann et al., 2008). In particular PM_{10}, or particles with an aerodynamic diameter smaller than 10µm are strictly depending on animal movements in the pen (Costa et al.,2009).
For these reasons, the study was addressed to estimate the lag time occurring from maximum level of activity and peaks of particulate matter (PM_{10} and $PM_{0.25}$ concentrations) in the barn, and to evaluate dust deposition times for the different PM size categories.

2. Methods

For this purpose, the trial was performed in the cold season, from November to January in two pig finishing rooms, with around 360 animals distributed in 16 pens, mean age of 140 d and mean weight of 73 kg. The floor was concrete slatted, eight valves released liquid feeding to the 16 pens three times a day.The facilities were mechanically ventilated by three chimneys (around

17000 m^3/h of air volumes exchange capacity each), with a climate controller set up on pigs temperature requirements system and based on a free running impeller (type Fancom FMS).
A Grimm Portable Laser Aerosol Spectrometer Model Mini-LAS 11-R was used in the facilities to evaluate continuously dust particles ranging from 0.25 µm to 30 µm, in mass and count. The instrument was placed in the middle of the pen in a protective shell, at a height of 50 cm, at the respiratory apparatus level of pigs. Measurements were performed continuously for 3 d every two weeks during the three months of the finishing phase.

3. Results

Rable 3.1 shows the characteristics and the mean environmental conditions in the facilities.

Table 3.1: Characteristics of the facility and parameters recorded in the room during the trial

Monitoring period	**November- January**	
Building	Floor	Slatted floor
	Manure removal	Vacuum system
Animals	Mean LW at the beginning(kg)	34
	Mean LW at the end (kg)	93
	Number of animals	363
	Type of feed	Liquid
Environmental conditions in the room	Mean Temperature (°C)	18.7 (15,03; 21,00)
	Mean RH %	61 (52;92)
Environmental conditions outside the room	Mean temperature(°C)	7,11 (5,4-12,00)
	Mean RH %	59 (35;93)
	Mean ventilation rate (m^3/h)	7905
	Mean PM_{10} concentration (µg/m^3)	780

As demonstrated in previous works (Costa et al., 2009; Costa et al., 2012), data showed a lag time between the beginning of increased animal activity (at visual observation) for feed release, and PM_{10} peaks. Greatest peaks were registered at the second feed administration (at twelve) eighteen minutes after the beginning of feed release (Figure 3.1). During feed assumption, PM_{10} reached the peak of concentration, up to 1400 µg/m^3, particles deposition (dust concentration of around 200 µg/m^3 with all animals resting) occurred 10 minutes later.
The concentration remained high during the positioning of pigs on the floor to rest, lowering to reach a linear "rest trend" only 90 minutes after the feeding time.

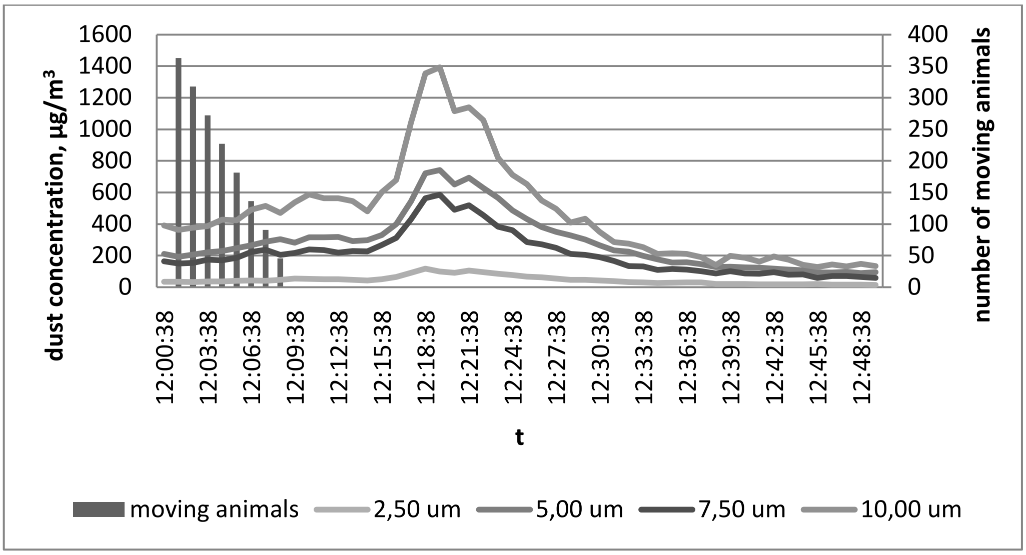

Figure 3.1: Trend of the concentrations of PM_{10}, $PM_{7.50}$, PM_5 , PM_5 and $PM_{2.5}$ in the facility at pig feeding time and during the afternoon

The same peaks detected for PM_{10} corresponded to peaks for smaller particle size classes as $PM_{7.5}$, PM_5 and $PM_{2.5}$ (Figure 3.1).

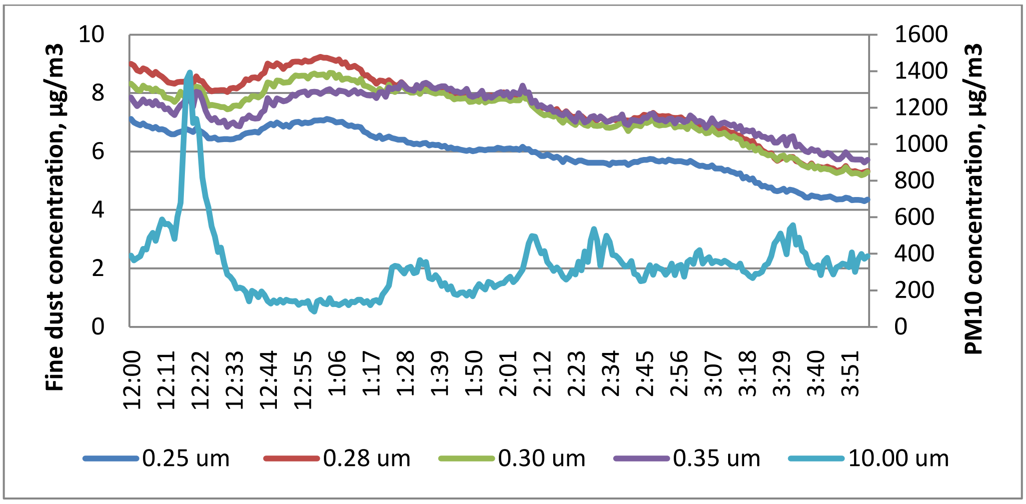

Figure 3.2: Trend of the concentrations of PM_{10}, and fine particles, $PM_{0.25}$, $PM_{0.28}$, $PM_{0.30}$ and $PM_{0.35}$ *in the facility at pig feeding time and during the afternoon.*

Figure 3.2 shows the different trend of fine dust concentration, intended as $PM_{0.25}$, $PM_{0.28}$, $PM_{0.30}$ and $PM_{0.35}$) in the facility in relation to PM_{10}. The concentration of these size dust particles was very low, i.e. up to 7 µg/m^3 for $PM_{0.25}$, one hour later the beginning of increased animal activity. The number of particles ($PM_{0.25}$, $PM_{0.28}$, $PM_{0.30}$ and $PM_{0.35}$) in the facility, expressed in number/l, showed the same slow decline during the 3 hours after the pigs feeding time, demonstrating a different trend in comparison with classes of upper dynamic diameter. An interesting result is the high number of fine particles related to their small concentration.

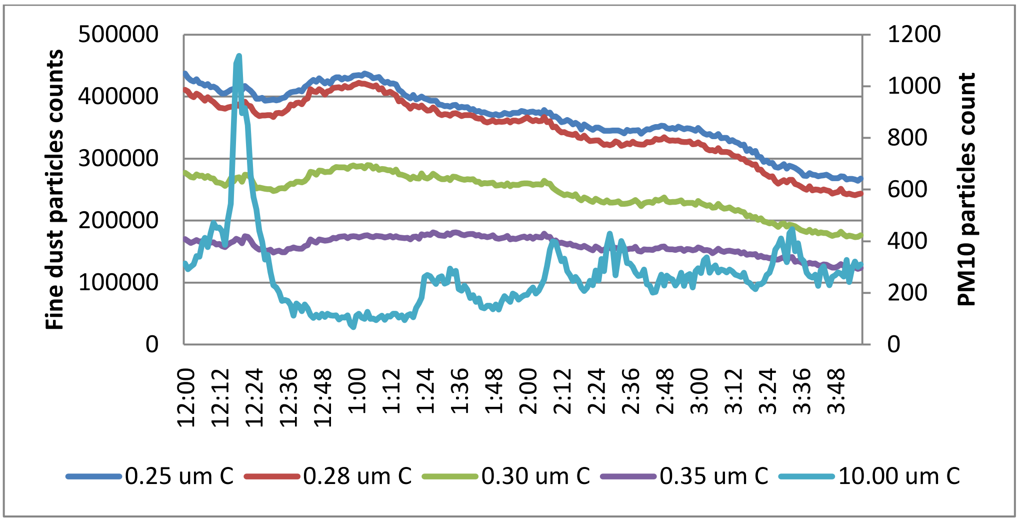

Figure 3.3: Trend of the counts of particles of PM_{10}, $PM_{0.25}$, $PM_{0.28}$, $PM_{0.30}$ and $PM_{0.35}$ *in the facility at pig feeding time and during the afternoon.*

4. Conclusion

These results take importance for the risk induced by environmental pollution in animal facilities for workers and veterinarians, since, for example, during vaccination time and inspection, animals reach a great level of activity.

Further studies addressed to analyze the type of dust raised in particular moment, would be helpful to avoid undesired risks for the health status of animals and workers, through additional good management procedures application.

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The need for International Standards on dusters: first proposal of test protocols for their functional evaluation and periodical inspections

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Keywords: duster, International Standard, test protocol, inspection

Summary

It is estimated that more than 200000 dusters, mainly used to apply sulphur dry powder in vineyards to prevent powdery mildew, are in use in Southern Europe. At present there are not reference International Standards for the inspection of in use neither for brand new dusters. In the ambit of a dedicated Technical Working Group within SPISE (Standardised Procedure for the Inspection of Sprayers in use in Europe) a very first proposal on how to carry out the inspection of dusters in use is under development on the basis of some requirements present in ISO 16122-3 concerning air-assisted sprayers for bush and tree crops and on the basis of some previous experiences made using this type of machinery at DiSAFA – University of Torino.

This first test protocol proposal foresees either to verify some constructive characteristics of the machine or to evaluate its performance, especially in terms of dust flow rate according to the adjustment set.

The applicability of some parts of this test protocol has been checked on three different models of dusters that were tested at DiSAFA – University of Torino. An analysis of the results obtained and of the practical problems faced during the trials is presented.

1. Introduction

The technique of distributing dry sulphur dust in vineyard is quite widespread, especially in Southern Europe (Italy, Spain, France, Greece, Portugal). In these countries it is estimated that about 200000 dusters are actually in use. Typically, the machines employed for distributing sulphur dust in vineyards are featured by a poor level of technology and the quality of dust distribution is generally poorly uniform (Marucco and Balsari, 2004), with deposits on leaves and bunches that generally are below 50% of the amount applied. Nevertheless, at present there is not an International Standard dealing with the technical features and the performance requirements for brand new dusters. The SPISE draft test protocol for inspection of dusters in use considered to make a functional test only to assess the performances of the dust dosing system and the uniformity of the air velocity on the two sides of the machine. But up to now any specific methodology has been defined to asses these parameters. With the aim to make a first evaluation of the applicability of the draft SPISE advice on duster inspection and to try to set up ad hoc test protocols for functional tests, preliminary trials were carried out on three duster models.

2. Materials and methods

The dusters examined

Tests were carried out on three different duster models, all featured by a "gravity" dosing system: 1) a MB G 300 duster equipped with a 50 liters tank, a 300 mm diameter radial fan and a dust dosing system having a range of six different positions from 0 to 5 on the scale of the control system; 2) a Cima 420 S duster equipped with a 200 liters tank, a 400 mm radial fan featured by a nominal air flow rate of 2100 m^3/h and a dust dosing system having a range of ten different positions from 0 to 5 on the scale of the dosing control system; 3) a VMA Rodeo LT 300 duster equipped with a 300 liters tank, a 450 mm radial fan featured by a nominal air flow rate of 4300 m^3/h and a dust dosing system having a range of eight different positions from 0 to 4 on the scale of the control.

Measurements of air velocity

On all the three duster models air velocity measurements were carried out using a Testo vane probe 16 mm diameter connected to a Testo 400 data logger. Measurements were carried out on the two sides of the machine that was positioned with the center of the spouts at a height of 0.5 m from the ground.

The machines were operated at a PTO speed of 540 rev/min and air velocity was measured in correspondence of the edge of the spouts, positioning the vane probe in at least 6 different positions along the spout profile, and at a distance of 1.5 m from the center of the machine (considering a typical vineyard inter-row distance of 3 m) at three different heights from the ground (referred to typical vineyard canopy heights): 0.5; 1.0 and 1.5 m (Fig. 2.1).

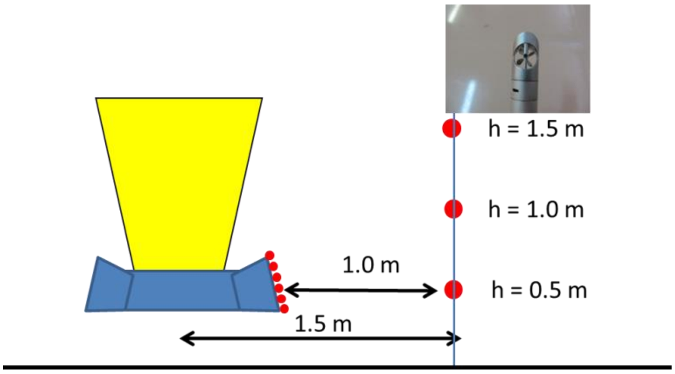

Fig.2.1: Scheme of the air velocity measurements carried out on the duster models tested.

Measurements of dust flow rate

A first set of tests were carried out using the MB G 300 duster and the VMA Rodeo LT 300 duster employing kaolin clay dust (Surround® WP manufactured by Novasource®) as test material, in order to avoid the manipulation of sulphur dust which is irritant and can generate environment problems during the test. The kaolin was considered a possible test material (easy to find, cheap and with low environmental impact) for comparing the dust dose rates related to the different settings of the machines.

Tests were carried out inserting 3 kg (about 10 liters) of kaolin in the tank, operating the machine in static position at 540 rpm and measuring the time until dust emission from the spouts collapsed. At the end of the trial the dust residue at the bottom of the tank was measured. For both the machines tests were made setting two different dosages corresponding respectively to the maximum of the scale of the dose control system (n. 5 for the MB duster and n. 4 for the VMA duster) and to an intermediate level (n. 2) and for each thesis three test replicates were carried out.

A second set of tests, aimed at evaluating the effects of sulfur type on the performances of the dosing system were carried out using the MB G 300 duster set at the maximum dosage (n. 5 on the scale of the control system) employing two types of sulfur dust: a) Mormino "Zolfo ventilato scorrevole" featured by an average size of the particles < 44 µm and a density of 1.95 kg/dm3 and b) Zanuccoli "Zolfo triventilato 93% S" featured by an average size of the particles < 44 µm and a density of 2.07 kg/dm3. Tests were made filling the tank up to its maximum capacity, weighing it on a weighing platform (PI/WWSE6T, ABC Bilance) featured by a maximum load of 6000 kg and an accuracy of 0.2 kg, then activating the duster in static position for one minute, weighing again the duster and calculating the dust flow rate by difference of weight. The operation was then repeated ten times until the dust emission from the spouts collapsed. At the end of the trial the dust residue at the bottom of the tank was measured. For each test three replicates were carried out.

3. Results and Discussion

Measurements of air velocity

The MB G 300 duster provided an average air velocity measured at the spout of 37.7 m/s on the right side and of 39.8 m/s on the left side of the machine with a difference of 6% between the two sides of the machine. The Cima S420 duster presented an average air velocity of 48.1 m/s measured at the right spout edge and an average air velocity of 48.2 m/s measured at the left spout edge with a difference of -0.2% between the two sides of the machine. Operating the VMA Rodeo 300LT duster an average air velocity of 44.9 m/s was measured at the right spout edge while an average air velocity of 36.1 m/s was measured at the left spout edge with a difference of 24% between the two sides of the machine. The values measured at 1.5 m from the machine centre indicated that the highest values were measured at 1.0 m from the ground and that the average difference between the air velocities registered on the right and on the left side of the machine was only -2%, but with a +300% difference registered at 0.5 m height and a -43% difference registered at 1.5 m height.

Measurements of dust flow rate

Using kaolin on the MB G 300 duster and setting the maximum level (n. 5) on the dose control system of the machine an average dust flow rate of 0.39 kg/min was obtained and an average residue of 1.32 kg of powder was collected in the tank at the end of the trial. This value was very low when compared to the nominal one indicated by the manufacturer (7 kg/min) for the same setting of the dose control system. Employing the VMA Rodeo 300LT duster and setting the maximum level (n. 4) on the dose control system of the machine an average dust flow rate of 0.80 kg/min was obtained and an average residue of 0.34 kg of powder was collected in the tank at the end of the trial. When the dose control system was set in position n. 2 of the scale, a 70% reduction of the dust flow rate was measured with an average powder residue in the tank of 0.27 kg. Also in this case the measured values resulted much lower with respect to the nominal ones indicated by the manufacturer (12.4 kg/min and 6.1 kg/min respectively).
Tests made operating the MB G 300 duster with the dose control system set at the maximum level and employing the two types of sulphur dust pointed out that the flow rate changed considerably in function of the tank filling level (Fig. 3.1).

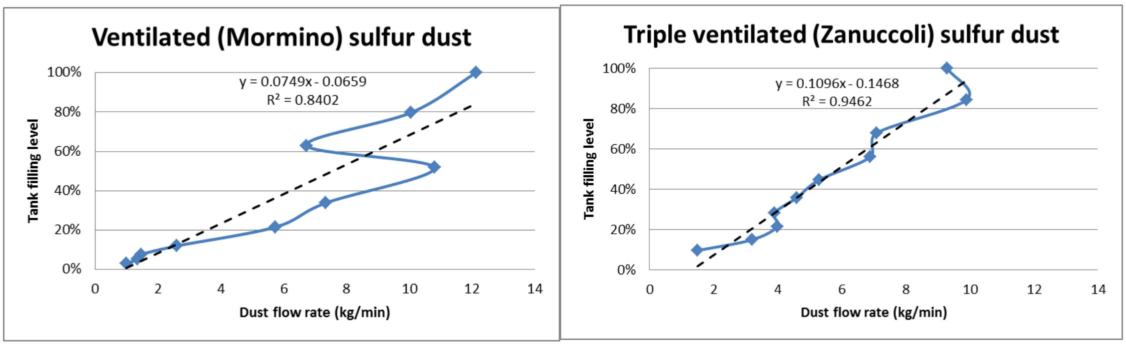

Fig.3.1: Trend of sulphur dust flow rate registered with the MB G 300 duster using two different types of sulphur dust and adopting the same dose adjustment (maximum value on the scale of the dose control system = n. 5).

Comparing the results obtained with the different test materials used in the trials (kaolin, ventilated sulfur Mormino and triple ventilated sulfur Zanuccoli) operating the MB G 300 duster set at the maximum dose rate and with the tank filled at the same level used with the two products (10% of its capacity) considerable differences in terms of dust flow rate and dust residue in the tank were observed. The use of kaolin produced a flow rate at least 50% lower if compared with sulfur and this seems to limit its use as an alternative material for tests.

4. Conclusion

A SPISE advice for the inspection of dusters in use is difficult to set up due to the lack of a reference Standard for this type of machines. First assessments made to measure air velocity indicated that, according to the duster model, considerable differences can be achieved in terms of symmetry of air distribution. A test protocol for air velocity measurements based on the method adopted in these preliminary trials could be easily defined and added in the draft SPISE advice, eventually providing a threshold level for the symmetry of air distribution on the two sides of the machine.

About dust flow rate measurements, problems were encountered in carrying out the trials also due to the difficulties in managing the dust emitted by the machines. Tests made using kaolin clay dust as test material and filling the tank with a limited amount of powder provided results very different with respect to the nominal values indicated by the manufacturers while tests carried out with sulphur dust indicated that the dose rate depends very much on the tank filling level and is also affected by the specific type of sulphur dust. Further tests are needed in order to verify if, independent of the duster model and of the setting, a consistent relationship can be found between the dust flow rate measured using kaolin and that measured applying sulphur. At present it is therefore difficult to indicate an appropriate test protocol for functional test to assess the dust dose rate applicable in the ambit of the inspections of dusters in use. Efforts are also needed in order to stimulate duster manufacturers to agree on the definition of an International Standard for new machines that should be able to guarantee a constant dose rate in function of the regulation set on the duster.

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Operating cost of milking in automatic and conventional milking systems

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Keywords: automatic milking, milking parlour, milking cost

Summary
The objective of this study was to estimate the operating cost of milking (€/tonne of milk) when cows were milked by an automatic milking system (AMS) as compared to a conventional milking system (CMS). Calculation were performed using as benchmark the average annual milk yield/cow of a Lombardy dairy farm where two groups of 49 and 50 cows were milked respectively by an AMS and a CMS over one year experimental period. Cows milked by the AMS produced 7.8 % more milk than cows milked conventionally (10,74 vs. 9,96 tonne/cow per y). The average annual fixed costs (AFCs) per cow in the AMS were 79 % higher than in the CMS, while the average annual variable costs (AVCs) per cow in the AMS were 48 % lower than in the CMS. Overall, the average annual total costs (ATCs) per cow were equal to 687 € and 677 € respectively in the AMS and CMS, which correspond an operating cost of milking (OCM) respectively of 64 and 68 €/tonne. Nevertheless, taking into account the extra feeding cost required to cover the additional milk yield produced by the cows milked in the AMS and the benefits originating from selling the extra milk quota, the ATCs per cow reduced to 519 € and the OCM decreased to 48 €/tonne (-29 % if compared with the CMS).

1. Introduction
Automatic milking represents a revolutionary innovation in dairy farming. The adoption of an automatic milking system (AMS) is to be considered as a new concept of managing a dairy farm, changing not only the way in which the milking is carried out but also the farmer's schedule, the feeding and the housing management, the monitoring of milk quality, cow and udder health, and cow fertility (Meskens et al., 2002). More than 10,000 dairy cow farms worldwide use AMS to milk their cows (de Koning, 2011; Lyons et al., 2014), and automatic milking can now be considered a well-established technology.
The most relevant benefits of automatic milking are the increase in milk yield and the labour saving. AM-systems reduce the heavy workload of milking and enable milking frequency to be controlled on an individual cow basis, according to her production level or stage of lactation, without incurring extra labour costs. All else being equal, cows milked more frequently throughout a lactation usually produce greater amounts of milk, up to 12 %, compared with cows milked twice a day (Jacobs and Siegford, 2012; Stelwagen et al., 2013; Wright et al., 2013). Milking with an AMS eliminates some labour tasks, but new ones are required including control of the AMS, checking of attention lists, visual control of the cows, and fetching animals that exceeded maximum milking intervals. Therefore, changing from a conventional milking system (CMS) to an AMS entails a new management approach (Svennersten-Sjaunja and Pettersson, 2008). The adoption of an AMS can allow to save about two-thirds of the time needed in conventional milking practices (Artmann & Bohlsen, 2000) or potential labour savings of 300 up to 1000 hours a year (Billon & Tournaire, 2002). Other studies found reduction in total labour of 10-18 % on farms with an AMS in comparison with the conventional twice daily milking (de Koning, 2001; Mathijs, 2004). AMS farms have been found to have higher capital costs, primarily because of higher maintenance costs and depreciation (Bijl et al., 2007). However, the economic impact of the AMS adoption depends on many factors (capacity of the system, increase in milk production, renovation or replacement of stables, type and amount of labour present on the farm, feeding system, etc.) whose costs are

difficult to be predicted. Moreover, the contribution of these factors to the change in farm profits depend also on management capabilities of the farmer.
The aim of this study was to estimate the operating cost of milking (€/t of milk) in an Italian dairy farm when cows were milked in an AMS as compared to a CMS.

2. Materials and Methods

In a Lombardy dairy farm the simultaneous presence of an AMS and a CSM allowed the herd to be splitted into two homogeneous groups. The Holstein Frisian herd of 99 lactating cows was randomly divided into two groups (G_1=49 and G_2=50), according to their lactation number and lactation stage. For the one-year testing period cows belonging to group G_1 were milked by an AMS one box system with free cow traffic. Cows of group G_2 were milked conventionally twice a day (12 h interval between two milking cycles) by a 5+5 herringbone milking parlour, equipped with automatic cow identification (RF-ID), milk metering technology and automatic cluster removers. Groups G1 and G2 were housed in the same barn, divided into two parts, in a combination of loose housing and mat-lined free stalls. All cows were fed with a total mixed ration of corn silage, grass silage, Alfalfa hay and concentrates administered ad libitum. Cows of group G1 received concentrate feed in the milking station up to 3 kg/day, based on daily milk yield.
Average annual fixed costs (AFCs, €) and average annual variable costs (AVCs, €) for the AMS and the CMS were estimated according to Lazzari (2007). AFCs included the amortization of the capital used to purchase the asset (AMS or CMS) and the costs for its insurance, management and maintenance. Calculations were based on market prices for the year 2015. Cooling tanks and building works were not included. Capital investments were estimated considering an average lifetime of 10 years and calculating a depreciation plan with an annual fixed interest rate of 2 % using the following formula:

$$R = C\frac{i(1+i)^n}{(1+i)^n - 1} \tag{2.1}$$

where: R = annual fixed installment; C = bank loan; n = number of years; i = annual fixed interest rate. The insurance cost (I_c) and the management cost (M_c) were estimated each as 0.3 % of the initial asset value (V_0) at time t = 0. The maintenance and updating cost (MU_c) was valuated as 3 % and 6 % of V_0, respectively for the CMS and the AMS. The MU_c was considered as a fixed cost and not as a variable cost because, differently from the majority of the agricultural machines, the milking systems are used on a daily basis, so their maintenance is carried out with predictable frequencies over the year.
AVCs were estimated by adding up the average unit cost of the main factors (electricity, water, detergents, disinfectants, and labour) used at each milking and calculated with the following formula:

$$Cf_k = Pf_k \times UCf_k \tag{2.2}$$

where: Cf_k = average unit cost of factor k (€/milking); Pf_k = average unit price of factor k (€/unit);UCf_k = average unit consumption of factor k (unit/milking). The average unit price (year 2015) and the average unit consumption of the main factors used in automatic and conventional milking are reported in Table 2.1. The total number of milkings performed by the AMS and the CMS was calculated multiplying the number of cows milked by the average daily milking frequency during the one-year experimental period.

Table 2.1: Average unit price (year 2015) and average unit consumption of the main factors used in automatic and conventional milking (Lazzari, 2007)

Factors	Consumption per milking		Unit price
	AMS	CMS	
Electricity (kWh)	0.35	0.45	0.22 €/kWh
Water (l)	4	9	0.04 €cent/l
Alkaline detergent (l)	0.0035	0.015	1.50 €/l

Acid detergent (l)	0.0015	0.015	1.50 €/l
Postdipping disinfectant (l)	0.0250	0.015	1.50 €/l
Labour (min)	0.5	2 min	12.5 €/h (0.21 €/min)

The operating cost of milking (OCM, €/tonne of milk) in the AMS and the CMS was calculated from the average annual total costs per cow (ATCs/cow = AFCs/cow + AVCs/cow) and the average annual milk yield/cow, corrected for fat content (4%), recorded respectively in groups G1 and G2. The extra feeding required to cover the additional milk yield produced by the cows milked in the AMS was calculated according to the French system (INRA, 1988):

$$MFU = 0{,}44 \times normalized\ milk\ [kg] \tag{2.3}$$

where: MFU = Milk Forage Units.

The cost of the additional MFUs was calculated from the average cost of the base feeding ration (6 €/cow) for the cows milked by the AMS. Taking into account this extra feeding cost and the gross benefit originating from selling the extra milk quota (36 €/100 kg of milk), the OCM for the AMS was recalculated.

3. Results and Discussion

Average annual milk yields, normalized trough the correction for fat content (4 %), were respectively 10,74 tonne of milk/cow for the AMS and 9,96 tonne of milk/cow for the CMS, confirming that all else being equal, cows milked more frequently throughout a lactation usually produce greater amounts of milk.

Fixed, variable and total costs related to the AMS and the CMS are summarized in Table 3.1. The AFCs per cow in the AMS were 79 % higher than in the CMS (470 €/y vs. 262 €/y), mainly due to the higher capital investment and the higher maintenance and updating costs related to the adoption of AM-systems, as reported by Bijl et al. (2007). On the contrary, the AVCs per cow in the AMS were 48 % lower than in the CMS (217 €/y vs. 414 €/y), mainly due to the lower labour costs. This finding agrees with those in other reports (Jacobs and Siegford, 2012; Stelwagen et al., 2013; Wright et al., 2013). Overall, the ATCs per cow were equal to 687 €/y and 677 €/y respectively in the AMS and CMS, which correspond an OCM respectively of 64 and 68 €/tonne. Nevertheless, each cow milked by the AMS produced on average 774 kg of 4 % fat corrected milk/y more than a cow milked by the CMS. Taking into account the extra feeding cost required to cover the additional milk yield produced by the cows milked in the AMS (102 €/cow per y) and the gross benefit originating from selling the extra milk quota (279 €/cow per y), the ATCs per cow reduced to 511 €/y. Therefore, the OCM decreased to 48 €/tonne (-29 % if compared with the CMS). Increasing milk yield without incurring in extra labour costs represents the major advantage of automatic milking compared to conventional milking.

Table 3.1: Average annual fixed costs, variable costs and total costs in automatic and conventional milking (values rounded to the nearest Euro).

TYPES OF COST (€/year)		AMS[1]	CMS[2]
Average Annual Fixed Costs (AFCs)	Fixed installment (R)[3]	14,472	8,238
	Insurance cost (Ic)	390	222
	Management cost (Mc)	390	222
	Maintenance and updating cost (MUc)	7,800	4,440
	Total	23,052	13,122
Average Annual Variable Costs (AVCs)	Electricity	3,581	3,614
	Water	74	131
	Alkaline detergent	244	706
	Acid detergent	105	115
	Postdipping	1,744	821
	Labour	4,883	15,330
	Total	10,631	20,717
Average Annual Total Costs (ATCs)		33,683	33,839

[1]49 cows, 2.6 milkings/day; [2]50 cows, 2 milkings/day; [3]Annual fixed installment for a 130,000 € (AMS) or 74,000 € (CMS) bank loan by a loan length of 10 years and an annual fixed rate of 2 %

4. Conclusion

The operating cost of milking was found 29 % lower when cows were milked in an AMS as compared to a CMS. Although the investments required for automatic milking systems are higher than for conventional milking parlors, the increase in milk yield and the labor saving may really lead to lower costs per kg of milk making the automatic milking a valuable alternative to the traditional milking systems especially for small family operated dairy farms.

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Using Statistical Process Control to monitor milking process

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Keywords: Statistical Process Control, Control Chart, milking parlour performance

Summary
Twenty milking parlours of Northern Italy were involved in a field study over one year. Milking performance data were extracted from the herd management software of each milking parlour at each milking session. Through the Principal Components Analysis, two new variables were identified (principal components) that can be interpreted as a synthetic index respectively of flow rates and duration and parlour efficiency. The milking process was then analyzed using Shewhart individuals control charts based on the principal components previously identified.

1. Introduction
The goal of a good parlour management is milking the cows gently, rapidly, and completely, attaching the milking unit just after a proper pre-milking routine and detaching the milking cluster as soon as possible after milk flow has stopped. Modern milking parlours allow the automated collection of many data for each cow being milked: milk yield, milk yield in the first 15, 30, 60 and 120 seconds after milking unit attachment, milking duration, average and peak milk flow rates, conductivity of the cow's milk, etc. These data can potentially be used to monitor the cows, milkers, milking equipment, and the overall performance of the milking process (Eicker and Stewart, 1998; Fuhrman, 2002; Reneau, 2000; Stewart et al. 1999, 2001). Despite the general agreement on the need to monitor performance, it is necessary to know how to use effectively data from milking systems. Data analysis is complicated by the fact that every process, regardless of how it is well designed, is always subject to a certain variability, which can depend on many random factors. A process, whose variability is caused just by "noise", is referred to as under control process. On the contrary, an out of control process exhibits variation due to the presence of special causes.
The objective of the work was to monitor milking process using the Statistical Process Control (SPC) and its primary tool, the control chart, developed by Shewhart (1931). SPC is a statistical method of interpreting time-series data, whose general principle is having a wide database collected on a regular basis that generates a historical perspective and a normal pattern to the data. Irregular patterns can be interpreted as management issues that need to be addressed (Shewhart, 1931; Montgomery, 2009).

2. Materials and Methods
Milking performance data from 20 milking parlours (17 herringbone, 2 parallel, 1 rotary) of Northern Italy were collected for SPC analysis. Common conditions to all the systems were the electronic identification of cows using RFID technology, the use of milk meters to measure milk yield for individual cows, the adoption of the same herd management software (AfiFarm v. 3.07, Afimilk, Afikim, Israel), and the vacuum pumps driven by variable speed drive units. The working parameters for all the milking parlours were 42 kPa system vacuum, 60 cycles/min pulsator rate, and 60 % pulsator ratio.
Overall, 7122 dairy cows (Holstein Frisian), milked two times per day during one year, were involved in the study. The following data were extracted from the herd management software of each milking parlour at each milking session: average milk flow rate [kg/min]; milk flow rate 0-15 s, 15-30 s, 30-60 s, and 60-120 s after the milking unit attachment; percentage of milk during the first two minutes of milking [%]; average milking time [min]; average milk yield/cow [kg]; low flow (below 1 kg/min) time [min]; cows milked/stall per hour [n]; milk yield/stall per hour

[kg]; milking efficiency [%]. Through the Principal Components Analysis (PCA), two new variables were identified (principal components) that can be interpreted as a synthetic index respectively of flow rates and duration (first component) and parlour efficiency (second component). The milking process was then analyzed using Shewhart individuals control charts (Reneau and Lukas, 2006), based on the principal components previously identified. In a control chart a series of measurements are plotted in time order on a template consisting of three horizontal lines: the centre line (tipically the mean), the upper control limit (UCL), and the lower control limit (LCL). The control limits were set at ± 3SD for detecting meaningful changes in milking process performance while achieving a balance between false positive (type I error) and false negative (type II error) indications (Benneyan et al., 2003). The statistical analysis was performed using JMP Pro 12 (SAS Institute Inc., Cary, NC).

3. Results and Discussion

The PCA principal component 1 (PC1) explained 58.3 % of the total variation (Figure 3.1) and distinguished milking parlours where a full milking routine (predipping, forestripping, teats drying before milking cluster attachment, and postdipping after the milking unit removal) was applied from parlours in which teats were only wiped or stripped before milking unit attachment (Figure 3.2). The full milking routine guaranteed better cow milking parameters in comparison with the partial milking routine (Table 3.1).

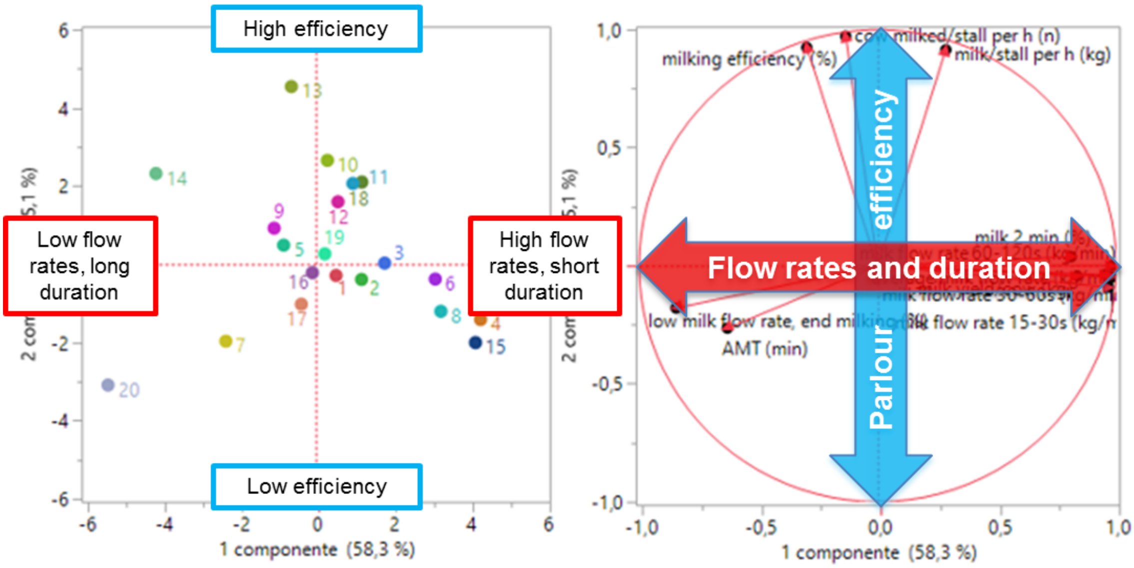

Figure 3.1: On the left, milking parlour plotted by PCA at the plane of principal components 1 (PC1) and 2 (PC2); on the right, the new variables identified and interpreted as a synthetic index of flow rates and duration (PC1) and as a synthetic index of the parlour efficiency (PC2).

PC 2 explained 25.1 % of the total variation and divided most milking parlours with a clusters-milker ratio lower or equal to 12 from the other parlours with a highest ratio, exception made for the "rapid exit parlours" number 11, 12, and 18 (Figure 3.2). The milking efficiency was significantly higher (39.6 vs. 31.0 %, P < 0.05) and the cows milked/stall per hour tended to be significantly higher (3.5 vs. 2.8, P = 0.09) when each milker managed up to 12 clusters. In general, for best parlour performance, the clusters must be attached to the next cow in the stall as soon as possible after a proper pre-milking hygiene and stimulation is executed, avoiding any possible delay (Stewart, 2001). Managing a limited number of clusters by the milkers seems to be useful for improving parlour efficiency. The only rotary parlour (number 7), with 82 milking stalls, showed a milking efficiency of 29.4 %, while the cows milked/stall per hour were 1.9.

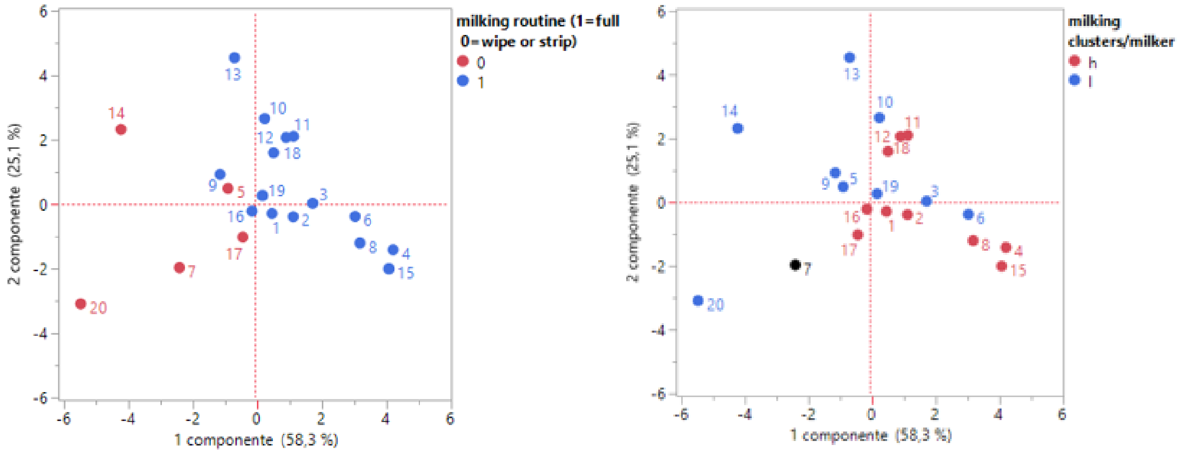

Figure 3.2: Component scores of principal component analysis of 20 milking parlours with full or partial milking routine (on the left) and high or low clusters/milker (on the right).

Table 3.1: Evaluation of the main cow milking parameters in milking parlours with full or partial milking routine

Cow milking parameters	Full milking routine mean±SD	Partial milking routine mean±SD
Average milk flow rate (kg/min)	2.64±0.27^{A}	1.98±0.36^{B}
Average milking time (min)	6.24±0.14^{a}	6.86±0.25^{b}
Milk flow rate 15-30 s (kg/min)	3.02±0.12^{A}	1.95±0.21^{B}
Milk flow rate 30-60 s (kg/min)	3.24±0.15^{A}	2.14±0.27^{B}
Milk flow rate 60-120 s (kg/min)	3.85±0.13^{A}	3.05±0.22^{B}
Milk 2 min (%)	39.08±1.08^{a}	34.76±1.57^{b}
Low flow time (%)	18.85±1.45^{A}	31.67±2.02^{A}

^{A,B} Values in the same row with different superscripts differ significantly ($P < 0.01$). ^{a,b} Values in the same row with different superscripts differ significantly ($P < 0.05$).

The Shewhart individuals control charts for PC1 and PC2 allowed to monitor the milking process within the different milking parlours, highlighting when a change occurred or was implemented (Figure 3.3). In this way, an improvement strategy can be applied, searching for special causes, if the process is out of control, or redesigning the same process, if it is in control.

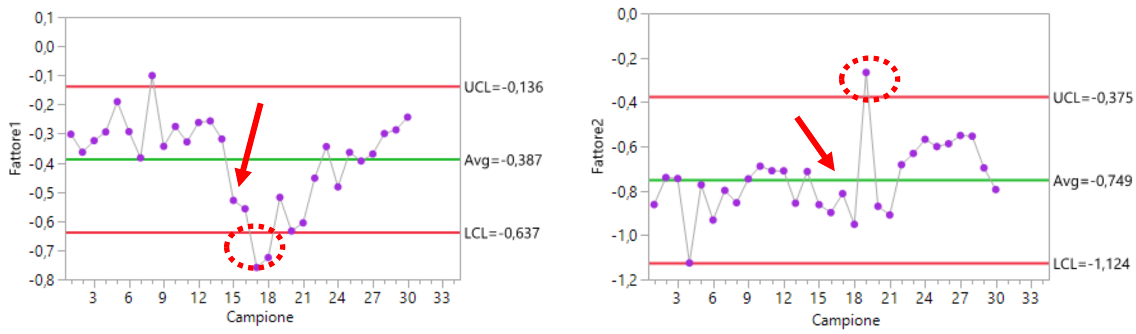

Figure 3.3: I charts for PC1 (flow rates and duration) and PC2 (parlour efficiency), milking parlour number 7, month of June. The arrows indicate the time when a change occurred or was implemented. The plotted circles indicate points out of control according to the 3-σ rule.

4. Conclusion

Implementing a full milking routine and managing the right number of clusters by the milkers can improve the milking process in terms both of cow milking parameters, and of parlour efficiency. Control charts can potentially be used in the daily management of milking processes for analysing routinely collected data and for reducing the so-called management by opinion.

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Tractive and soil compaction performances of an agricultural tractor fitted with rubber tracks

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Keywords: agricultural tractor, rubber tracks, traction efficiency, soil compaction

Summary

The objective of this study was to compare the tractive and the soil compaction performances of a conventional wheeled tractor with the fully tracked version of the same model.
The tested tractors were connected each other through a steel chain equipped with a load cell. The performances of the towing tractor were evaluated using the towed tractor as a brake, then the tractors were inverted in order to test both. The traction efficiency and the maximum draft force of the tractor were measured through the load cell and the tractor parameters acquired with a CAN logger. The soil compaction was evaluated through the analysis of soil bulk density and cone penetration test.
The results show a reduced soil compaction for the tracked tractor with respect to the wheeled version despite of the increase of the tractor mass due to the four rubber tracks weight. Furthermore, the tractor equipped with rubber tracks showed an improvement of the traction efficiency, especially on low grip surfaces.

1. Introduction

From the birth of agricultural mechanization, agricultural tractor main specifications have evolved over the years to keep pace with the development of the agricultural processes (Sahal, 1981). Regarding traction systems, tractors could be divided into two main categories, wheeled and steel-tracked tractors. The latter provides higher tractive performance and lower soil compaction (Ansorge, & Godwin, 2008), but nowadays this traction system is rarely used due to its complexity and the difficulties of driving steel-tracked tractors on paved roads. In the last decades, rubber belt tracks for agricultural machines became a popular solution, in fact they combine excellent tractive performance and low soil compaction without motion problems (Bashford, Jones, & Mielke, 1988). A further evolution of this technology was the development of triangular rubber track systems that can be installed on conventional wheeled tractors. The objective of this study was to compare tractive and soil compaction performances of a conventional wheeled tractor with the fully tracked version of the same model.

2. Materials and Methods

The tests were carried out with two New Holland T7.260, one fitted with standard wheels and one with rubber tracks designed by Camso Inc. (Camso Inc., Canada) (Table 2.1).

Table 2.1: Specification and settings of the two tested tractor

Traction system	Tractor Model	Engine	Total tractor weight [kg]
Wheels(Front/Rear tyres): Michelin MACHXBIB 600/65 R28 Michelin MACHXBIB 710/70 R38	New Holland T7.260 Power Command	NH NEF (194 kW)	8000
Rubber Tracks (Front/Rear tracks): Camso 24D18C Camso 30D23MC	New Holland T7.260 Auto Command	NH NEF (194 kW)	14824

In order to test the tractive performances of the two tractors, those were connected each other with a load cell (full-scale range= $3*10^5$ N) and a steel chain (Figure 2.1). This layout permits to use the towed tractor as a brake that gradually increase the resistance force acting on the other tractor. Tractive performance parameters such as speed and slip percentage were acquired with a

CANcaseXL (Vector Informatik GmbH, Germany) CAN logger, while the draft force was measured through the load cell.
The tests were performed on a 50 m long field test track on both dry and wet soil conditions, and each test condition was repeated four times for each tractor.
The dynamic traction ratio (A_d) was evaluated by (2.1):

$$A_d = \frac{D_{lc}}{m_t} \tag{2.1}$$

where D_{lc} is the draft measured by the load cell and m_t is the total mass of the tested tractor. In order to show the relationship between slip percentage and A_d, the obtained data were fitted with a second order polynomial regression.

Figure 2.1: Wheeled and tracked version of the New Holland T7.260 during the test

The plastic limit (PL) of the agricultural field on which the tests took place is 27.11% and the liquid limit (LL) is 56.05%, therefore the plasticity index (PI) is 28.94% and the soil is classified as inorganic clays of high plasticity (ASTM, 2010). The mean value and the standard deviation of soil bulk density measured during the tests on the dry soil were respectively 1028.89 kg/m^3 and 123.94 kg/m^3, while the mean value of the soil moisture content (on dry mass basis) was 23.48% with a standard deviation of 1.43% (ASTM, 2009). Moreover, during the tests on the wet soil the mean value of soil bulk density was 1463.33 kg/m^3 (standard deviation=130.19 kg/m^3) and the soil moisture content (on dry mass basis) was 72.19% with a standard deviation of 1.65%.
To evaluate the soil compaction performances of the two traction systems on both soils, the measurement of soil bulk density and cone index test (ASAE, 2003) were performed after the tractors passed through the not compacted soil.

3. Results and Discussion

In Figure 3.1 are reported the trends of the Dynamic traction ratio as a function of the slip percentage in all the tested conditions.

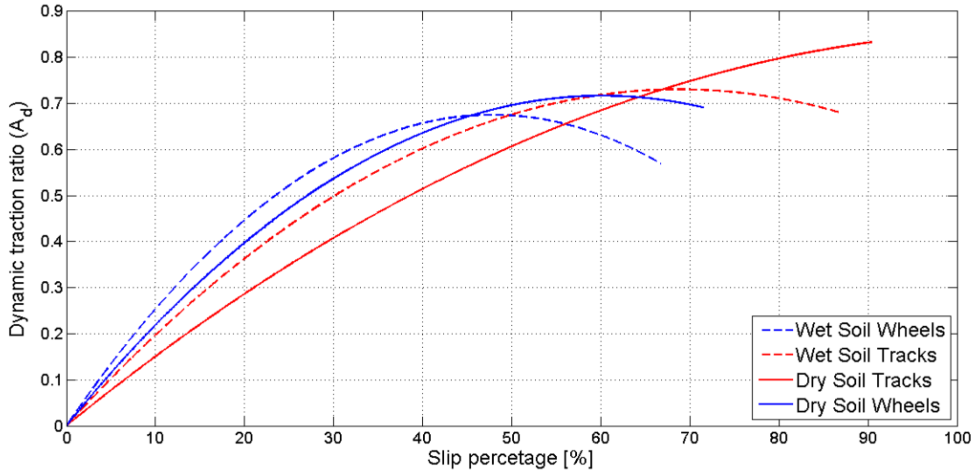

Figure 3.1: Relationship between Dynamic traction ratio and Slip percentage for the wheeled tractor (Wheels) and for the tracked tractor (Tracks) on both dry and wet soil

One can note that the tractor equipped with rubber tracks reaches higher values of A_d both on dry and wet soil. Moreover, the graph shows that with slip percentages under 65% for the dry soil and 45% for the wet soil, the wheeled tractor has higher A_d values than the tracked tractor. Regarding the soil compaction performances of the two traction systems, the Soil bulk density measured values are reported in Figure 3.2.

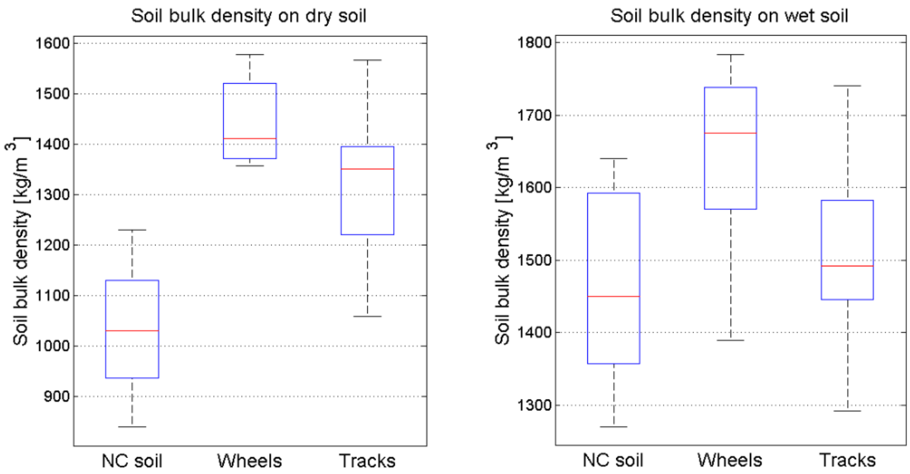

Figure 3.2: Soil bulk density values for the not compacted soil (NC soil) and after the passage of the wheeled (Wheels) and the tracked (Tracks) tractor.

The mean values of soil bulk density on dry soil measured after the passage of the wheeled and the tracked tractor are respectively 1410.81 kg/m3 and 1351.35 kg/m3, while on wet soil are respectively 1675.68 kg/m3 and 1491.89 kg/m3. Therefore, despite the tracked tractor is heavier, it shows less soil compaction than the wheeled tractor, especially in wet soil condition. The penetration resistance values obtained with the cone penetration test are showed in Figure 3.3

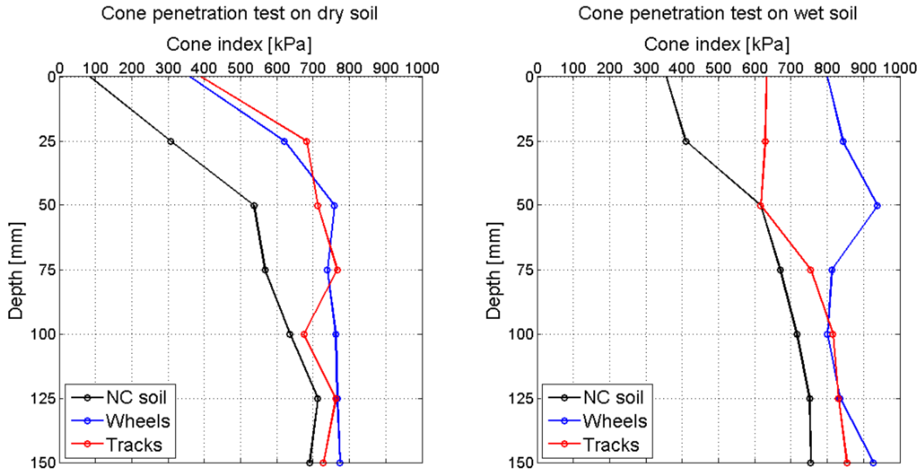

Figure 3.3: Cone penetration test for the not compacted soil (NC soil) and after the passage of the wheeled (Wheels) and the tracked (Tracks) tractor.

The diagram depicts that on dry soil there is not a significant difference between the values obtained with the two different traction systems. On the other hand, on wet soil in the depth range between 0 mm and 75 mm the tracked tractor shows lower penetration resistance values than the wheeled tractor.

4. Conclusion

In this paper, a comparison was made between the tractive and the soil compaction performances of a conventional wheeled tractor with the fully tracked version of the same model. The analysis of the results shows that the tracked tractor reaches higher values of the dynamic traction ratio both on dry and wet soil. Moreover, despite the tracked tractor is heavier, it has better soil compaction performances than the wheeled tractor, as shown by the soil bulk density and penetration resistance measured values.
The results introduced in this paper will be useful for the evaluation of the benefits in terms of tractive and soil compaction performances provided by a tractor fitted with rubber tracks. A further development of this work may be the execution of new field tests on different soil types.

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Worker's energy consumption during weed management

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Keywords: Oxygen consumption, heart rate, metabolic rate, occupational illness

Objectives

Weeds management, as well as any other agricultural practice, represents one the working sectors where professional accidents and diseases occurrence is significant. The existing regulatory obligations take into account the workers' welfare in a wide sense. Indeed, beside the traditional risk agents, a new attention is paid to the ergonomic aspects. Among the factors affecting the psychophysical workers' safety, the aerobic metabolism engendered while carrying out specific duties in agriculture and the stress that goes with it, constitute important aspects. Through the evaluation of some functional parameters of the human body, it is possible to determine how the individual reacts to physical stress to which he is subject. The present work focuses on this issue, and aims to evaluate the worker's energy consumption during weeding.

Methods

The experimental trials assessed two workers aged 28 years old in average, during weed management using a brush cutter (figure 1). The experimental sampling considered the determination of the metabolic rate by the measurement of the oxygen consumption rate at level 4 (expertise) according to UNI EN ISO 8996:2005 standard using the partial method advised for light and moderately heavy works as follows:

$$RQ = \frac{\dot{V}_{CO_2}}{\dot{V}_{O_2}}$$

$$EE = (0.23RQ + 0.77)5.88$$

$$M = EE \times \dot{V}_{O_2} \times \frac{1}{A_{Du}}$$

Where:

RQ is the respiratory quotient;
$\dot{V}O_2$ is the oxygen consumption rate, in litres of oxygen per hour;
$\dot{V}CO_2$ is the carbon dioxide production rate, in litres of carbon dioxide per hour;
EE is the energetic equivalent, in watt hours per litre of oxygen (W×h/l O_2);
M is the metabolic rate, in watts per square meter;
A_{Du} is the body surface area, in square meters, given by the Du Bois formula:

$$A_{Du} = 0,202 \times W_b^{0,425} \times H_b^{0,725}$$

In which:
W_b is the body weight, in kilograms;
H_b is the body height, in meters.

The measurements of functional parameters such as oxygen uptake ($\dot{V}O_2$), respiratory exchange ratio (RQ) and heart ratio (HR) were recorded in real time with a portable metabolimeter K4b^2 (COSMED).

As described in the previously mentioned standard, both of the steady state (or preliminary period) and the main period (of full activity) were monitored. The first one is reachable after 3 to 5 minutes, and indicates the period in which the work is carried out at a low intensity, while the second period lasts 10 minutes.

Figure 1: Functional parameter measurements in real time with the metabolimeter K4b^2 during weeding trials.

Results

Meteorological conditions recorded an average temperature of 27°C, a relative humidity HR of 54% and a barometric pressure of 744 mmHg. Data analysis highlighted that the amount of consumed oxygen (VO_2) during the whole period of trials, was equal to 48,04 ±25,23 $lO_2 \times h^{-1}$ in average. Considering the two monitored periods separately, this value corresponded to 43,38±20,82 $lO_2 \times h^{-1}$ in average for the steady state, and reached 54,18±26,82 $lO_2 \times h^{-1}$ during the main period.

Figure 2 reports VO_2 e VCO_2 trends over the time. Respiratory exchange ratio (RQ) mean value in the achieved trials was equal to 0,8 indicating that the work was realized in aerobic conditions without lactic acid production. The heart ratio (HR) mean corresponded to 98±17 bpm, while the highest value corresponded to 156±25 bpm.

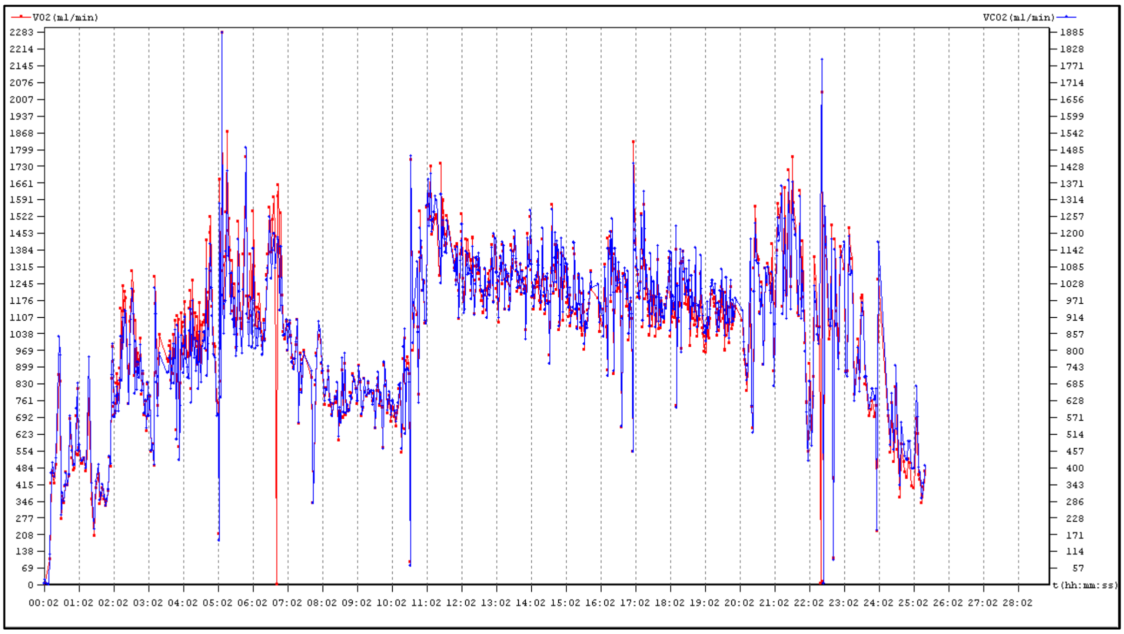

Figure 2. VO2 e VCO2 trends during weeding.

The determined metabolic rate mean value was equal to 143 W×m^{-2} (or 229 kcal×h^{-1}). According to the evaluation of the metabolic rate at level 1 (screening), such a value corresponds to gardener's duties, which lie in "agriculture" occupation category (method 1A). In addition, it refers to a "moderate" metabolic rate (Class 2) when considering the kind of activity (method 1B).

The results of the achieved trials were obtained in a comfortable working situation (mild temperatures, flat terrain, etc.) by operators with good health conditions. If, for example, weather conditions were harder (high or low temperatures), this agricultural practice would have been more difficult, due to the effort of the human body thermoregulation system to maintain the necessary thermal equilibrium.

In the recent years, the scientific studies and researches reached a noticeable progress to improve working conditions and support the constructors to realize machines and devices that are more adequate to prevent professional risks, and to preserve workers' safety and health in agriculture that should be considered according to a multidisciplinary approach including those factors that are often neglected.

Issues in ensuring the minimum safety requirement for in-use manure spreader: overview and preliminary results from the PROMOSIC project

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Keywords: Design for safety, Manure spreaders, Harmonized standards, Agricultural machineries

Summary
In-use manure spreaders are potential source of fatal and nonfatal accidents mainly due to the entanglement of operator because of inadequately shielded moving parts of the machinery (eg. rollers, conveyor belts, power transmission system). In order to guarantee the minimum safety requirements on in-use units, some measures of compliance to the last edition of harmonized safety standard (EN 690:2014) should be taken. Nevertheless, such measures could result difficult to implement or economically unaffordable. The aim of this study was to analyze the most suitable solutions to be adopted on in-use trailed manure spreader and to verify feasibility of such solutions ensuring minimum safety requirements in accordance to the most recent safety standards. Results confirmed that majority of the in-use manure spreaders would not comply with the most recent harmonized standard especially for what concerns protection against the risk of entanglement. Moreover, the study pointed out solutions to achieve required level of safety for operators verifying for some of them the effective technical feasibility and the economic impact.

1. Introduction
Entanglement in machines is one of the most common cause of injury associated with non-tractor agricultural machinery. In particular, some authors report that the majority of injuries occur when an individual became entangled in an inadequately shielded part of the machinery (Hartling et al., 1997).
According to international statistics (Gerberich et al., 1998; Tricot & Al-bassit, 2014; Chinniah, 2015) manure spreaders are a notable source of injury caused by entanglement. This kind of machines, typically used for transportation and application of manure on fields, can be responsible of accidents due to unintentional contact of operators' upper and lower limbs with moving parts such as the spreading devices (rollers), the conveyor belt, and the power transmission system. Accidents usually occurs during three different work phases documented as the most hazardous: cleaning, maintenance and unblocking (Al-bassit & Tricot, 2014). A number of authors remark that, beside the incorrect behavior of users, another important risk factor is the age of the machine (Baker et al. 2008; Kogler et al. 2014). Indeed, according to a study by Baker et al. (2008) the odds of injury increase by 4% for every year increase in the age of the machine, generally because older units are not equipped with the most up-to-date features according to safety standards (Fargnoli et al., 2010).
As regard to in-use manure spreaders, implementation of fundamental safety requirements is mainly regulated by the Machine Directive (Directive 2006/42/EC) and the Italian decree on Occupational Health and Safety (D. Lgs. 81/2008), in application of the European Framework Directive on Safety and Health at Work (Directive 89/391 EEC). With regard to this, the Machine Directive urges farm holders, manufacturers and suppliers of agricultural machineries to assess the conformity of their machines with national laws and safety requirement and to adapt them according specific harmonized standards provided by CEN (the European Committee for Standardization).

On the other hand, the commitment for users to ensure minimum safety requirements on existing machinery often represent a serious issue: most of the farm operators, being small and medium sized, are not able to bear additional costs due to the mechanical interventions on the machinery (Lorencowicz & Uziak, 2015; Narasimhan et al., 2010).
Based on these considerations the study aims at identifying appropriate solutions to eliminate and/or reduce risks due to contact, entanglement, dragging, cutting and crushing in agricultural and forestry machineries.
The specific objects of the study are: i) to analyze solutions to adopt on in-use trailed manure spreader to ensure safety requirements in accordance to the most recent safety standard EN 690+A1 and ii) to point out the main technical and economic issues in implementing the identified solutions.

2. Materials and Methods

The study was conducted in three main stages. The first stage consisted in examination of the most relevant regulations and standards related to manure spreaders and in the identification of major hazards and typical accidents. A deeper analysis focused on EN 690, the European harmonized standard specific for manure spreaders, that is the main reference to assess conformity to minimum safety requirements. Special attention was paid to the novelties introduced with the last edition of the standard, revised in 2014.
In the second stage of the study, a sample of manure spreaders in use on farms from Northwest Italy was examined. Following the standard requirements and updated sections, on-site measurements and pictures were collected in order to compare older units and to carry out a qualitative analysis. Thus, most significant technical intervention to achieve required safety requirements were identified. In doing this, most representative models of manure spreaders were selected: towed machine, equipped with a rear-spreading device with vertical rotors. The mean age of observed machinery was about 20 years.
In the third and final stage of the study, different individuals such as manufacturers, suppliers, users, mechanical workshops operators, were interviewed to point out major technical and economic obstacle in adopting the identified solutions.

3. Results and Discussion

Results of the qualitative analysis detail, for each respective section of EN 690 standard, the main technical features detected on in-use machines not complying with minimum safety requirements and summarize the key highlights gathered from interviews with users, manufactures, suppliers and mechanics. Solutions and most likely costs for adaptation to standards of in-use manure spreader are also discussed.
The investigation on the analyzed sample of in-use units confirmed that majority of the manure spreaders already present in farms would not comply with the most recent harmonized standard especially for what concerns protection against the risk of entanglement. Indeed, among inspected machines, in most cases: i) shearing and crushing points were not protected by proper safety shields; ii) safety distances and protective device dimensions did not comply with standard. These conditions were observed in different parts of machineries: for manual controls (particularly those intended for adjusting the speed of conveyors), at the front and rear turning points of conveyors with slats and for transmission shafts. In these cases the solutions proposed by safety standard consists in guarding with protective shields and plates any access to shearing and crushing points. Interviewed professionals confirmed the technical feasibility of this solution on in-use machines, even though some manufacturers complained about the restrictiveness of safety distances.
Additional solutions were deduced from standards and interviews to prevent or limit accidental contact with moving parts of the machineries. As regard spreading devices, a signaling system (acoustic or visual) should be provided to signalize when spreading device is working and machine is not advancing. This system consists in inductive proximity sensors fitted on wheels and rollers' transmission shaft and it is already present on the most recent models of spreaders. Although interviewed professionals did not perceived the signaling system as a performant

solution, all respondents reported the device could be quite easily installed also on in-use spreaders.
Another feature thought to prevent accidental contact with spreading devices is a hydraulically lifted back wall (guillotine or tilting door) between the load body and the roller. Technical feasibility of this solution is often related to transmission system and, as regard in-use manure spreaders, most of them are not equipped with a hydraulic system, for this reason it can results a more complex solution to actuate.
Finally, solutions to prevent operators to access in the load body during cleaning and maintenance phases were analyzed. In particular the presence of a free wheel could allow to run the rollers manually from outside the load body while the ladder dimensions should allow operator to control the interior of the spreader but not to enter in it. Indeed according to reports received by the farmers and manufacturers, many operators are accustomed to enter the load body for cleaning or maintenance (eg. oiling of conveyor chains).
As a result of the information provided by the interviews, a list of probable adjustment costs was obtained for some of the mentioned solutions. The integration of a hydraulically lifted back wall (guillotine or tilting door) would be the most expensive solution, with a minimal total cost of € 2.500. On the other hand, the cost of other suggested interventions would range from a minim of € 150 (eg. protective guards integration) to € 500 (eg. electrically powered signaling system).
In undertaking economic feasibility evaluation, it is important to compare these figures with the prices of new spreaders (ranging from € 15.000 to €50.000). Indeed a major critical issue identified by respondents is the relative low value of manure spreaders compared to other types of agricultural machineries.
Moreover the costs of most of the suggested interventions, considered economically affordable on in-use manure spreader, may vary according to the dimension of the specific machine and for peculiar intervention in which hydraulic drive system is needed.

4. Conclusion

This study, examined various technical features for reducing or eliminating risks related to entanglement for in-use manure spreader. The identified solutions were based on the observation of a number of case studies and on the qualitative analysis of the essential technical interventions needed to increase the intrinsic safety level of already existing machineries. The study confirms that most of required interventions on used manure spreaders are technically feasible with affordable costs by most companies. Nevertheless, complexity and costs of interventions increase with the age of the machine. In particular, some solutions proposed in harmonized standard resulted possible only on machines equipped with hydraulic drive system. In this case, technical implementation resulted very difficult to be applied on oldest units, since modification may be incompatible with mechanical components or structural parts. Moreover the adaptation to the current safety standard resulted economically not-convenient on smaller units, this kind of machines have become nearly obsolescent and have no market value but they are still very diffused in Italian small-medium sized farms.

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A laboratory test bench for nozzle spray droplet analysis

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Keywords: Pesticide application, Image analysis, Drop pulverisation

Summary
This paper presents a low cost laboratory test bench, designed and built at the Section of Mechanics and Mechanisation of the Department of Agricoltura, Alimentazione e Ambiente (Di3A) to analyse nozzle sprays according to the procedure established by ISO 5682-1. Moreover, spraying at the same time natural (fruits or leaves) or artificial targets (water sensitive papers – WSP), it allows studying the correlations between spray features, water sensitive paper surface coverage and spray deposit on the targets.
The test bench is made of a trolley with a 70 L tank, a diaphragm pump driven by a 230 V AC electric motor, a spray boom, pressure and flux transducers, and all the system control devices. The spray boom is applied to a mobile platform that moves along two rails parallel to the plane of the trolley, in such a way the distance between target and nozzle is 0.5 m. According to the procedure established by ISO 5682-1, the nozzle under test, while moving at a speed selectable in the range 0–1.5 m/s, sprays a test liquid above Petri dishes containing silicon oil of appropriate kinematic viscosity. The images of the drops trapped into the oil are acquired by using a high resolution (24 Mpixel) DSLR camera and then processed via image analysis software.
Preliminary tests have shown the functionality of the whole system and the capability of the image analysis system of detecting drops of minimum diameter of 6 μm.

1. Introduction
Spray deposit and superficial coverage are the most important factors affecting the efficacy of a phytosanitary treatment as well as the impact on the environment and the human health (Balsari *et al*., 2005; Friso *et al*., 2015). The measurement of the spray deposition usually requires a tracer to be added to the spray mixture (Pergher, 2001; Pascuzzi and Cerruto, 2015; Pascuzzi *et al*., 2016), whereas the assessment of the superficial coverage can be achieved by using artificial targets as Water Sensitive Papers (WSP) (Cunha *et al*., 2012; Salyani *et al*., 2013; Cerruto *et al*., 2013; Cerruto *et al*., 2016). Spray deposition and superficial coverage are affected by many factors, but probably spray spectrum is one of the most important ones (Matthews, 2004; Nuyttens *et al*., 2007; Hewitt, 2008). In fact, small droplets, due to their drifting inside the canopy, can reach the target more easily, but they are more subjected to evaporation, whereas large droplets, due to their mass, are more subjected to fall to the ground.
Hence the knowledge of droplet spectrum is a key point in assessing the quality of a pesticide application. Commercial drop size analysers are based on Laser Diffraction (LD) or Phase Doppler (PD) systems (Nuyttens *et al*., 2006), while custom made solutions are based on Digital Image Analysis (DIA) systems (Lad *et al*., 2011). This paper presents a low-cost laboratory test bench, built at the Section of Mechanics and Mechanisation of the Department of Agricoltura, Alimentazione e Ambiente (Di3A). It allows the characterisation of the nozzle sprays according to the procedure established by ISO 5682-1 (ISO, 1996).

2. The test bench
Figure 2.1 shows the whole test bench. It consists of a movable trolley carrying a 70 L tank, a diaphragm pump driven by a 230 V AC electric motor, and a spray boom carrying one multiple nozzle holder. The hydraulic circuit has two manually selectable lines, each with adjustable pressure: high pressure line (up to 3 MPa) and low pressure line (up to 0.6–0.7 MPa). Start and stop spraying sequences are managed by an electro-valve. In the upper part of the system, a

mobile platform carries the spray boom; the platform, supported by four wheels, moves along two rails 3 m long and 0.6 m spaced pulled by two parallel toothed belts.
Travel speed and acceleration and deceleration ramps of the mobile platform are closed-loop controlled by means of a 300 ppr rotary quadrature optical encoder, applied to a 240 W, 24 V DC brushed motor. Maximum speed for the mobile platform is 1.5 m/s. Fluid pressure at the nozzle end and flow rate are both measured in real-time by means of suitable transducers. In order to allow tuning the system parameters and managing spray trials, a suitable user interface that runs on a PC or on a Tablet has been designed and implemented. For sensors' data and speed measurement, specific real-time graphs are provided. The software allows saving all log data on a standard ASCII comma separated value file format that can be easily treated by any math software.

Figure 2.1: The whole test bench.

3. The image acquisition system

According to ISO 5682-1, the nozzle under test, while moving at constant speed, sprays the test liquid above three Petri dishes containing silicon oil. As test liquid we used clean water with the addition of the soluble colouring agent Poinceau Red. To eliminate the effects of vibration, Petri dishes were placed on a separate table, mechanically isolated from the trolley. The images of the drops trapped into the oil were acquired by using a high-resolution (24 Mpixel) DSLR camera equipped with a macro lens, suitably anchored to the trails in fixed positions with respect to the Petri dishes. Images were analysed using the *ImageJ* software that, after calibration with a known image, allowed measuring the spray drop diameters and then all the spray features.

4. Preliminary results

Preliminary tests were aimed at assessing the functionality of the mobile platform, pressure and flow rate transducers, as well as the capability of the image acquisition system. Figure 4.1 shows an example of real time graph recorded with sampling frequency of 8 Hz while spraying with an Albuz ATR 80 yellow nozzle (European colour code). Pressure and flow rate mean values were 1.15 MPa and 1.08 L/min, in accordance with manufacturer data (1.07 L/min at 1.1 MPa and 1.12 L/min at 1.2 MPa). Flux sensor provides volume values: flow rate was calculated in Excel considering a base time of 1 s. Small fluctuations around the mean pressure value are due to the pulsations of the pump, while fluctuations in flow rate are due to the shortness of the base time chosen for calculation. Figure 4.2 shows an example of an image acquired after a spray test. Due to the camera resolution (24 Mpixel) and the focal length of the macro lens, the system is capable of detecting drops of 6 μm in diameter.

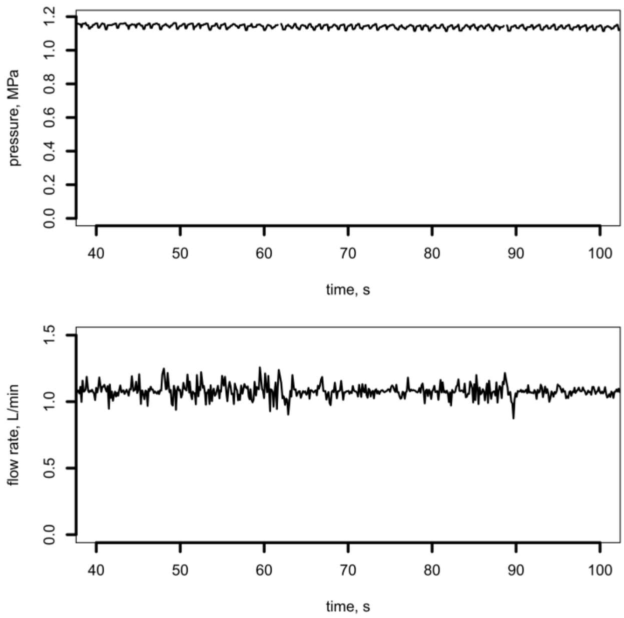

Figure 4.1: Real time pressure and flow rate values.

Figure 4.2: Example of drop image.

4. Conclusion and perspectives

The paper deals with the development of a low-cost laboratory test bench suitable to analyse nozzle sprays according to the ISO 5682-1 procedure. The measurement method is intrusive, but the strength of the system lies in its low cost. Preliminary tests have shown its usefulness under several aspects:

- The control system of the trajectory of the mobile platform ensures a constant speed while spraying over the Petri dishes.
- Transducers allow real time measuring of pressure and flow rate, so allowing correlating spray features and working nozzle parameters.
- The optical system allows detecting drops of about 6 μm in diameter: higher precision requires using higher resolution cameras.
- Future developments regard the optimization of the control command interface.

Experimental activity will be oriented to study correlations between spray features, superficial coverage on WSP and deposits on natural targets.

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Technical solutions for reducing the risk of roll-over while working under trees with an agricultural tractor

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Keywords: Roll-Over Protective Structures (ROPS), Self-deployable ROPS, low profile tractor, finite element method

Summary

In this paper, the results of an Italian National Institute for Insurance against Accidents at Work (Inail) research activity on reducing the risk of roll-over of agricultural tractors used under trees are presented. In particular, the following technical solutions are considered and described:

1. systems for reducing the activation force for manually bringing the foldable ROPS in safety configuration;
2. compact roll-over protective structures (CROPS);
3. self-deployable ROPS (autoROPS);
4. innovative low profile agricultural tractor.

A common methodology has been adopted for designing ROPSs and the devices, where present, installed for improve their mobility. This methodology is based on computer aided design (CAD), finite element analysis (FEA) and dynamic simulations (multibody technique).
Finally, the results achieved are presented and discussed, considering the possible future developments.

1. Introduction

The roll-over risk is the main risk related to the use of agricultural tractors. For this reason the presence and the use of roll-over protective structure (ROPS) and seat belt is compulsory, even for old manufactured tractors. Nowadays, many narrow-track wheeled and crawler agricultural and forestry tractors are equipped with two posts front mounted ROPSs. These kind of ROPSs are mainly of two different types: fixed or completely foldable. In Italy many agricultural and forestry tractors are equipped with the foldable type. The main reason lies on the necessity to work under trees and/or in greenhouses or similar environments, and a completely folded ROPS fulfils this necessity. However, from a safety point of view, the use of this kind of ROPS does not comply with the required safety level with respect to roll-over risk when in folded configuration. In Italy this situation leads to an important number of accidents per year, most of them fatal, which involves tractors used with a folded ROPS. Thus, as a first result of Inail research activity, the following technical solutions have been considered as achievable and able to reduce the risk of roll-over while working in specific narrow environment conditions (e.g. under trees, in greenhouses, etc.):

1. systems for reducing the activation force for bringing the foldable ROPS in safety configuration;
2. compact roll-over protective structures (CROPS);
3. self-deployable ROPS (autoROPS);
4. innovative low profile agricultural tractor.

2. Materials and Methods

Based on the experience acquired in the development of the Inail national guide lines for retro-fitting ROPSs on old agricultural and forestry tractors, the same materials and methodology have been applied in the design of ROPSs and relative devices herein presented. In particular, CAD and FEA software have been used for the virtual prototyping and the experimental test rig implemented in the Inail research centre of Monte Porzio Catone (Rome) has been used for validation. The validation of compact ROPS (CROPS) has been developed also in cooperation with the ROPS testing station of the University of Milan in Treviglio.

The methodology applied for each of the previous points consists in the following three steps:

1. design by means of a parametric CAD model of the structure fitted on a virtual model of narrow-track or tracklaying tractor. By means of reverse engineering approach, the main frame of the tractor is reproduced in a virtual environment. Thus, it is possible to verify potential interferences with structural elements of tractor (Figure 2.1);

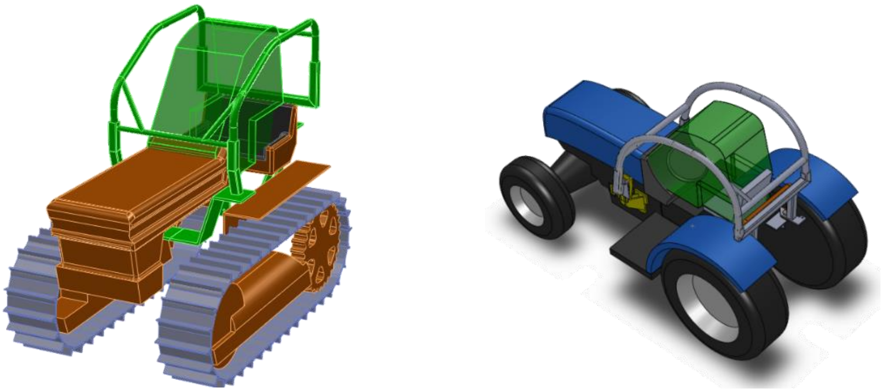

Figure 2.1: Reverse engineering and virtual prototype of ROPS

2. structural verification by means of finite element analyses (FEA) according to the applicable OECD code. The finite elements simulations are necessary in order to verify that the geometric solutions adopted are able to withstand the required forces and to absorb the proper energy as specified by the relevant OECD code (Figure 2.2);

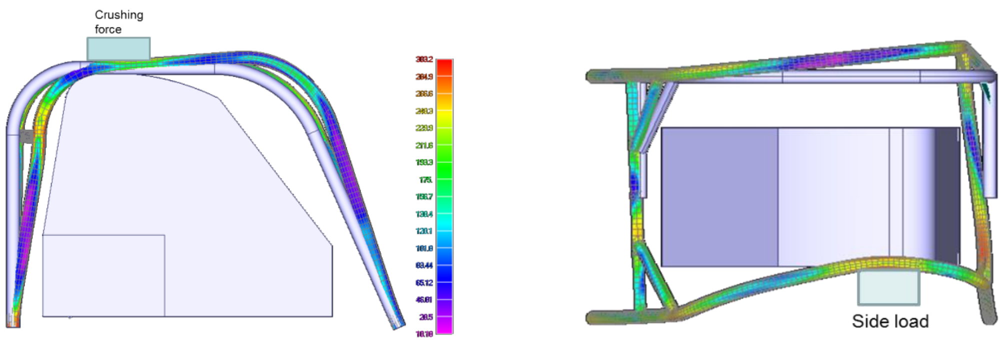

Figure 2.2: Example of FEA according to OECD code

3. kinematic and dynamic analyses. Where there are mobile portion of the structure (e.g. foldable or movable ROPS) it is necessary to analyse their motion, not only in terms of displacement, velocity and acceleration (kinematic), but also investigating the activation forces (dynamic) (Figure 2.3). In particular, the resultant activation forces shall be compliant with ergonomic principles defined in relevant international standards, as for example the OECD code 6 which defines a specific test procedure to ascertain the activation force of the moving 2-post front mounted roll-bars;

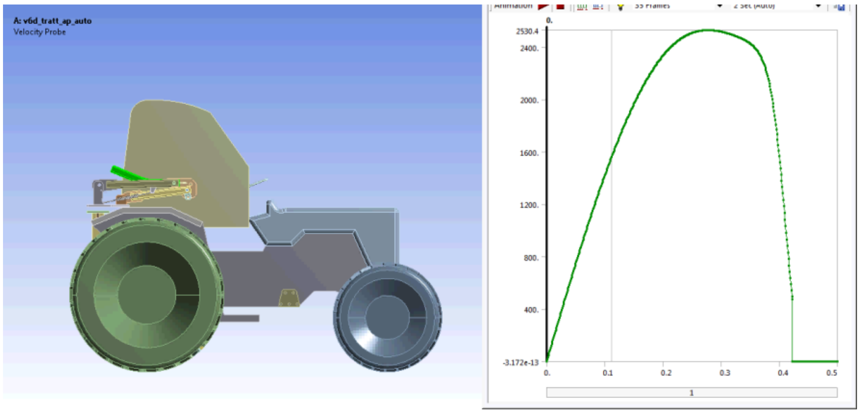

Figure 2.3: Example of kinematic analysis

4. experimental tests. Finally, the functionality of the structure it-self and of tractor fitted with it are investigated on specific test rigs by means of physical prototypes (Figure 2.4).

Figure 2.4: Example of experimental tests (on the left, courtesy of University of Milan in Treviglio)

3. Results and Discussion

For each of the objective, the results achieved by means of the research activity are:

1. *systems for reducing the activation force for bringing the foldable ROPS in safety configuration* – the design of specific devices (e.g. gas springs or helicoidal compression/traction springs) and kinematic structure of foldable ROPSs in order to reduce the effort for placing it in safety configuration. The information acquired will be useful in order to give the final users the opportunity to apply these systems to foldable ROPS realized in compliance with the information of Inail national guide line;
2. *compact roll-over protective structures (CROPS)* – the design of specific CROPSs and the inclusion into the Inail guide line of technical information and drawings necessary for realizing CROPSs and retro-fitting them on old manufactured tractors;
3. *self-deployable ROPS (autoROPS)* – the design of a four-bar linkage ROPS and a telescopic ROPS in order to verify the possible benefits of a self-deployable protective structure with an innovative kinematic design. The experimental tests necessary to validate the structures in infield working conditions are under development;
4. *innovative low profile agricultural tractor* - starting the analysis of an innovative compact narrow-track wheeled agricultural tractor in order to significantly reduce the overall height from the ground.

4. Conclusion

On the basis of the research activity's results, the proposed systems for reducing the activation force for moving foldable ROPS in safe configuration are feasible for ROPSs already compliant to Inail guide line, as an upgrade. However, that solution continues to rely on the attitude of the operator. For this reason, the main objective is to find solutions, which do not rely on operator, in order to increase the safety level with respect to roll-over without significantly reducing tractor's functionality. Thus, fixed CROPSs designed for old tractors seem to be the first step towards this direction. They are already applied with positive results for some specific kind of cultivation (e.g. vineyards, hazelnuts). Self-deployable ROPS, with specific shape and kinematic, and the design of a complete new compact tractor are the challenge for the next Inail research activity. The aim is to investigate their applicability in terms of reliability, functionality, costs and, of course, level of safety achieved.

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Contribution of the Self Protective Structures (SPS) to the driver's safety in case of combine harvester roll- or tip-over

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Keywords: combine-harvester, overturning, self-protective structure

Summary
Other than agricultural and forestry tractors, also for the Self-Propelled Machines (SPM) the risk of overturning cannot be excluded. For this reason, the self-levelling models of some categories of SPM have been available on the market for a long time; notwithstanding this, several fatal rollovers involving SPM still occur in Italy.
In some cases the features of some important components of the machine, defined Self Protective Structures (SPS), help to reduce significantly the driver's injury in case of roll- or tip-over. The various components of a traditional combine-harvester were considered, in order to ascertain their possible contribution as suitable SPS, considering the principle of "minimum requirements". More in detail, the grain tank of the machine was then considered as a case study, due to its large dimensions and fitting position on the main frame of the combine harvester. The minimum structural requirements of the grain tank were then defined (e.g. steel sheet thickness), as well as some shape ratios and distance between this component and the driver's place. After having ascertained the component as a suitable SPS, its contribution could be taken into account for the possible drafting of new Standards for the testing of ROPS to be fitted on SPM.

1. Introduction
The European Directive 2006/42/EC provides the minimisation of the risks to operators working with machinery. Of course, it must also be applied to Self-Propelled Machinery (SPM). One of the main risk when using SPM is their overturning, especially in case of travelling on slope and/or turning at the end of the field (Kogler et al., 2015): it is so necessary to adopt all possible countermeasures to reduce the risk level. The most common solution applied worldwide is the fitting of a Roll-Over Protective Structure (ROPS), providing a suitable protection in case of roll- or tip-over, of course if the driver remain inside of the safety zone, i.e. if he/she is secured with a safety belt properly fastened.
Altough ROPS fitted on agricultural and forestry tractors from many decades are tested and certified in accordance with validated Standards, (Cavallo et al., 2013), a similar approach is not still now adopted for SPM. Recently the problem was faced up thanks to the EN ISO 16231 standard, in particular under the point of view of the SPM stability requirements. In detail, for the combine harvester, altough self-levelling models are by time available on the market, the potential overturning risk is widely proven, especially when working on steep slopes. On the other hand, some manufacturers of other SPM have recently fitted a ROPS on models of self-propelled sprayers, grape harvesters, comb-side delivery rakes, etc. (Rondelli and Capacci, 2010), but at present no combine–harvesters manufacturer provided a ROPS on his machines. Indeed, the combine-harvesters are equipped by some basic parts of the machine assuring a certain level of protection in case of overturning, i.e. the grain tank for the side roll- or tip-over (Pessina and Facchinetti, 2016).
Coming back to the ROPS fitting, it must be noted that the most common standards applied for the ascertainment of their strength were been studied for agricultural and forestry tractors or earth-moving machinery, and therefore for many reasons they could not be completely suitable for the application to the SPM. As a consequence, there is an urgent need to draw up one (or more) dedicated standards, taking into account the design and technical characteristics of the combine harvesters, as well as their typical performance.

A recent survey carried out in Italy (Pessina and Facchinetti, 2016) pointed out that actually are sold about 150 combine harvesters per year, shared on a potential of more than 100 different models available on the market. Moreover, each model is offered in several versions, taking into account different optionals sometime considered as being quite important in terms of machine stability, such as tyres, steel or rubber tracks, oversized grain tanks, etc. In any case, due to the driver's place location, the proper fitting of a ROPS on the combine harvesters is possible only if significant modifications (i.e. reinforcements) of the main frame are preliminarily carried out.

1.1 The Self-Protective Structures (SPS)

In its first part, ISO 16231 introduces and defines SPSs as "*structural components of the machine with sufficient strength to provide a deflection limiting volume if the machine overturns*". Consequently, in 2013 INAIL (the italian National Institute for Insurance against Accidents at Work) considered necessary to go deep into the issue, verifying the SPSs mechanical characteristics and possibly to develop a test method (reliable and repeatable) for the assessment of defined minimum requirements.

With reference to combine harvesters, some so-called "hard points" can then identified, being them elements fitted on the machine in each configuration (i.e. also when the cutting bar or cutting head is removed), showing a proper structural strength in case of overturning.

The hard points are then used as a reference to draw the planes on which the machine would lie in case of overturning in the various directions (however not taking into account the elastic/plastic deformations probably occurring) (**fig. 1**).

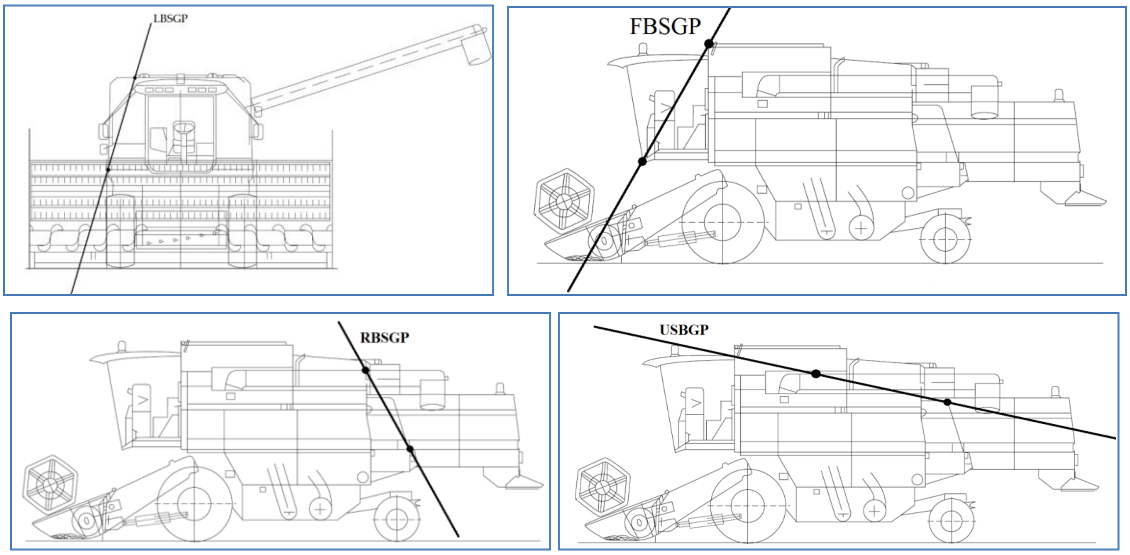

Fig. 1 – Lateral (LBSG), front (FBSG), rear (RBSG) and upper (UBSG) simulated ground planes, taking into account the combine harvester hard points (*courtesy INAIL*).

If carried out in a real mode, the strength test of the hard points would require the availability of the entire machine, or as an alternative at least of all its structural members. For combine harvesters, this cannot be reasonably practicable for several reasons, such as: the big size of the machine, inconsistent to the existing test bench performance; the remarkable costs of manufacturing, transporting, handling of the specimen to be tested; the limited availability of prototypes to be tested and (last but not least) the poor favour of the manufacturers to develop a complicated procedure resulting into potentially unreliable data.

2. Materials and method

At a first step, the principle of "minimum requirements" was established, being that the base on which establish an element as eligible SPS. In this regard, a case study was investigated, i.e. the grain tank of a traditional combine harvester. In fact, due to its design and manufacturing features, this component plays a quite important role in the overall machine resistance in case of side and rear overrun (but much less in the front direction, due to the usual location of the driver's place). The grain tank features of a top range combine harvester of a leading Italian manufacturer was then examined in detail, under the points of view of its dimension, strength of the carcass and attachment modes to the chassis of the machine, taking into account also the steel sheet thickness and quality and the fixing bolts diameter and quality. Considering the normal combine harvester mass distribution, and consequently the most frequent overturning type (side-rear), also the dimensions and the location of the grain tank and that of the driver's cab were compared.

3. Results and discussion

In **tab. 1** the main technical features of the examined combine harvester are reported, while in **fig. 2** the main dimensional and strength data of its grain tank are shown.

On the basis of this set of information, in **tab. 2** are indicated some minimum requirements of the grain tank to be considered as eligible SPS. If this check is positive, the SPS could then be properly tested in order to ascertain its maximum strength in case of overturning. In this view, a virtual test using CAD, FEM and subsequent dynamic analysis (e.g. using Ansys software) could be considered the most appropriate solution, in order to calculate the amount of energy absorbed by the SPS in case of roll- or tip-over. To fully ascertain the SPS contribution for the driver's protection in case of overturning, load simulations should not limited to determine whether a given SPS can absorb a given energy, but should be driven up to the limit of SPS collapse, in order to fully ascertain the total amount of energy absorbed (**fig. 3**). As a consequence, the testing of a ROPS fitted on a SPM could (fully or partially) take into account the SPSs contribution, through a decrease of the energy to be absorbed by the ROPS.

Tab. 1 - Main technical features of the combine harvester studied.

Mass	
in running order, without cutting head and empty grain tank	16,990 kg
in running order, with 9 m width cutting head and empty grain tank	20,070 kg
grain tank capacity (without extensions)	9.5 m³
in running order, with cutting head and full grain tankl (maize density: 740 kg/m³)	27,100 kg
Dimension	
Overall length, width, height (without cutting head)	9.24 x 3.30 x 4.56 m
Wheelbase	3.86 m
Height of the grain tank	3.99 m
Tyre	
Front	800/65 R32 STR
Rear	500/60 - 22.5 10 p.r.

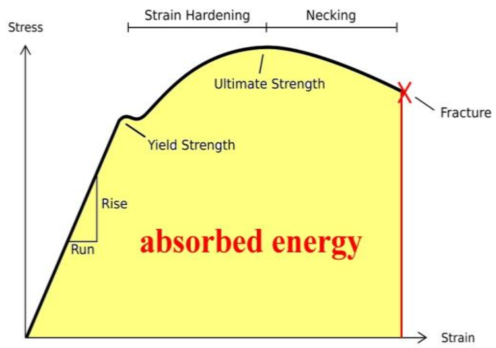

Fig. 3 - Typical stress-strain behviour of a steel structure.

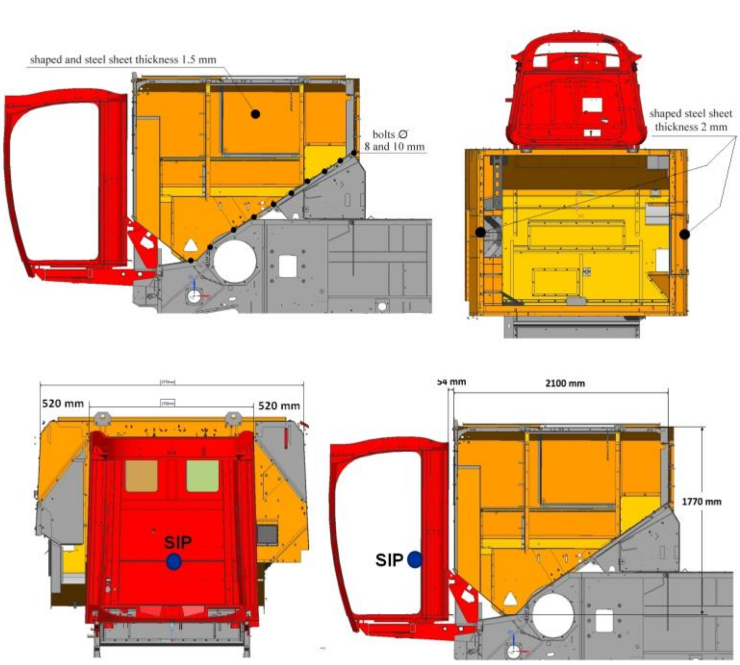

Fig. 2 - Main strength (top) and dimensional (bottom) data of the studied grain tank.

4. Conclusion

Due to the several machine categories and the considerable differences between the models offered on the market within the single category, the driver's protection in case of overturning of the SPM (including the combine harvesters) is quite difficult to be properly assured.

SPSs play an important role for the protection in case of roll- or tip- over, but their contribution must be carefully assessed and evaluated, by adopting validated methods. On the other hand, the real SPSs tests are very difficult to be carried out, and are likely to yield random results (e.g, due to the various fixing modes to the test bench). Computer simulation is a viable alternative, but to be reliable and repeatable it has to be carefully regulated. As a consequence, the need to develop ROPS test procedures specifically dedicated to each category of SPM is still urgent. A useful example to be followed could be the ISO 3471 standard, which provides different loads for a wide range of earth-moving machines.

Table 2 - Minimum requirements of the grain tank of a combine harvester as eligible SPS.

Steel sheet minimum tickness	1.5 mm
Minimum diameter and grade of the fixing bolts to the machine structure	8 mm - 8.8
Grain tank capacity	f (machine mass)
Shape ratios (length/width; length/height; width/height)	f (capacity)
etc…	

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Energy efficiency of narrow tractors used in wine and fruit cultivations

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Keywords:

Summary
Over the last years many national and international organisations have defined methods for the saving of energy in labour operations and for the resulting reduction of the environmental impact. Also in the agricultural mechanisation sector, some attempts have been made to calculate some Energy Efficiency Indexes (EEI), such as the "Powermix" from DLG (Germany). Starting from the results of the application of its Code 2, also the OECD (Organisation for Economic Co-operation and Development) is working for the definition of one or more EEI(s). The main goal of this paper is the implementation of these EEIs, concerning in particular the narrow tractors for wine and fruit cultivation, starting from a detailed analysis of the working conditions and the frequency and duration of the operations. The experimental data will be considered for creating different operating cycles, taking into account the real vineyard and orchard working conditions of the main agricultural operations carried out, highlighting as a final goal the suitability of the tractors for different tasks and usage intensity, both in terms of engine load and working time.

1. Introduction

Due to the increasing cost of energy and the need to reduce the environmental impact, over the last years studies and researches on energy saving have increased remarkably at a worldwide level, also in the agricultural sector.

In literature, many studies on tractors usage in defined open field conditions can be found. In particular, thanks to the continuous technological innovation and the enhancing of electronics, data collection has become much more practicable and widely applicable (Bietresato et al., 2015). Lindgren (2004) studied numerous field operations, adopting CAN-bus and exhaust gases analyser, with the aim of understanding the behaviour of the tractor engine while working on field and of predicting fuel consumption and related exhaust gas emissions. Similarly, Janulevičius et al. (2013) assessed exhaust gas emissions in different working conditions, in order to identify specific emission values and to understand when and how they show variations. Additionally, Pitla et al. (2016) studied field operations in US and linked the engine features to work states on fields by means of GPS instrumentation, which allowed for understanding where and to what are due on field the best and worst fuel consumption rates. With a similar view, in a given field operation also Bacenetti et al. (2017) studied engine features, fuel consumption and exhaust gas emissions in different work states (i.e. effective work, turning and stationary idling conditions), introducing the possibility of enhancing the environmental impacts assessment. Moreover, Perozzi et al. (2016) studied the idling conditions of a tractor along its life span, with the aim of understanding the effect on consumption and energy efficiency of the fuel in idling conditions, which are often underestimated.

In view of this increased interest, not only the scientific community started focusing on the relationship of agricultural machinery operations and energy use efficiency, but also many national and international organisations have been defining methods to calculate Energy Efficiency Indexes (EEI). Among these, DLG (German Agricultural Society) (http://www.dlg.org/home-en.html) decided to investigate the real EEI of agricultural tractors used in open field with its "Powermix": in practice, this means that the most common field conditions are simulated on track and on road through 12 standardised operating cycles, in order to gather information on features such as absorbed power and fuel consumption. Similarly, also OECD (Organisation for Economic Co-operation and Development) is working on the

definition of one or more EEI(s) by deepening knowledge on fuel consumption values obtained from the application of Code 2 (performance test).
In any case, all these EEIs do not concern the narrow tractors used in wine and fruit production processes, which play, instead, a quite important role on Italian cultivating conditions. In particular, vineyard and orchard are very diffused and so narrow track tractors are very popular in Italy, but in this case the open field work conditions and the connected EEIs are not applicable. Also, because some Italian manufacturer are market leader of this type of tractor, specific EEIs could be profitably developed. Therefore, the main goal of this research is the definition of EEIs suitable for narrow tractors used in grape and fruit cultivations.

2. Materials and Method

To define suitable EEIs for tractor used in vineyards and orchards, the study started from a detailed analysis of the working conditions and the frequency and duration of the operations.
Various parameters have been considered, such as travelling and engine speed, hydraulic and PTO power usage, task time duration, etc. The data were obtained in terms of measuring torque, engine speed, etc. by means of several transducers (torque meter, load cells, encoders, angular velocity sensors, etc). The experimental data have to be considered for the creation of some different operating cycles, taking into account the real vineyard and orchard working conditions of the main agricultural operations, as follows: pre-pruning; shoot removing; trimming; fertiliser spreading; leaf-stripping; shredding; traditional spraying; pneumatic spraying; dusting; grape harvesting.
In detail, the PTO power was measured thanks to a torque metre and a contactless angular velocity sensor, connected to a CPU unit with a real-time recording module, at a frequency rate of 10 Hz (**fig. 1**). The hydraulic power requirements were obtained by the statements of the single tractor (and/or implement) provided by manufacturer, on the basis of the expected values of oil flow under pressure (from technical specimen). In order to define the PTO and hydraulic power absorbed and the engine speed settled in each operation considered, a preliminar smoothing of the recorded field data was carried out, highlighting the relevant average values in the different tasks of the single operation (**fig. 2**). For each operation, the data were collected for a time duration of about 12 min.

Fig. 1 - The torque meter used for the PTO power recording.

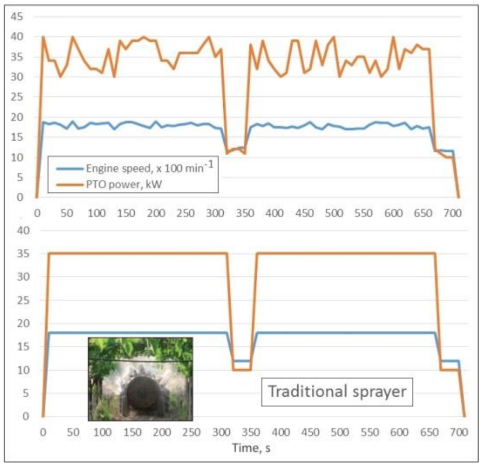

Fig. 2 - Example of preliminar smoothing of the recorded field data.

3. Results and Discussion

In **fig. 3** the power requirement of each single operation considered is shown, as well as the engine speed.

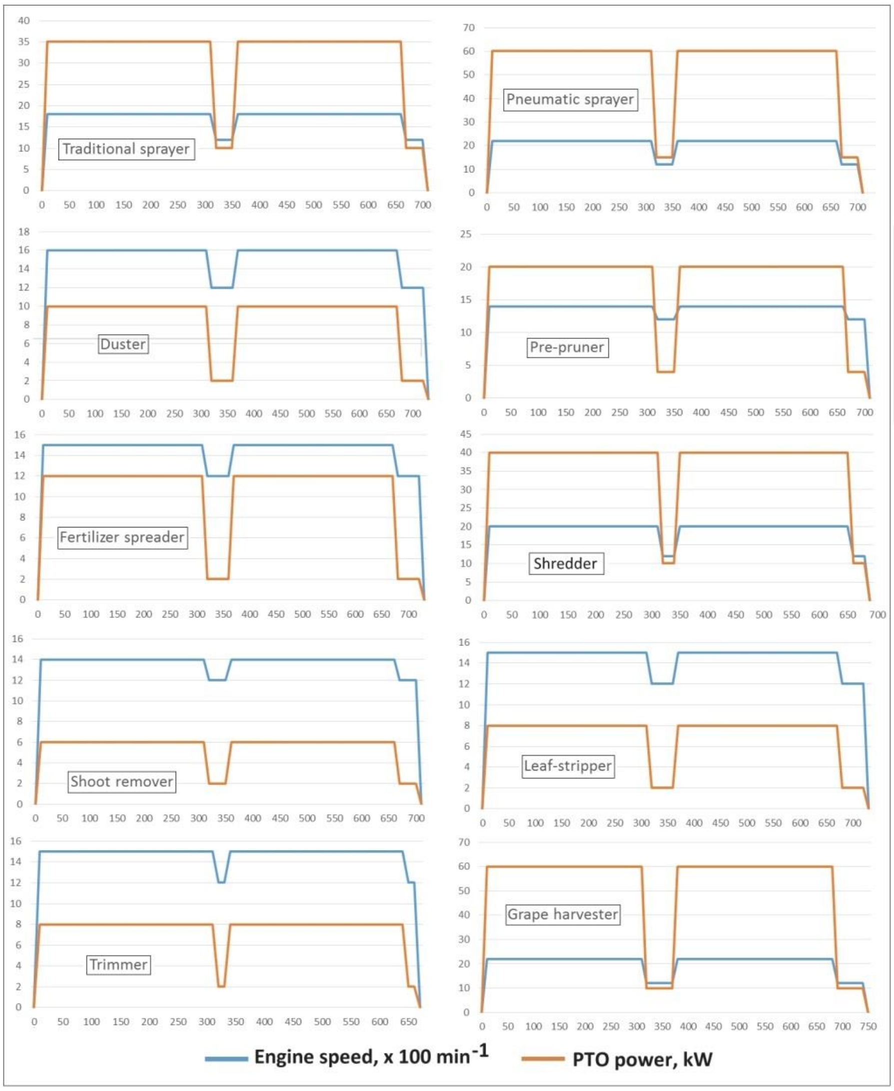

Fig. 3 - Power requirement and engine speed of the operations considered.

The following remarks can be made:

- among those investigated, the spraying, the shredding and the grape harvesting were the 3 operations requiring a high amount of power,. In particular, the sprayers were one mechanical (but having two counter-rotating fans ∅ 700 mm) and the other pneumatic. The sprayers and the shredder were moved mainly through the PTO, while the grape harvester required power both through the PTO and the hydraulic pump of the tractor;
- all the other operations required a low power, mainly delivered through the tractor hydraulic pump. In particular, the shoot removing, the leaf stripping and the trimming absorbed less than 8 kW;
- to obtain a comparable working capacity (at similar engine speed), the pneumatic sprayer is requiring about 70% more power than the traditional (fan and nozzles) sprayer;
- the operations requiring high power were carried out with the engine settled at about 2000 min^{-1}, while for those absorbing low power the engine speed were maintained at about 1500 min^{-1}. Apart the speed, also the engine load (i.e. the throttle position, and as a consequence the fuel delivery) was changed, affecting both the hourly and the specific fuel consumption.

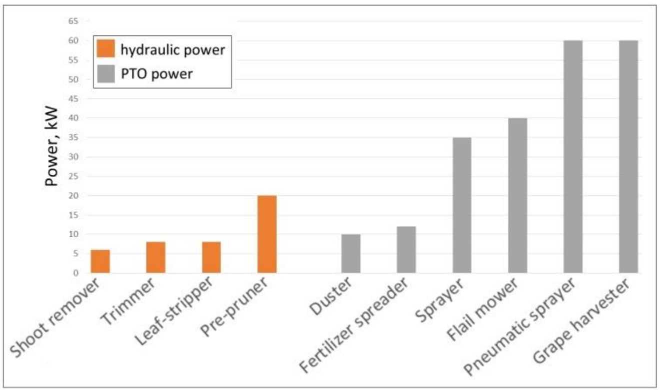

Fig. 4 - Detail of power requirements of the investigated operations

In **fig. 4** a comparison among the power requirements of the investigated operations is shown. High PTO power is delivered for the running of the grape harvester and the pneumatic sprayer, while a high need of hydraulic power was recorded for the pruner. This could represent a critical point, because the modern narrow tractors show an excellent capacity to transfer high power through the PTO, but sometimes they are equipped with a hydraulic system showing a flow capacity not always sufficient to feed properly all the applications requiring oil under pressure.

4. Conclusion

The data shown in this paper are finalised to define not only just one but some EEIs, showing the suitability of the narrow tractors for different operations and usage intensity, both in terms of engine load and working time. As a final goal, a dedicated software will be created, able to predict the energy cost of an operation, referring to its execution using a given tractor and under defined working conditions.

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Updated LCIA computation of an agricultural tractor based on open-access datasets

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Keywords: Agricultural Machinery, Life Cycle Inventory, Carbon Footprint, Fossil Energy

Summary
Life cycle assessment and the related computational frameworks are even more important tools in agricultural engineering to assess, to evaluate, to revise and to improve agricultural processes on the base of their environmental load. The free availability of proper, detailed and reliable life cycle datasets to perform these investigations is a crucial aspect. In the present work an updated Life Cycle Impact Assessment (LCIA) of an agricultural tractor has been performed with the aim to show how computation may be entirely based on fully open-access databases and analysis software. Life Cycle Inventory data (LCI) of the agricultural tractor during its lifetime, have been taken from the life cycle inventory database Agribalise®. This database does not provide data for the background processes, thus two further LCI databases, i.e. the European ELCD and the USLCI, were fitted to the foreground system. The LCIA computation was performed according to the ILCD 2011 impact assessment methods package. All the used databases were imported into openLCA, a free and open source software. The functional unit (FU) was "one kilogram of tractor during its entire lifetime". Focusing on the two main impact indicators, global warming potential (GWP, kgCO2eq/FU) and fossil energy demand (FED, MJ/FU), the tractor impacts were 7.29kgCO2eq and 134MJ. For GWP, the production stage accounts for about 44%, the maintenance about 44%, the repair stage about 12%. For FED, the production stage accounts for about 36%, the maintenance about 53%, the repair stage about 10%. The overall process main direct contribution to GWP was electricity use (1.68kgCO2eq), and synthetic rubber for tires (production and maintenance) in the case of FED (about 42MJ).

1. Introduction
Often indicated as "cradle to grave" analysis, Life Cycle Assessment (LCA) provides a device for analytically evaluating the environmental burdens associated to products or processes, and driving their development strategies also in view of the impacts of raw materials selection and/or maintenance and the end-of-product-life different pathways. Of course, LCA has a great potential to face environmental issues related to goods and services, and it is of growing importance also in the agri-food sector. The International Organization for Standardization (ISO) published a standard series (ISO 14000) where the LCA arrangement is structured in detail. In particular, the ISO 14040:2006 gives a broad standard to perform a meaningful LCA study. Nevertheless, LCA is very often still seen as prohibitively tedious and above all expensive, being based on complex and paid data banks and analytical tools. This is especially true for practitioners, small and medium enterprises, as well as young scientist who have to deal with the LCA topic with limited resources. Across these subject there is a lack of knowledge about the open-access availability of LCA data (both life cycle inventory data, LCI, and life cycle impact assessment data, LCIA) and analytical tools that can be fitted to perform a full or at least a simplified life cycle study. In this contest, one of the most interesting initiatives is probably openLCA Nexus, recently developed by GreenDelta (an independent sustainability consulting and software company founded in 2004, Berlin-Germany). It comes as a data repository and hub for life cycle and sustainability data, providing both pay data and open-access free data. Furthermore, the open source LCA software openLCA is supported. The aim of this work is to show how some open-access LCA data sources can be suitably fitted to

perform a LCA study. The agricultural tractor is a nodal means of production of several agricultural processes. In the present work an updated LCIA computation of an agricultural tractor has been performed. Computation was entirely based on fully free available databases and analysis software.

2. Materials and Methods

LCI data of an agricultural tractor during its lifetime (10000 hours), comprehensive of production, maintenance and repair stages, have been taken from the free available life cycle inventory database Agribalise® (version 1.2, year 2013) (Koch and Salou, 2016). This database provides 136 LCI datasets for arable, horticultural and livestock products. The database does not provide data for the background processes, thus the free available European ELCD life cycle database (version 3.2, year 2015) was fitted to the foreground system. Processes that are not present in the ELCD have been taken and adapted from the US-NREL life cycle database. The LCIA computation was performed according to the free available database of ILCD 2011 impact assessment methods package, as developed by Joint Research Centre (JRC) of the European Commission. All the used databases were imported into openLCA, a free and open source software for modelling the life cycle of things. The functional unit (FU) used in the study was "one kilogram of tractor during its entire lifetime".

3. Results and Discussion

The life cycle study has been entirely based on open-access data. The procedure is summarized below, step by step:

1. The openLCA software has been downloaded from http://www.openlca.org/download/, then it was installed on a common PC running Microsoft Windows 10 Pro (compatibility of versions has to be checked)
2. The LCI database Agribalise® (version 1.2, year 2013) has been downloaded from https://nexus.openlca.org/database/Agribalyse, then it was imported into the software
3. The LCI database ELCD (version 3.2, year 2015) has been downloaded from https://nexus.openlca.org/database/ELCD, then it was imported into the software
4. Unit processes that were missing in the ELCD have been taken from US-NREL life cycle database (available at https://uslci.lcacommons.gov/uslci/search) and manually created in the software paying attention to proper mapping and cross-linking
5. The openLCA LCIA methods package (v.1.5.6) has been downloaded from https://nexus.openlca.org/database/openLCA%20LCIA%20methods, then it was imported into the software
6. A proper and detailed mapping between flows of ELCD unit processes and that of Agribalise® was done, as well as against the LCIA database.

Once completed the above procedure, the process named "Tractor, LT 10000h" was selected from the Agribalise® database. According to Koch and Salou (2016) the database comprises LCI data sets of 191 machines which were derived by parameterization, based on weight and life time, of "agricultural machinery" LCI data sets of ecoinvent v2.0. The selected tractor process includes a lot of entries belonging to four life cycle stages/action, i.e. production, maintenance, repair and waste management. These stages were not discriminated for the purpose of computation in the original structure of the process. Thus, to highlight and to weigh each contribution, the original process has been split in to four sub-processes, namely "tractor maintenance stage", "tractor production stage", "tractor repair stage" and "tractor waste management". These sub-processes were scaled and parameterized adding up the final process named "Farm tractor during its life time", whose functional unit was "one kilogram of tractor during its entire lifetime". Figure 3.1 gives a schematic representation of the built model.

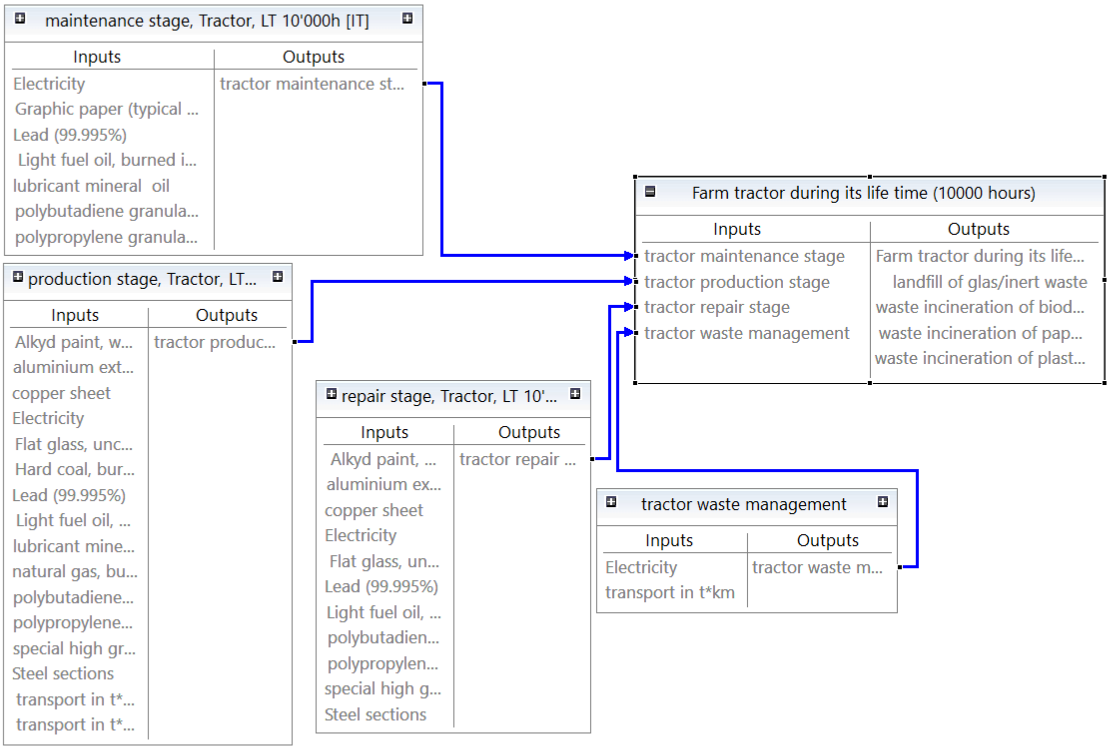

Figure 3.1: Graphical representation of the tractor LCA model

Table 3.1 gives the main LCIA results according to the ILCD 2011 impact assessment methods. Each indicator refers to the functional unit (FU) "one kilogram of tractor during its entire lifetime". The amount of FU which may be ascribed to a specific process performed by the tractor, can be computed by multiplying the weight of the considered tractor by the operation time (i.e. how long the tractor is used for the process) and dividing the result by the lifetime of the tractor. It should be noted that the impacts of table 3.1 are consistent under the assumed life time of 10000 hours. In fact, the life time has no effect on emissions during manufacture and disposal of the tractor, but does determine emissions during maintenance and repair. Thus, if a different life time is assumed, the model has to be rebuilt. The Agribalise® database also provide parameterized processes for 7500, and 12000 hours tractor life time. Among impacts reported in Table 3.1, focus could be placed on the most widespread and referenced indicator global warming potential (GWP, kgCO_2eq/FU), along with the fossil energy demand (FED, MJ/FU) which accounts for about 134MJ/FU.

Table 3.1: LCIA results of an agricultural tractor during its entire lifetime (10000 hours)

n°	Impact category	Result (amount/FU)	Reference unit
1	Acidification	2.65E-02	Mole H+ eq.
2	Climate change	7.29E+00	kg CO2 eq.
3	Freshwater ecotoxicity	1.13E+00	CTUe
4	Freshwater eutrophication	1.89E-05	kg P eq.
5	Human toxicity - carcinogenics	1.80E-08	CTUh
6	Human toxicity - non-carcinogenics	4.74E-07	CTUh
7	Ionizing radiation - ecosystems	2.58E-06	CTUe
8	Ionizing radiaton - human health	1.63E-01	kg U235 eq.
9	Land use	6.60E-03	kg SOC
10	Marine eutrophication	4.30E-03	kg N eq.
11	Ozone depletion	1.49E-07	kg CFC-11 eq.
12	Particulate matter/Respiratory inorganics	1.37E-03	kg PM2.5 eq.

13	Photochemical ozone formation	3.23E-02	kg C2H4 eq.
14	Resource depletion - mineral, fossils and renewables	1.30E-04	kg Sb eq.
15	Resource depletion - water	1.30E+00	m3
16	Terrestrial eutrophication	4.70E-02	Mole N eq.

Reliability of these results could be checked by comparing literature data, but reports on this topic are rather limited. One possible benchmark is the computation of the same impact indicators by using ecoinvent LCI database (v.2) fitted to SimaPro software, i.e. one of the most used LCA software programs globally. This latter computation gives a GWP of 8.62 kg CO2 eq against 7.29 kg CO2eq of the present study, with a percentage deviation of about 15%. Fossil energy demand from SimaPro was 111 MJ/FU against 134 MJ/FU of the present study (percentage deviation of about 20%). Audsley (1998), gives 112.64 MJ/FU and 8.57 kg CO2eq referred to a 4WD tractor for FED and GWP, respectively. These values are closed to those of SimaPro. From Lee et al. (2000), 76.7 MJ/FU and 4.76 kg CO2eq referred to a small size 2WD tractor, can be extrapolated. These values are far from those of this study and previously reported literature. Some final considerations can be drawn on the processes contribution to impacts. For GWP, the production stage accounts for about 44%, the maintenance about 44%, the repair stage and disposal about 12%. For FED, the production stage accounts for about 36%, the maintenance about 53%, the repair and disposal about 10%. The overall process main direct contribution to GWP was electricity use (1.68kgCO_2eq), and synthetic rubber for tires (production and maintenance) in the case of FED (about 42MJ).

4. Conclusion

The work gives guidelines on how to make a LCA study by exploiting full open-access resources. The results obtained for an agricultural tractor are fully consistent with literature data.

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Durability design criteria for agricultural powershift transmissions

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Keywords: agricultural tractors, transmission, durability, duty cycle.

Summary
Over the last decade, tractor manufactures are trying to reduce as much as possible the specific tractor weight in order to reduce material cost, increase payload, and tractor efficiency for less demanding operations. Thus, designing lightweight components is getting more and more important even in the agricultural machinery industry where durability, reliability and product diversification are strategies for increasing the market share. Designing lightweight components requires a detailed knowledge of service loads in terms of expected maximum load amplitudes and their occurrences throughout machine life. Recently, autonomous data-loggers were used to monitor vehicle operating parameters during real customer usage in order to acquire the most common operating conditions. The aim of this study was the definition of a method to analyse data from a fleet of machines in order to set durability targets for power-shift transmissions.
An onboard data-logger able to acquire and store the tractor working parameters was installed on a fleet of 181 tractors of different rated engine power. Tractors were located in different countries and each one was used for a year. Engine and transmission operating parameters were acquired and from them, the damage per hour of each gearwheel was calculated through the inverse-power law. Data was then statistically analysed in order to extrapolate the most severe usage pattern, through the calculation of the joint frequency matrix. The data analysis reveals high variability in customer usage especially in terms of relative frequency of used gear ratios. Moreover, on heavy tillage work, engine torque is highly variable due to soil variability, but the average engine torque is limited to the 75% of the maximum. Through this methodology, tractor manufactures can design lighter transmission components and match customer expectations.

1. Introduction

Tractor manufacturers must reduce production costs to be globally competitive. Thus, they are trying to reduce as much as they can the specific weight of their tractors in order to reduce material cost, increase payload, and tractor efficiency especially for less demanding operations (such as implement transportation, haying, etc). Nevertheless, material saving can impair machine durability if the material cannot withstand the stress occurring on service (Strutt & Hall, 2003). On service, customers may change tractor configuration (i.e. mass and its distribution between the two axles, wheel radius, etc.), working operation (i.e. implement width, operating speed and depth, etc.) and machine set up. These may significantly affect service loads and therefore a large load variability may be encountered between different tractor samples (Kim, Ryu, & Kim, 2001; Lee, Pan, Hathaway, & Barkley, 2005; M. Mattetti, Molari, & Sereni, 2017). For these reasons, service loads have to be recorded on a different machines in order to faithfully cover all the realistic conditions. Then, the most damaging one can be extrapolated through appropriate statistical methods (Dressler, Gründer, Hack, & Köttingen, 1996) which can be used to design accelerated tests (Michele Mattetti, Molari, & Sedoni, 2012). Extrapolation methods are based on the load modeling through parametric and non-parametric methods. These methods requires a large number of observations, otherwise the estimation might be poor, consequently the larger is the fleet of monitored vehicles, the more precise will be the results from the extrapolation (Johannesson & Thomas, 2001). With the widespread integration of CAN-Bus and ISOBUS into agricultural machines, tractor operating parameters can be easily acquired with CAN-Bus data loggers (Molari, Mattetti, Perozzi, & Sereni, 2013). These parameters were used to estimate the length of the tractor inactivities during its lifetime

(Perozzi, Mattetti, Molari, & Sereni, 2016) and tractor operating efficiency (Pitla, Lin, Shearer, & Luck, 2014).

The aim of this study was the definition of a method to analyse data from a fleet of machines in order to set durability targets for power-shift transmissions.

2. Materials and Methods

The methodology was applied on a family of 4WD tractors, equipped with a power-shift transmission with 19 forward gears and 4 rearward gears. A sample of 181 tractors located in different countries was selected using the stratified sampling approach. Each tractor was used for a year in a farm so that data is acquired under real working conditions. On each machine, a CAN-BUS data logger (Vector CANcaseXL log, Stuttgart, Germany) was installed to acquire vehicle bus data. Especially, the following signals were recorded: engaged gear, primary-shaft speed and torque and vehicle speed. For each tractor, the primary-shaft torque signals were reported as percentage with respect to the maximum engine torque; thus, data from different tractors could be analysed together. Combining the engaged gear, primary-shaft torque and speed signals, a three-dimensional time at level counting procedure was carried out (Johannesson & Speckert, 2013), so that, for each gear ratio, a joint frequency matrix between primary-shaft torque and speed was obtained. The occurrences of each matrix were indicated in relative frequency. Thus, the most frequent operating point of each gear was derived. From each matrix, the equivalent torque with a damage exponent equal to 4, the average speed and the relative frequency of occurrences of each gear were calculated.

3. Results and Discussion

A typical form of the joint frequency matrix, for a gear in the medium range, is shown in Figure 3.1. One can note that tractors during real operations are run in any operating point as almost all the occurrences of the matrix cells are higher than 0. Only, the cells located at the corners on top register no occurrences as the engine cannot produce high torque at the two extreme operating speeds. Tractors, on the 10^{th} forward gear, are mostly used around the speed where the engine generates the maximum power that is at 2000rpm, so that field productivity is maximised. Moreover, in the same gear, tractors are run most of the time at full load, where the engine can generate, on steady conditions, only the 78% of the maximum engine torque.

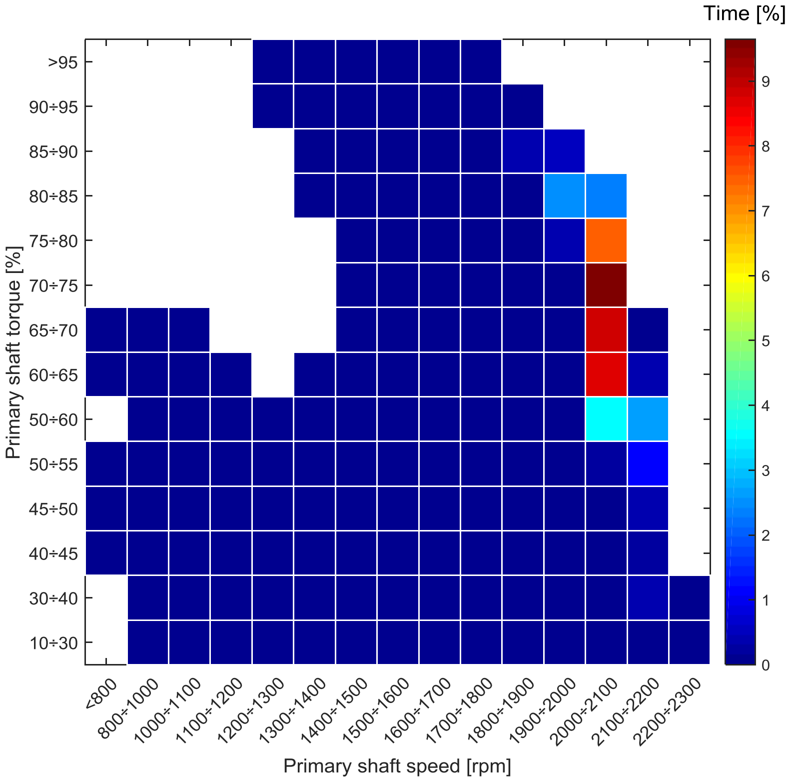

Figure 3.1: Example of the joint frequency matrix of the 10th forward gear of a monitored tractor

4. Conclusion

Tractor manufacturers extensively collect load data to increase the knowledge about the usage of their products. This data can be also used to extrapolate durability targets, so that customer expectations are met. In this paper, a methodology for that purpose was developed for power-shift transmissions of agricultural tractors and it relies on appropriate statistical methods. The findings of this paper are that tractor engines are run at the speed where the engine produces the maximum power so that tractor productivity is maximise. This information, combined with the other that is possible to record from the vehicle bus, permits to design lightweight transmissions without affecting the operating durability and reliability. This methodology should be further developed in order to analyse data from tractors with continuously variable transmissions where the combination of the mechanical and hydraulic subsystems makes load calculations non-trivial and engine operating points may be significantly different than for power-shift transmissions.

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A survey on work safety in agricultural farms and a risk model

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Keywords: farm risk, risk matrix, safety survey, safety guidelines.

Introduction

Specific surveys on health and safety conditions of working people have been conducted at both European and national level. Recently, the Ministry of Health has promoted a Research Programme on occupational safety and health. One of the priorities has been to establish a national, permanent infrastructure to monitor how workers awareness about risks at the workplace, consistently with the objectives of the National Health Service; (Inail, 2014, Cecchini et al 2010, Marucci et al 2013). This kind of investigation is based on telephone surveys involving both the workers and their employers. Another survey was conducted in the agricultural sector based on face-to-face interviews conducted by specialists. The legal framework in Italy has evolved in recent years, following the adoption in 2008 of Decreto Legislativo (Decree) n. 81 of April 9, 2008, on the regulation and enforcement of workplace health, safety and welfare. This fundamental text, modified by Decreto Legislativo No. 106 of 2009, contains 306 articles and 51 attachments and introduces the principle of organisation in risk prevention, since both the employers and the workers are committed to safety management practices. Unlike other European legal standards (e.g. for food safety, environment protection of animal welfare), work safety standards are not part of the common rules for direct support schemes under the European common agricultural policy. However, compliance with work safety rules and national guidelines is required by many Italian Regions as a mandatory condition in order to apply for public support schemes, including those of the Rural Development Plans.As indicated by previous work, risk prevention and safety rules, while representing substantial requirements for any agricultural farm, are often difficult to introduce and partly still unattended in many cases. Thus, the first objective of this study was to investigate current levels of work safety in a sample agricultural farms located in the region Friuli Venezia Giulia.

Methods

The data used in this study derived from two separate surveys, conducted to assess safety levels in the Animal husbandry sector and in the vine growing – wine producing sector in the Region Friuli Venezia Giulia. In the second case, a number of other farms with different specialisation or mixed production were also included. For the purpose of the present study, this made up a sample of 103 agricultural farms, with a prevalence of dairy farms and farms with vineyard and/or horticultural crops (Table 1).

Table 1 - The farm sample.

Type of farm	No.	%	Average size (ha)
Dairy farms	36	35.0	67.5
Other livestock	17	16.5	89.9
Vineyard and winery	24	23.3	55.6
Horticulture and nursery	12	11.7	9.4
Other	7	6.8	14.9
Mixed	4	3.9	240.5
Cereal crops	3	2.9	42.3

All farms	103	100.0	63.9

These farms were located in all of the six Health Districts in Friuli Venezia Giulia, each controlled by the respective District Agency. Part of these farms (56.3%) employed hired personnel, while 43.7% were family farms, allowed by the law to use a simplified safety management scheme.

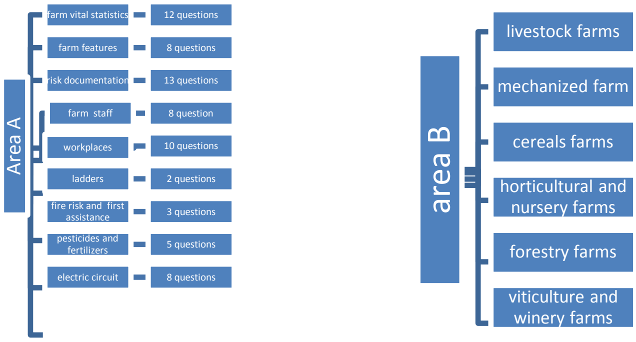

Figure 1 - Areas A and B.

Each of the farms was visited by one evaluator and all data were recorded following a specific questionnaire. This was divided in two areas (Figure 1):

- area A, including general information about the farm;
- area B, which varied depending on farm specialisation, and was further divided into three profiles: B1: farm machinery; B2: personal protective equipment (PPE); B3: specific risks.

Results

Comparing the main findings from the survey suggested that many agricultural farms to the purpose of the present study, we analysed: a) whether official documents and records were actually present at the farm; b) how safety management was organised; the presence of protection devices on tractors; the use of prevention and protection equipment.
Table point a) show farms which are subjected to full application of Decreto 81/08 including official documentation. The main document required, i.e. the risk assessment document, was absent or inadequate in 34.5% of the farms; other required documents were missing even more often, including a scheme for medical surveillance of workers (34.5), the scheme for emergency procedures (41.4%), and the record of periodic inspection of lifting equipment (44.8%). Only those documents provided by third parts were mostly present, such as the Compliance certificate (lacking in 10.3% of farms), the Book of use and maintenance of equipment (8.6%), the Pesticide safety sheet (25.9%), or those required for purchasing pesticides (Pesticide license: 24.1%). Particularly remarkable was the absence of a plan for machinery and equipment maintenance (36.2%), because of its great importance for accident prevention.

Table 2. Managers and services.

	Not present (% of farms)
Safety manager	17.2
Medical doctor	48.1
Fire prevention manager	33.3
First-aid manager	34.6
Workers' supervisor	63.0
Training and information service (workers)	38.3
Special training service (managers)	44.3

The law also requires every farm with hired personnel to officially appoint a number of figures in charge of the different protection and prevention services (Table 2). While a safety manager (or head of the prevention and protection service, PPS) was mostly present (82.8% of the farms), other figures were often missing, including a doctor designated for periodic medical surveillance (48.1% of farms), or the supervisors for fire prevention (33.3%), first aid (34.6%) and workers' safety during actual work (63.0%). Additionally, 38.3% of the farms were not providing the workers with sufficient training and information services, while 44.3% did not have any special training for the various managers and supervisors. Most of the farms had adequate toilet and shower services and dressing rooms for the workers. The width of the main entrance to the farm (minimum: 5 m) was mostly in line with the law. Protections on gaps or trenches were, however, missing in 28% of their farms. Most remarkable was the absence of any Interference risk analysis, i.e. a plan to avoid risks owing to the presence at the farm of external personnel, especially contractors for cereal or grape harvesting. Only 8.6% of farms had conducted a proper analysis of such risks.
In approximately one half of the farms, a specific analysis was made to assess the main features of the tractors (Table 3). The average nominal power was 63 kW, and the average age was 20.9 years. The average annual usage (328 h/year) was related with the small average land area (63.9 ha, Table 1), and was far from the level suggested for profitable management (at least 600 h/year). These data offer some clues as to the current difficult economic situation in most of the farms: the reasons are many, which cannot be fully discussed here. Anyway, this makes even more difficult for these farms to bear the costs involved by current requirements for risk prevention and protection.

Table 3. Tractors at the farms.

	no. of tractors	Power (kW)	Age (years)	Usage (hours)	Usage (hours/year)
Dairy farms	54	76.6	20.7	7339	355
Other livestock	18	65.6	21.6	7078	328
Viticulture	62	57.1	15.3	4444	290
Horticulture and nursery	26	50.3	27.8	3610	130
Other	2	40.4	24.8	1750	71
Mixed	29	61.8	26.1	15329	588
Cereal crops	5	64.7	20.0	6958	348
All farms	196	63.1	20.9	6873	328

In fact, missing protection devices are mostly related to the tractor's old age. In most of the sample farms, tractors were equipped with ROPS, protection of moving parts such as belts and fans, and of hot surfaces (Table 4). Remarkably, however, a safety belt was missing at the driver's seat in 55.1% of the tractors; PTO guards were also missing in 24.7% of the tractors.

Table 4. Protective devices.

Protective item	missing (% of tractors)
ROPS	5.2
Safety belt	55.1
Protection of belts & fans	7.6
Protection of hot surfaces	10.8
Safe access to driver seat	13.6
PTO guards	24.7
CE marking	37.6

Owner handbook	8.0

The percentages of farms that were providing their workers with personal protection equipment (PPE) is low. In general, only basic PPE were present (like overalls in cotton and mechanical protection gloves), while specific PPE were seldom found. The main findings from the survey suggested that many agricultural farms were sufficiently aware of the risks associated with their specific production systems, or with the machinery used, but had a tendency to neglect them to some extent, particularly in order to avoid the related economic costs. More important, information about legal obligations was generally insufficient, as was the understanding of the possible cost, in terms of fines, damage compensations and similar, that failure to comply with the rules might cause.
This suggested that most farms would take advantage of some simple informative tool, e.g. in the form of a software, in order to quickly detect the most critical situations.

Conclusions

The survey was important to improve current knowledge about work safety in agricultural farms, and was also useful to increase the farmer's awareness about the specific risks involved by the different production systems.
A further step will be to improve safety conditions through proper informative and self-assessment tools. Since the survey had shown that most of old tractors and machinery were defective in one way or another, we prepared a software to help the farmer check each machine and detect any improper or missing protective device, or to amend it in order to fulfil legal requirements.
Finally, this work was instrumental to building a database about current situation of agricultural tractors and implements in use in the Region Friuli Venezia Giulia.

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Screw log splitter design and risk management

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Keywords: agricultural machine, log splitter, occupational safety.

Introduction

Agriculture has always been considered as one of the sectors with the highest risk of accidents and injuries. In 2011 there were 47 054 accidents reported to, compared with 57252 accidents in 2007 showing a decline of 17.8%. The fatal accidents reported to INAIL, which exclude those that occurred due to non-professional use and/or not protected operations were 109 in 2011 with an increase compared to 2007, when overall fatal accidents were 104 (4.8%). In the case that are considered also fatal accidents occurred after non-professional and/or not protected operations, those related to the use of tractors and agricultural machinery were 167 in 2011 of which 141 related to the use of the tractor and 26 related to the use of agricultural machinery. The Equipment Directive is the European Directive 2006/42/EC issued in 2006 aims to "reduce the social costs of numerous accidents caused directly by the use of the equipment. It is focused on the integration of safe equipment design and construction as well as proper installation and maintenance" (Directive 2006/42/EC, consideration 2). In order to ensure the safety and health protection, the equipment considered by the abovementioned Directive must comply with the essential safety requirements which take into account the state of the art at the time of construction and all technical and economic requirements. The Directive was implemented by the Italian Republic with the Legislative Decree 17/2010. The article 5 of this Decree states that the manufacturer of the equipment or his authorized representative must ensure that all equipment complies with essential safety requirements and health protection set out in Annex I of the Directive, before placing it on the market and/or putting into use. Article 7 of this Directive says that "the equipment manufactured in accordance with harmonized standards (Official Journal of the European Union), shall be presumed to meet the essential safety and health protection covered by this harmonized rule. An agricultural machine is considered "in accordance" when it is built based on all above-mentioned technical standards and, therefore based on the Equipment Directive. All equipment has to possess the technical standards concerning its specific type, documentation of origin as well as the certification that no modifications were performed on the equipment. In some more complex cases is also necessary to consider experts which perform adaptations on the equipment and must declare the successful modification in accordance with all available guidelines. At the moment, in the agro-mechanical sector are present and in use different types of equipment. The aim of this work was to design and develop a conical screw log splitter which meets all the above-mentioned requirements and regulations.

Methods

The project set-up was planned and performed in 2013. From the methodological point of view the work was divided into three phases as follows: 1; data collection on injuries related to the use of cutting equipment. Numerous news articles regarding injuries related to cutting and wood sawing were found by internet search. Currently, no specific database for such accidents is available; 2; technical and regulatory analysis. For the analysis of the conical screw log splitter the technical standard EN 609-2: 1999 + A1: 2009 (E) was considered; 3, project design. The developed model was based on two types of analysis, one referring to the volumes processed by the equipment and the other related to the intrinsic forces, resistance of the single components. To determine the volumes and the forces that can be processed by the log splitter we have considered three types of wood: poplar, beech and fir. We have searched for specific maximum and minimum weights of green wood and humidity above 50%. It was calculated the volume of

the wood logs which were similar to cylinders with heights from 0.4 to 1.6 m, all having the same diameter of 0.3 m.
The guards and the rotation bar of the log splitter must resist the force. After the calculations of all involved forces we have continued with the design of the tool according to the requirements of the technical standard EN 609-2:1999+A1:2009. The log splitter was sized to work with logs of about 50 cm in diameter and 1 meter of height with a conical screw of 100 mm diameter. We performed the project set-up which was subjected to verification and technical regulations. Afterwards, we made a virtual 3D model. The model has been reproduced as a static model in 1: 5 scaling. After the implementation of the project, the booklet for its use and maintenance was prepared. In addition, we performed a comparison of the hypothesized log splitter and the commonly used hydraulic log splitters.

Results

With a detailed research we identified 52 accidents that occurred from 2003 to 2014 in Italy, during cutting and sawing of wood. The age of the injured has been divided into four classes: 0-20, 20-40, 60-80 and 80-100 years; the majority of accidents affected people between the ages of 60 and 80 years (36.7%). The injured men were 87% while only 13% were female. The 81% of accidents has resulted in an injury, while 19% had a fatal outcome. In 46.2% of injuries the sites of the lesion were hands, in 14.4% the thigh and in 11.5% the face. The type of equipment involved in the accident included the log splitter in 32.6%, followed by chain saws (26.1%), circular saw (21.7%) and ax (10.9%). The cause of the accident could be attributed to the age of the machine or non-standardized modifications. The volume of the logs varied from 0.03 m3 to 0.11 m3, all examined logs had a diameter of 0.3 m. The weights of the logs ranged from 23.74 kg (poplar) up to 113.04 kg (fir). For the same power of the tractor, the engine torque and the Ftg decrease with increasing speed of the PTO; switching from a torque of 200 Nm at 2457.80 revolution/ min of the PTO to a torque of 702.23 Nm at 700 revolution/min of the PTO. At higher rpm of the PTO corresponds a lower Ftg transmitted to the log from the conical screw and a milder split action of the log. Ftg increases with the decreasing diameter of the screw; considering a rotation speed of the PTO of 540 revolution/min, going from a Ftg of 1.86 t applied to the log by the screw with a 200 mm diameter, to a Ftg of 2.47 t applied to the log by the screw of 150 mm diameter, up to Ftg of 3.71 t, applied to the log by the screw with 100 mm a diameter. Smaller diameter of the conical screw corresponds to a more effective log split action and with the increased Ftg applied to the log decreases the risk of jamming of the machine as well as the possibility that the log enters into a rotation because it is stuck with the conical screw. The moment of the trunk strength decreases as the speed of the PTO and the length of the log increase. In fact considering a log of 1 m length the moment of the trunk passes from 2457.80 N (200 revolution/ min) to 702.33 N (700 revolutions/ min). Considering a 220 revolutions per minute of the PTO, the moment of the trunk shifts from 6144.51 N possessed by 0.4 m long log to 1536.13 N possessed by a log long 1.6 m. The force related to the kinetic energy increases with the number of revolutions of the PTO, considering a fir log of 1 m, we pass from a force equal to 251.60 kgforce (200 rpm) up to a force equal to 3078.01 kgforce (700 rpm). Moreover, the force increases as the length of the log increases; considering a log of silver fir and a 200 rpm, the values go from 40.26 kgforce for a log of 0.4 m to 644.10 kgforce for a log 1.6 m long.
The power supply cart moves bounded within the guides while the log splitter is working. The bottom surface of the cart is 500 mm long and 740 mm wide and has the profiles that allows the firm holding of the log. The cart has a useful height of 1300 mm and is closed on the two sides (rear and right one), while the left side is open to allow the loading and unloading of the log. The front side is closed to a height of 200 mm, in order to retain the logs on the cart. The complex of external protection has the aim to prevent operator contact with the conical screw. The protection on the right side of the machine has a length of 1080 mm for the entire length of the machine while the guard on the left side is 577 mm long in order to allow the operations of loading and unloading of the machine; the front guard covers the whole machine. On the upper side the protection covers entirely the machine. The brake lever clutch and the inverter are

located outside of the above-mentioned protections. The log is loaded from the left side on the cart, and then, using the handle, the cart is pushed forward until the log comes into contact with the conical screw that splits it. At the moment that the log is splatted, the carriage is pulled outward allowing the discharge of the chopped wood, which has remained on the cart. The overall protections and the specific cart avoid the operator contact with the conical screw during its rotation. The lever that controls the release transmission mechanism and the inverter allow to promptly stop the machine in case of any danger and to free out any jammed logs. In addition, to prevent the rotation of the log which remains stuck is provided a rotation bar. The designed log splitter meets the essential safety requirements of EN 6092:1999+A1:2009 and of the European Directive 2006/42/EC. The log splitter is designed with a conical screw diameter of 100 mm that can develop the necessary force to break logs as calculated. In the case that the designed machine is driven by a tractor with a power of 52 kW the range of useful forces to split the logs goes from 10.02 tforce (200 revolutions/min) to 2.80 tforce (700 revolution/min). These considerations make this designed log splitter comparable to a vertical or horizontal hydraulic log splitter that develops a power of 10 t. The model was produced in 1:5 scaling and was issued its user and maintenance manual. The comparison of the designed log splitter and a traditional hydraulic log splitter shows that the model developed is potentially competitive with those marketed at the moment. The introduction of security elements has only partially decreased the performance of the equipment by increasing the operation time about 10% However, these security elements increased the costs, the final price of the proposed model is from 1000 to 1200 € VAT included which is still in accordance with other technologies on the market. Added and improved elements of this tool are undoubtedly the safety parts that make this log splitter at low risk of accidents. It is also important to notice the greater ease of construction, ease of maintenance and increased operational duration compared to other conventional hydraulic models.

Conclusions

This work developed an innovative contribution in the agricultural mechanics, developing new equipment that is in accordance with the highest levels of security and performance. The research, based on an occurred accident, created the foundations for future projects which have to focus on safety planning in order to avoid numerous accidents and injuries. In addition, it should be emphasized that not only the design but also the cognitive aspect such as informing and training of the workers on the farm or working place must be the starting point for any operation. The adaptions of the machine to the mandatory regulations do not increase the costs and overall performances remain unchanged. The death of a person during the use of non-regulated equipment has moral consequences, but also economic and social ones. In this study also emerged the critical issues related to the use different tools or equipment which are maintained or modified without standard guidelines or self-implemented and altered avoiding any regulations or even rational logic.

Concept of a safety system to be used when performing dynamic tests of stability on agricultural machines

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Keywords: dynamic stability tests, tiltable and anglable platform, incipient rollover of a machine, anti-reversal safety system, vehicle's trajectories in a controlled environment

Summary
An innovative test facility to be installed within the "*Agroforestry Innovation Laboratory*" of the Free University of Bozen-Bolzano, located at the upcoming "*NOI - Technology Park*", has been developed with the aim of performing new stability tests on agricultural machines. It is basically a large *tiltable platform* (about 15×15 m), and it is composed by two test systems integrated together, (1) the *tiltable and angleable plane* and (2) the *tiltable turntable*. During the tests at this facility, machines are given some specific motions (rotation around a vertical axis, translation on circular trajectories). The considerable masses (up to 5000 kg) of the tested machines have raised the need to equip the facility with a safety system able to retain the vehicles when they reach the overturning. Studying the possible motions and trajectories of tested vehicles, a system that can provide up to 6 selectively-lockable degrees of freedom has been proposed. It can be named to as: *system with rotating-translating pincer-cage and carousel-like arm*.

1. Introduction
With the aim of overcoming the limits of the tests that are currently carried out to characterize the agricultural machines' stability (mainly to static rollover), new tests inquiring the static and dynamic stability of agricultural machines and an innovative test facility able to perform these new tests have been conceived. This test facility will be installed within the "*Agroforestry Innovation Laboratory*" of the Free University of Bozen-Bolzano, located at the upcoming "*NOI - Technology Park*".
This facility is basically a large *tiltable platform* (about 15×15 m), and it is composed by two test systems integrated together, (1) the *tiltable and angleable plane* and (2) the *tiltable turntable*. Real agricultural vehicles can be tested statically on the turntable, rotating around a vertical axis, or, rather, undergo a dynamic test on the plane, by made them travel on complete circular paths at different speeds and with different inclinations of the plane. The plane offers also the possibility to angle itself at half of its extension, creating an edge useful for simulating the abrupt slope-changes that a machine can meet going out of rows in the field.
The execution of real-scale dynamic tests with machines having considerable masses (according to the platform project: up to 5000 kg) raises very important issues regarding the general safety. Indeed, the tests to be conducted on this equipment aim at verifying the machines' stability in several conditions, so they can lead the vehicles to the overturning. However, an unstopped overturning must be avoided at all to prevent serious damages to people and things near the test facility, due to the dangerous condition of having a relevant mass in a not-controlled motion within an enclosed area.
Therefore, this work presents the study that was made to concept a retaining system for the machine in test.

2. Materials and Methods
The followed conceptual-design process took place in *two main phases*, according to a *top-down approach* started from the general problem-statement of "conceiving a safety system to be used when performing tests of stability on agricultural machines":

1. *Definition of the test system's requisites and concept of its operating principle(s)*; this phase has started with the analysis of the tests that can be performed on the tiltable platform and of the test systems installed on it, then the minimum requirements and constraints have been enumerated and formalized in technical terms (e.g.: positions of anchoring points, minimum dimensions, needed number of degrees of freedom);
2. *Design of the safety system's main features and first general dimensioning of the system*; with the help of some conceptual schemes and CAD drawings, the system has been delineated at increasing levels (notice that the detailed dimensioning of the system's components is a step subsequent and it was not addressed).

3. Results and Discussion

The design of the safety system able to retain an overturning vehicle has started from the *characteristics* (shape, dimensions) of the two main subsystems that are present in the innovative test facility for agricultural machines, and, in particular, from the *types of motion* that a vehicle can have when it is tested with these systems:

- the *tiltable and angleable plane* is composed by two flat half-planes joined together through an articulation hinge, capable to have different inclinations with respect to the ground and supported by the main structure (*Figure 3.1*); the tiltable and angleable plane is wide enough to let a vehicle travel on its two half-platforms, both when the they are aligned (i.e., they have the same inclination, thus forming a unique flat surface with an extension of 15×15 m), and when they have different inclinations and, therefore, between them there is an edge useful for simulating the abrupt slope-changes that a machine can meet going out of rows in the field; the trajectories of tested vehicles are circular only when the platforms are aligned, otherwise they are developed spatially (*Figure 3.2*);
- the *tiltable turntable* has a circular shape and it is inserted in the lower half-platform of the test facility, so that it has the capability to be inclined with respect to the ground ("tiltable"; *Figure 3.3*); the turntable is composed by four flat quadrants, on which a vehicle is placed motionless, and the quadrants can rotate together around an axis perpendicular to the surface supporting the vehicle, thus allowing to vary the angular position of the vehicle's longitudinal axis with respect to the maximum-slope direction of the tiltable structure.

The motion own by the vehicle in test on the turntable (basically it is fixed in the same point, even if differently oriented) is less problematic than the motion of a vehicle undergoing a dynamic test (i.e. travelling on the tiltable and angleable plane), so this latter case has substantially driven the concept and development of the anti-overturning safety system. The solution illustrated hereinafter includes an aerial part that rotates with the vehicle under test and, in case of incipient overturning, it allows the vehicle to quickly load its weight on the intermediate plane through a central pillar (*Figure 3.4*), thus resulting to be retained by the safety system. The connection of this safety system to the intermediate plane is necessary, considering the possibility of inclination of the half-planes with respect to it. Only a safety system connected to the intermediate plane has the ability to stay in a nearly-symmetrical position (from an angular point of view) with respect to the two inclinable half-platforms.

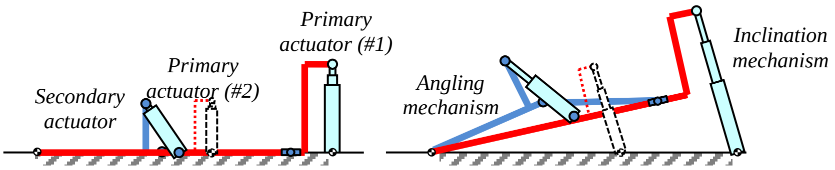


*Figure 3.1: Schematic side views of the platform in a rest configuration (*left*) or tilted and angled (*right*). The tiltable frame is red, the secondary structure, necessary to generate the angle between the half-platforms, is blue. The final project can have another primary actuator (#2) at half of the support frame, synchronized to the primary actuator (#1).*

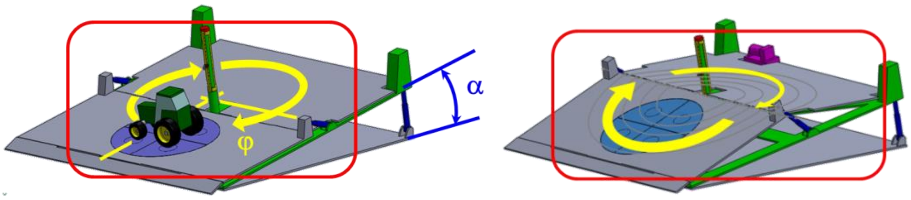


*Figure 3.2: Dynamic tests on a flat (*left*) or on an angled (*right*) surface use the whole plane of the tiltable platform; the angles which characterize the spatial position of the machine under test are also evidenced. The reported trajectories (in the picture on the right) will be travelled as indicated by the yellow arrows during dynamic tests (radii: 2.5, 3.5, 4.5, 5.5, 6.5 m).*

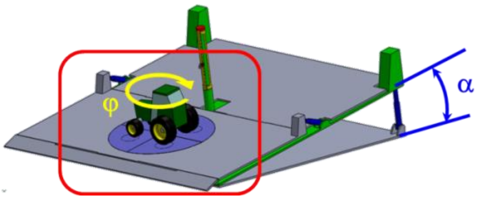


Figure 3.3: Static tests use only the turntable inserted in the lower half-platform (in evidence the characteristic angles: α global inclination of the support plane; φ angle between the vehicle's longitudinal plane and the maximum slope direction).

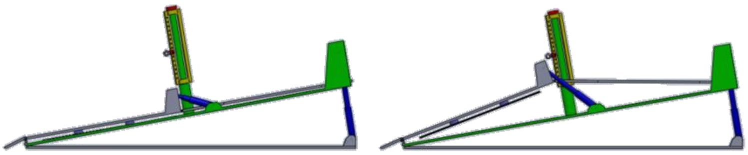
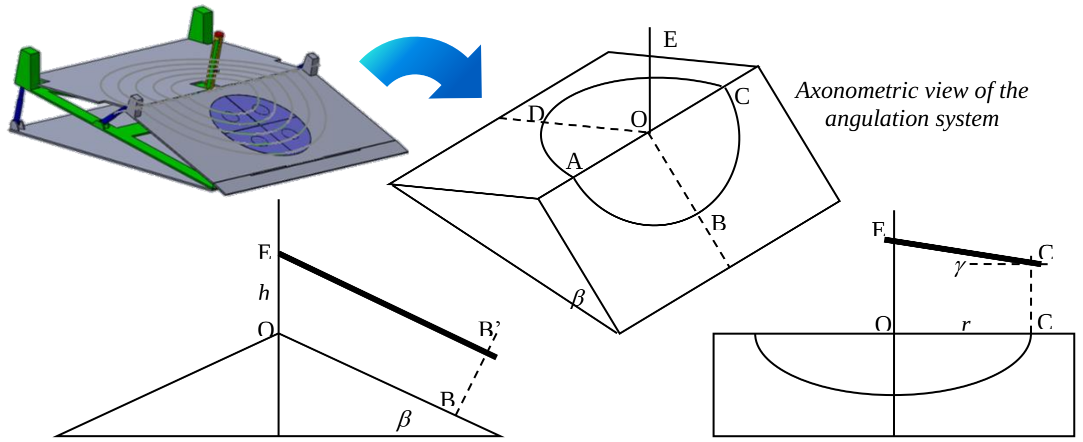


Figure 3.4: Side views of the platform with the pillar used by the safety system; the pillar is connected to the intermediate tilting structure and it has always a symmetrical angular position with respect to the two inclined half-platforms (see in particular the figure on the left).

Even in the simplified hypothesis that the pillar is placed exactly at the center of the platform, when the platform's plane is angled the length of an eventual connection with it (e.g., a wire rope or a chain) varies between a minimum and a maximum depending on the position of the vehicle in the trajectory, i.e. if it is near the edge (*Figure 3.5*, points A, C) or, rather, in the center of the semi-platforms (*Figure 3.5*, points B, D). This is why it is necessary to give the safety system a specific degree of freedom corresponding to a radial shift from the center. Furthermore, the spatial trajectory that a vehicle can travel during a test on this innovative platform is perfectly circular only when the support-plan is not angled and other degrees of freedom must be provided to the retaining system. Starting from these considerations and studying the possible motions and trajectories of a tested vehicles, we therefore propose a system that can provide up to 6 degrees of freedom and block selectively some of them in case of danger (*Figure 3.6*).
Looking at its technical characteristics, it can be named to as: *system with rotating-translating pincer-cage and carousel-like arm*. In this system, the cage is supported by an arm with a counterweight and has two rotational degrees of freedom around the central pillar. The connection elements of the cage to the arm allow the rotation of the cage pin around its axis, the rotation around the arm axis, a shift along the arm, and a limited angulation (a rolling angle for the vehicle).



Side view of the angulation system, the height of point E is due to the vehicle's height when in position B

Side view of the angulation system, when the vehicle is in position C

Figure 3.5: Simplified scheme of the angulation system for the half-platforms.

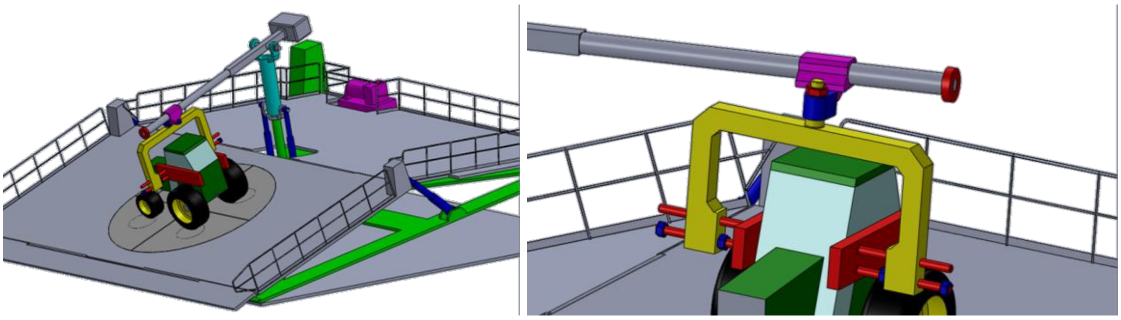


Figure 3.6: System to prevent the free overturning of the vehicles under test.

4. Conclusion

During the tests at the innovative test facility that will equip the new "*Agroforestry Innovation Laboratory*" of the Free University of Bozen-Bolzano, machines are given some specific motions (rotation around a vertical axis, translation on circular/spatial trajectories). Studying the possible motions and trajectories of tested vehicles, a system that can provide up to 6 degrees-of-freedom has been proposed. It can be named to as: *system with rotating-translating pincer-cage and carousel-like arm*. This system is able to freely follow a vehicle during its tests but retains it when the vehicle reaches the overturning condition, thanks to an automatic selective-block of its degrees of freedom.

Functional analysis as a conceptual instrument for studying and developing new farm-implements. An application to the design of a hand-tool for collecting kaki fruits.

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Keywords: design process, creative design, agricultural-implement design, functional analysis, kaki-collection implement.

Summary
A novel design-approach for studying and developing new farm-implements or tools is illustrated here, describing the different steps and its main conceptual instrument: the functional analysis (FA). In the present case (concerning the tools for fruit-harvesting), the FA was used to prepare a multidimensional matrix of the technical requirements; the same matrix was then used to classify the current design-requirements, verify any pre-existing solution normally present in commercial tools.
The method is therefore applied to a first prototype of a hand-tool for collecting kaki fruits, usable also with very ripe fruits (i.e., ready to be eaten). It has been decided to undertake the design of a tool to harvest kakis due to the remarkable difficulties the picker has usually to face with the manipulation of these particularly-delicate fruits (including the phases of abscission, interception/grasping of fruits and adduction to the operator). The designed tool resulted to be very practical to be used, cheap and effective in ensuring the product integrity during the harvesting.

1. Introduction

The development of a new agricultural implement is a complex and creative process that requires a multidisciplinary approach. Many skills of the designer are involved in this process, including his ability of re-elaborating already-existing solutions, together with his personal creativity, with the purpose of finding the best configuration to fulfil a requirement expressed in technical terms. Due to the crucial role of creativity, there is the need of making effective the ideational process, avoiding any issue that could bring to partially-suitable solutions or to reinvent existing tools already on the market.
The study reported here has the aim to illustrate a proposal of systematization of the design-approach for agricultural tools, codifying it in sequential steps centred on the so-called *functional analysis* (FA). The effectiveness of the approach is then proved by showing its application to a case-study: the design of a hand-tool for collecting kaki fruits (i.e., the fruits of the Diospyros kaki tree).

2. Materials and Methods

A "functional" approach focuses on what a particular tool (or a part of it) should or can do, in terms of actions or, better, *functions*, with the elements interfacing with it. The functional description of an agricultural tool (hence its *functional analysis*) is the central part of the creative approach proposed here, because it allows the designer to define, with a systematic approach considering many points of view at the same time, a tool by shaping its design, even complex, depending on the basic functions that it must perform. This creative process can be applied by adopting the following procedure, divided into 4 phases:

1. *functional analysis*; analysis of existent tools in terms of technical-functional characteristics own by each of them, extrapolation of the common characteristics,

structuring of information by means of a synthesis matrix (the functional matrix) and compilation of the matrix (placement of existing tools within the matrix);

2. *requisite matching*; encoding the current needs in terms coherent with the functional matrix's terms; use of the matrix in order to verify if the satisfaction of current needs can be realized by already-existing technical solutions (i.e., possibly borrowed from other equipment not specifically born for the purposes that we are trying to reach), or, instead, if a new solution should be developed;
3. *creative synthesis*; modification of an already-existing solution or proposal of a completely new solution on the basis of the technical needs highlighted by the functional matrix; conceptual design of the tool/implement; eventual application of the principle of modularity for the generation of a full range of tools;
4. *engineering*; detail design of a tool/implement on the basis of the technical characteristics highlighted by the functional matrix (hence: dimensioning, choice of materials).

3. Results and Discussion

The above-illustrated method is here applied to a first prototype of a hand-tool for collecting kaki fruits, usable also with very ripe fruits (i.e., ready to be eaten). It has been decided to undertake the design of a tool to harvest kakis due to the remarkable difficulties the picker has to face with the manipulation of these particularly-delicate fruits (including the phases of: abscission, interception/grasping of fruits and adduction to the operator).

In particular, we identified four fundamental constructive principles that should be considered when designing a harvesting tool that is both useful and effective:

1. the *principle used in the separation of the fruit from the plant* (e.g., cut or rip/twist);
2. the *implementation/operating system* (e.g., fully-manual or mechanical-aided);
3. the *man-machine interface* (e.g., the use of double or single handles in hand-tools);
4. the *temporary-storage capability* (e.g., the presence or not of a volume for accumulating the harvested product).

The information collected at this step of the creative process can be organized in a multi-dimensional matrix (the functional matrix), where a single dimension of this matrix corresponds to one of the enumerated constructive principles. In the present case, it is therefore possible to predispose a 4-dimension matrix (*Figure 3.1*) having 2^4=16 different combinations of principles (every principle has only 2 different possibilities/values), hence 16 different possibilities of classification of existing harvesting tools.

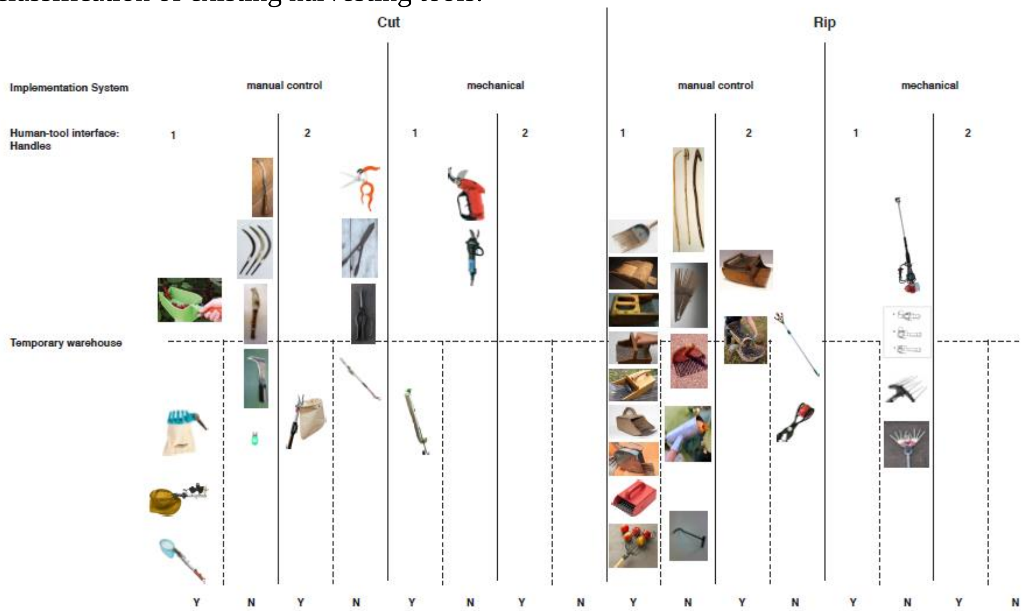

Figure 3.1: Functional matrix for harvesting tools.

A new harvesting tool has been therefore designed on the basis of:

- the functional matrix (hence considering already-existing harvesting tools),
- the characteristics of the fruits to be collected (pseudo-spherical fruit, weight of up to 500 grams, smooth, shiny, thin shell, tendency to soften with increasing maturity in a way similar to a kiwifruit, tough peduncle),
- the characteristic of the plant (height of up to 10 metres if not controlled, 3 metres in cultivation fields, fruits close one another on the plant, particularly-flexible branches).

Therefore, a tool with the following characteristics has been designed (*Figure 3.2*):

1. "cut" principle used in the separation of the fruit from the plant (i.e., for the harvesting phase of fruit abscission), through a pair of integrated steel scissors;
2. "fully manual" system for operating the blades of the scissors, through a lever-and-cable system;
3. "single handle" man-machine interface, basically a 2-metre rod (made of light material, such as wood or aluminium) that is hold by the operator with both the hands, but which needs only one hand to operate the integrated scissors by acting on the lever;
4. temporary-storage "present", in form of hemispherical basket, made with a net in stainless steel (suitable for the direct contact with the fruits), shaped to enclose a fruit during the cutting and then to contain a single fruit until it is brought to the operator (it is functional to the harvesting phases of interception/grasping of fruits and adduction to the operator); the choice of the net was done not to limit the visual of the operator on the fruit to be collected.

Thanks to the common materials/components used, the first prototype of the proposed hand-tool had a total cost of about 25-30 euros; the cost would be even lower in case of mass-production. The first field tests have been fully successful, with the 100% of the fruits resulting to be undamaged during the harvesting.

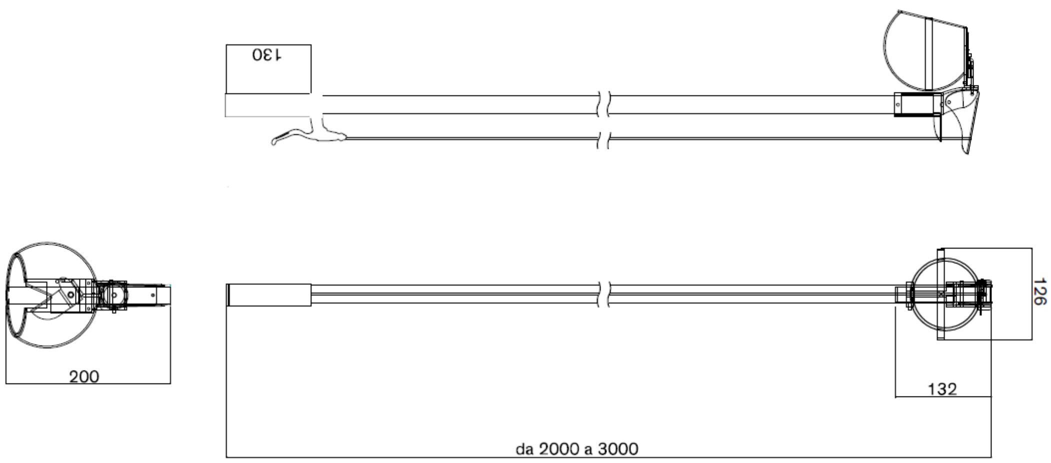

Figure 3.2: Technical drawings of the hand-tool for collecting kaki fruits.

4. Conclusion

The creative process has been systematized in a four-stepped effective procedure: the first two steps are mainly analytic, the others, instead, creative and synthetic. In particular, thanks to the FA, core of this approach, it is possible to study many existing solutions and understand how a new project will relate with these, in terms of required innovation-degree and of focus-points for the creative action.

The presented case-study has demonstrated the applicative easiness and effectiveness of the procedure; hence, a kaki-collecting hand-tool with many innovative features has been developed: it is easily scalable, uses components readily-available on the market and ensures the product integrity during the harvest.

Normative and operative issue on the use of ULV

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Keywords: fogger, knaspsack mistblower, droplets size, functional inspection

Summary
Droplet size sprayed by different models of foggers and knapsack mistblowers, adjusted to apply different volume rates, was measured using a laser diffraction instrument (Malvern Spraytec). Thanks to a dedicated software, for each equipment and setting tested, the instrument provided the droplets parameters used to characterize the sprayed droplets size (VMD or D50, D1, D90 and V100).
Droplets sprayed by knapsack mistblowers resulted slightly coarser, with VMD ranging from 77 to 90. Concerning foggers tested (one cold fogger and one thermal fogger) results pointed out that ultra fine droplets were sprayed, featured by VMD values ranging between 37 and 78 µm according to the size of the dosing nozzles.
The draft of test protocol for the inspection of foggers in use was prepared on the basis of elements available in EN ISO Standard and in analogue documents already prepared and used in some EU countries. The draft test protocol seems to be applied without problems for the inspection of this type of PAE in use.

1. Introduction
Ultra Low Volume (ULV) Pesticide Application Equipment (PAE - hot fogger, cold fogger, knapsack mistblower fitted with ULV kit) are sprayers which produce very small droplets (50-60 µm) and allow to apply pesticides with very low volume application rate. At present, for these type of PAE no EN/ISO Standard methods and requirements for both brand new and in use machines are available.
In Italy the national law which implements the EU Directive 128/2009 on sustainable use of pesticides (D.lgs 150/2012 and the relative National Action Plan) requires the mandatory inspection also for the ULV sprayers in use. At the same time in some Italian Regions restrictions about the minimum size of droplets emitted by the sprayers have been introduced, aimed at containing spray drift and its environmental and bystander risk. If this latter aspect should not be a problem for the foggers, as they are usually operated indoor (e.g. in glasshouses and storerooms), it could pose limitations for use of knapsack mistblowers in open fields. As there is not a bibliography on the subject, this work was aimed at assessing the droplets size generated by four models of commercial knapsack mistblowers and two models of commercial foggers.
Moreover, a specific draft test protocol for the inspection of foggers in use was prepared.

2. Materials and methods
Droplets size
Tests were carried out in the Crop Protection Technology Laboratory at DiSAFA – University of Torino (Italy), using a Malvern Spraytec laser diffraction instrument to measure the size of droplets, expressed in terms of VMD (D50), D10, D90, and V100 (percentage of volume of drops having a diameter smaller than 100 µm - Van de Zande, 2008), generated by 2 different foggers (thermal and cold) and 3 knapsack mistblowers (Table 2.1).
Droplets size measurements were carried out positioning the outer edge of the spout of each sprayer tested at a distance of 500 mm from the laser beam and aligning the centre of the spout with the laser beam axis.
Tests were conducted spraying deionised water (at 20°C temperature) in conditions of air temperature of 21-25°C and relative humidity of 85-90%

Table 2.1: Different models of ULV sprayer tested.

Sprayer	Air speed (m/s)[1]	Nominal flow rate (L/min)
A –Thermal fogger dosing nozzle 1	--	0.24
A - Thermal fogger dosing nozzle 2	--	0.54
B - Cold fogger dosing nozzle 1	--	0.15
B - Cold fogger dosing nozzle 2	--	0.33
C - Knapsack mistblower 1	10.3 – 6700 rpm	0.70
D - Knapsack mistblower 2	5.9 – 7300 rpm	0.75
E - Knapsack mistblower nozzle 1	6.8 – 6000 rpm	1.10
E - Knapsack mistblower nozzle 2	6.8 – 6000 rpm	1.40

Draft protocol for functional inspection of fogger

The draft of test protocol for the functional inspection of foggers in use was prepared on the basis of elements available in EN ISO 16122-1 and EN ISO 16122-4 and in documents already prepared and used in some EU countries like Belgium and the Netherlands.

3. Results and Discussion

Droplets size

VMD of droplets emitted by the tested foggers always resulted below 80 µm. Finer droplets sizes were registered when the reduced liquid flow rates were employed; in these cases also the V100 value resulted very high (90%) (Table 3.1).
Knapsack mistblowers generally sprayed droplets slightly coarser (featured by VMD ranging between 77 and 90 µm). Droplets size in this pneumatic equipment was affected not only by the liquid flow rate but also aby the air velocity. In this case, the percentage of droplets with diameter below 100 µm resulted lower with respect to the ones found using the foggers.

Table 3.1: Results obtained.

Sprayer	D10 (µm)	VMD (µm)	D90 (µm)	V100 (%)
A - Hot fogger dosing nozzle 1	17	37	87	90
A - Hot fogger dosing nozzle 2	26	64	166	72
B - Cold fogger dosing nozzle 1	29	56	99	90
B - Cold fogger dosing nozzle 2	32	78	153	64
C - Knapsack mistblower	37	90	169	58
D - Knapsack mistblower	29	77	186	68
E - Knapsack mistblower nozzle 1	35	81	172	65
E - Knapsack mistblower nozzle 2	37	85	178	67

Comparing the droplet size spectra obtained for the tested sprayers with that of the reference nozzle (ISO flat fan 03 operated at 3 bar pressure, VMD = 240 µm) indicated by the British Crop Protection Council (BCPC) it is possible to classify the droplets generated by foggers and knapsack mistblowers as very fine (VF) and fine (F) respectively. In Figure 3.1 examples of droplets spectra obtained using a thermal fogger and a mistblower are reported.

[1] data (measured 3 metres from the point of delivery) take from ENAMA Certificate

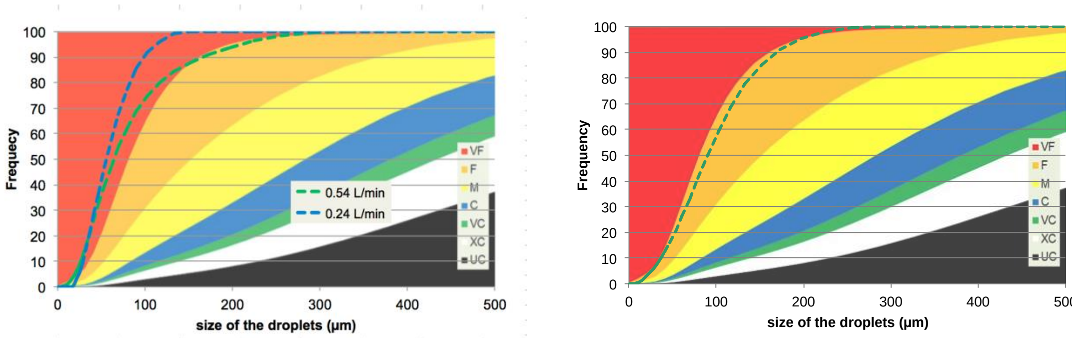

Fig.3.1: Examples of droplets spectra of hot fogger (sx) and knapsack mistblower 1 (dx).

Draft protocol for functional inspection of fogger

Pre-inspection

Follow EN ISO 16122-1 requirements (when applicable).

Safety of the machine

All guards (covers, locking, etc.) belonging to the machine are present, do not show excessive wear and function properly.

The exhaust pipe is sufficiently shielded or fitted with warning labels to avoid injury by heatin.

The fuel tank (if present) shall be in good condition, shows no leakage and equipped with a matching cap and functioning breather.

The gasoline pipe (in present), including filters, check valve, diaphragm, dispensing needle shall be in a good condition and does not show any leakage.

Fuel tank (in present) shall be well fixed.

The exhaust pipe (if present) shall be in good condition.

The mechanical condition of electrical power (if present) shall be in good conditio, considering moisture, dirt and corrosion.

The protection, clearing and earth conductors shall be not interrupted.

Tools, controls, contactors, switches and warning signs/labels shall be in good condition.

The connecting lines or mobile lines shalll be not damaged or improperly repaired.

All the associated installation and plugs shall be in good condition.

The electrical system has not undergone any modifications, in particular in the safety features, which affect the safety.

The condition and status compressor (if present), drive, tank, hoses and pipes, shall be in good condition.

Test method: visual check

Requirements of the machine

Concerning leaks and dripping, spray mix agitation, spray liquid tank, measuring, controls and regulation systems, lines and filtering system, nozzles output follow the indication of EN ISO 16122-4 (when applicable).

Other specific requirements

The ignition and functioning burner shall function properly (thermal fogger).

Functioning compressor shall function properly (cold fogger).

During a trial run of the machine is visually checked whether the formed droplet spectrum is uniform and sufficiently fine.

Test method: function test

4. Conclusion

Droplets size measurements carried out on ULV sprayers confirmed their very fine level of pulverisation. On one hand this is a positive aspect as, operating at a defined spray volume, fine

droplets enable to increase target coverage and this is very important for contact PPP. However, very fine droplets are more susceptible to evaporation and drift, so attention shall be paid in order to prevent this phenomena especially when operating with environmental temperatures over 30°C and in windy areas. If fogger use is recommended only indoor, as there is no way to significantly increase the droplets size, for knapsack sprayers that are often operated outdoor it is necessary to reduce the engine rotation speed at the minimum level indicated by the manufacturer and to increase the liquid flow rate in order to get coarser droplets. Some experimental data registered at DiSAFA during ENAMA certification tests of new knapsack mistblowers pointed out that reducing the engine and therefore the fan rotation speed by 20% it is possible to increase the average droplets size up to 60%.
Concerning the draft test protocol for foggers in use, it will be re-examined by the competent SPISE Technical Working Group to publish and disseminate it as SPISE Advice (as it already happened for boom sprayer and orchard sprayer adjustment and for the inspection of train sprayers).
This with the aim to use this document as basis for a future International Standard.

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Proposal of an advanced facility for testing the static stability of agricultural machinery

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Keywords: stability of agricultural machines, spatial position of a vehicle's center of gravity, static tests of stability, innovative testing equipment, tilting turntable

Summary
A critical analysis of actual tests and test-facilities used for inquiring the static stability of agricultural machines has been the starting point for a conceptual-design process: it has allowed defining an innovative test solution named the *tilting turntable*. This test device is composed by a circular support, installed on a tiltable structure and capable to rotate around a vertical axis by 360° with a vehicle positioned on it. Some sensors allow: (1) localizing the vehicle's centre of gravity, (2) measuring the load distribution/transfer at different positions of the vehicle's longitudinal axis with respect to the maximum slope direction and, even, (3) quantifying the trim change and downstream-tire(s) flattening. The tilting turntable is part of the test facility that will be installed within the "*Agroforestry Innovation Laboratory*" of the Free University of Bozen-Bolzano, located at the upcoming "*NOI - Technology Park*".

1. Introduction
The tests that are normally proposed to characterize the stability of an agricultural machine are substantially of two types: (1) static tests of lateral overturning of a vehicle in a straight-ahead configuration, (2) static tests of lateral overturning of a vehicle in a specific steering configuration (only for articulated vehicles; *Figure 1.1*), inspired by norms for telehandlers, pallet stackers, double stackers and order-picking trucks (UNI EN, 2015; UNI ISO, 2012).
These tests have as output the angle of lateral overturning of a vehicle, measured with all the vehicle's tanks completely filled with their liquids and some weights are on the seat, to simulate the presence of the driver. In particular, this angle corresponds to the inclination of the support plane needed to make a wheel lose contact. These lateral stability tests can give the height of the centre of gravity (COG; *Figure 1.2*) but not the front-to-rear position of the COG's projection on the vehicle's supporting plane (i.e., its coordinate along the vehicle's longitudinal axis).
There is also a third category of tests, less used, carried out via a system oscillating like a pendulum and capable to lodge the whole vehicle on it; the output of this test is the distance of the tractor's centre of gravity from the oscillation point, and, thus, the vertical position of the COG.
As argued, all the above-presented tests do not allow providing the complete spatial position (three Cartesian coordinates) of the COG in relation to a frame of reference fixed to the vehicle and, therefore, they prevent the prediction of the stability conditions of that vehicle when it travels on variously-inclined slopes and at angles with the maximum-slope direction different from the test conditions. Therefore, for example, the correct intervention-time of an active-safety device based on the reaching of an incipient overturning cannot at all be calibrated through these tests, and this is a critical drawback if wanting to raise the global safety of these machines.
Our objective was therefore to conceive a test-device that can overcome the above-highlighted shortcomings, letting the experimenters have a complete knowledge of the behaviour of any vehicle when operating on sloping grounds.

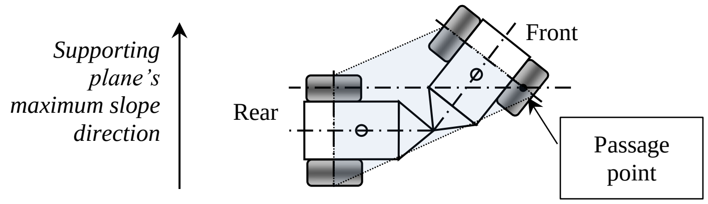

Figure 1.1: Specific configuration for testing the static stability of articulated farm tractors in a particularly-critical scenario (turning), due to the heavy deformation of the support polygon (Bietresato, Carabin, Vidoni, Mazzetto, & Gasparetto, 2015; Mazzetto, Bietresato, Gasparetto, & Vidoni, 2013; Mazzetto, Bietresato, & Vidoni, 2013; Vidoni, Bietresato, Gasparetto, & Mazzetto, 2015)*; in this configuration the internal wheel's axis passes through the centre of the external wheel of the part upward* (UNI EN, 2015; UNI ISO, 2012).

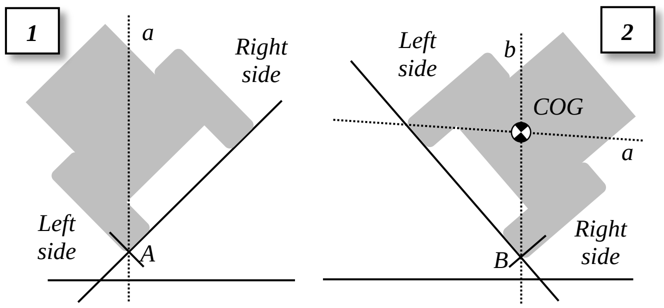

Figure 1.2: Determination of the COG's position in a vehicle's transversal plane thanks to two subsequent lateral-rollover tests (the COG is at the intersection of lines a and b). With this type of test, the COG's position along a direction parallel to the vehicle's transversal axis is undetermined.

2. Materials and Methods

The conceptual-design process followed for the present case took place in *two main phases*, according to a *top-down approach* started from the general problem-statement of "conceiving a new facility for testing the static stability of agricultural machinery":

3. *Definition of the test system's requisites and concept of its operating principle(s)*; this phase has started with the analysis (pros, contras) of actual tests and test facilities, then the minimum requirements and constraints have been enumerated and formalized in technical terms (e.g.: minimum dimensions, minimum achievable inclination angle, method of placement of the vehicle on the test rig);
4. *Design of the test system's main features and first general dimensioning of the system*; with the help of some conceptual schemes and CAD drawings, the system has been delineated at increasing levels, until arriving to the definition of the type and position of the actuators suggested to operate the system.

The detailed dimensioning of the system's components is a step subsequent to the conceptual design so it was not addressed (it will be let out on contract to an external design firm).

3. Results and Discussion

As all static tests for vehicles forecast that the vehicle under test is placed, motionless (maybe in different configurations) on a plane with an increasing slope, all facilities thought for testing the static stability of machines require basically a simple and flat inclinable plan (*first technical requisite*). The plan can be inclined by operating on its main frame, articulated at one end with the base, through a linear actuator according to a triangular pattern with a variable-length member (i.e., the actuator, for example a hydraulic jack; *Figure 3.1*).

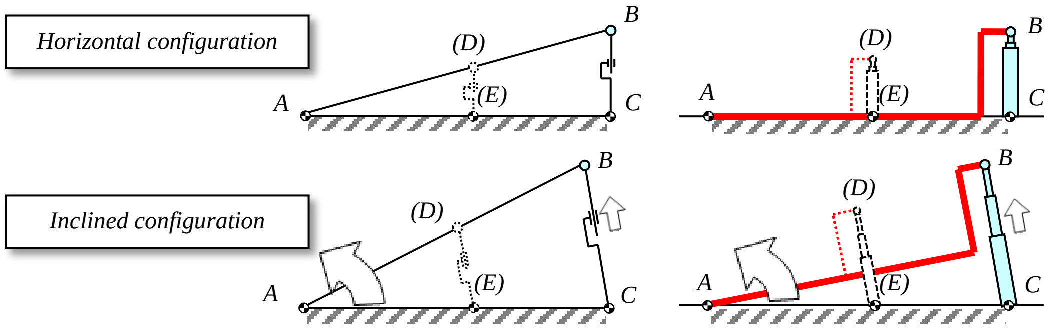

Figure 3.1: Kinematic scheme (left) and mechanism (right) for generating the inclination of the support plane (in red). If the system will require a higher structural resistance, the indicated kinematic scheme could be eventually replicated by placing two parallel actuators per side (BC and DE) operating simultaneously.

A *second technical requisite* can be delineated by considering the need for executing a stability test of a stationary vehicle on a slope with the longitudinal axis of the vehicle having any angle between -180° and +180° with respect to the maximum slope direction of the support surface (hence including also the usual lateral-stability tests). The described type of test can be named test of "*global static stability*". To avoid executing many incipient overturning tests with the vehicle in different angular positions and configurations (however, necessarily in a finite number), we conceived an innovative solution making use of a (tiltable) circular support, capable to rotate around a vertical axis by 360° with the vehicle positioned on it. This system is called the "*tilting turntable*" (*Figure 3.2*) and it is completed by providing the support plane with sensors able to feel the weight sustained by each wheel of the vehicle. To do so, the turntable is divided into four quadrants (one per wheel) and each of them is equipped with a robust strain gauge interposed between the quadrants and the main frame.
The different weights measured by the turntable's strain gauges at different inclinations of the support structure are useful to fully localize the COG with respect to the vehicle. Moreover, by rotating the turntable at a set inclination of the frame, it is possible to explore with continuity (not only at a limited set of values) all angular positions of the vehicle's longitudinal axis with respect to the maximum slope direction, measuring the load distribution/transfer in the meantime.
Finally, this type of test equipment can be further completed by positioning some inclinometers or diastimeters on the machine under test: the continuous monitoring of the distance between the vehicle's chassis and the supporting plan can evidence the trim change and downstream-tire(s) flattening (tests of "*global static load transfer*", "*frame's real inclination*", "*tires' deflection*").

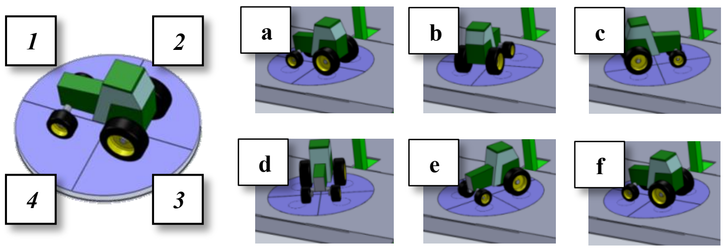

Figure 3.2: Turntable predisposed with strain-gauges to measure the weight on each individual support (quadrant) at different inclination angles (left); measuring session for the global static stability test (pictures a-f; right).

4. Conclusion

The new-concept device, the *tilting turntable*, has the following characteristics: (1) the turntable has a circular shape and it is divided into quadrants capable of measuring the weight sustained by each of them due to the motionless vehicle positioned on them; (2) the turntable is installed on a tilting structure, and therefore it is able to simulate different gradients of the ground on which the vehicle is placed; (3) the turntable can rotate around an axis perpendicular to the surface supporting the vehicle, thus allowing to vary the angular position of the vehicle's longitudinal axis with respect to the maximum-slope direction of the tiltable structure.
This equipment will allow precisely locating the centre of gravity of a vehicle and making many experimental (static) tests simulating a lot of working conditions of agricultural machines on slopes.
It will be installed within the "*Agroforestry Innovation Laboratory*" of the Free University of Bozen-Bolzano, located at the upcoming "*NOI - Technology Park*".

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Proposal of a system to perform dynamic tests of stability on agricultural machines

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Keywords: agricultural machinery stability, dynamic stability tests, innovative test equipment, tiltable platform

Summary
The tests that are normally proposed to characterize the stability of agricultural machines suffer from evident limitations, first of all being limited to static conditions only, thus neglecting the presence of the centrifugal force or not considering at all the load transfers that can occur in real situations. The critical analysis of actual tests and test-facilities has been therefore the starting point for a conceptual-design process aimed at defining an innovative dynamic-stability test solution, named the *tiltable and angleable plaftorm*. This facility is wide enough to let vehicle travel on it and has two half-platforms that can assume different inclinations, hence resulting to be aligned or forming an angle. It will be installed within the "*Agroforestry Innovation Laboratory*" of the Free University of Bozen-Bolzano. The different tests that can be performed with this facility will simulate better the real conditions that a vehicle in motion undergoes, thus helping the analysts to study new active safety devices.

1. Introduction

The tests that are normally proposed to characterize the stability of an agricultural machine are substantially of two types: (1) static tests of lateral overturning of a vehicle in a straight-ahead configuration, (2) static tests of lateral overturning of a vehicle in a specific steering configuration (only for articulated vehicles), inspired by norms for telehandlers, pallet stackers, double stackers and order-picking trucks (UNI EN, 2015; UNI ISO, 2012). These tests suffer from evident limitations, first of all being limited to static conditions only. Indeed, although these tests are able to identify the lateral overturning angle of a machine, they do not take in any way into account the load-transfer phenomena related to the velocity factor, concerning not only the appearance of a centrifugal force applied on the centre of gravity, but also a readjustment of the machine's trim due to all the components having a certain elasticity (tires, suspensions where present, supports of the cabin) or having a degree of freedom in the plane transversal to the machine's longitudinal axis (suspended loads, liquids, inconsistent solids such as grain products, stacked solids such as pseudo-spherical fruits). The behaviour of a system of this type, having a dynamically-variable trim, could be difficult to predict a priori by only knowing the position of the centre of gravity inquired under static conditions. For the above-explained reasons, with the aim of overcoming the limitations of actual testing facilities, we have studied an innovative system that allows to investigate experimentally also the described dynamic aspects, hence allowing reproducing any real-scale manoeuvres in a controlled and safe environment.

2. Materials and Methods

The conceptual-design process followed for the present case took place in *two main phases*, according to a *top-down approach* started from the general problem-statement of "conceiving a new facility for performing dynamic tests of stability on agricultural machines":

5. *Definition of the test system's requisites and concept of its operating principle(s)*; this phase has started with the analysis (pros, contras) of actual tests and test facilities, then the minimum requirements and constraints have been enumerated and formalized in technical terms (e.g.: minimum dimensions, minimum achievable inclination angle,

trajectories of the vehicle on the test rig);

6. *Design of the test system's main features and first general dimensioning of the system*; with the help of some conceptual schemes and CAD drawings, the system has been delineated at increasing levels, until arriving to the definition of the type and position of the actuators suggested to operate the system. Notice that the detailed dimensioning of the system's components is a step subsequent to the conceptual design, so it was not addressed (it will be let out on contract to an external design firm).

3. Results and Discussion

Test system's requisites have been enucleated considering that a sideways overturning or a lateral rollover of an agricultural machine is a dangerous event that can be triggered by the existence of one (or more) of these three, quite common, conditions (Chisholm, 1979a, 1979b; Coombes, 1968; Guzzomi, 2012):

1. *Excessive ground-gradient*; a machine is travelling on a support plane that is globally flat but not horizontal, in particular the machine's travelling direction is different from the maximum slope direction of the ground;
2. *Critical surface harshness*; a machine is travelling on a support plane that is horizontal but not uniformly flat, in particular the machine meets a local modification of the ground slope (e.g. an obstacle, a rut or a hole in the trajectory of a wheel) and one wheel can lose the contact with the soil, thus modifying the support polygon (Myers, 2008);
3. *Excessive turning speed*; the driver attempts to execute a manoeuvre at a speed incompatible with the desired turning radius, in particular the so-produced centrifugal force deviates the weight force from the direction perpendicular to the support plane till the resultant's projection falls outside the support polygon.

If the first overturning condition is mainly static and can be inquired by using a simple *tiltable plane* capable to vary its inclination (all actual test facilities are of this type), the other two conditions imply instead that the vehicle under test is somehow in motion until it meets a local slope-change (second condition) or it has enough room to execute a turning manoeuvre (third condition), maybe on a sloping ground (it could constitute an aggravating circumstance, as explained hereinafter). The simulation in a controlled environment of the latter condition needs therefore a *tiltable plane* that is wide enough to let a vehicle (eventually equipped also with a trailer) travel along complete circular trajectories with increasing speeds and at different inclinations of the surface. Instead, concerning the second condition, one of the most critical but common situations at this regard corresponds to the presence of a slope change at half of a turning trajectory: this is a typical situation that a tractor experiments when exiting from an interrow in a field located on an hillside, therefore with a loss of contact of the most external wheel. The most suitable test equipment uses a support plane in which is possible to create a slope change and therefore an edge, for example using a plane divided into two halves whose inclination can be different. The required equipment is therefore an *angleable plane*.
The above-described characteristics can integrated together to create a single, innovative test facility specifically thought for inquiring the dynamic-stability properties of real-scale agricultural machines: the *tiltable and angleable plane*. This test system is composed by two flat half-planes joined together through an articulation hinge, capable to have different inclinations and supported by the main structure (*Figure 3.1*).

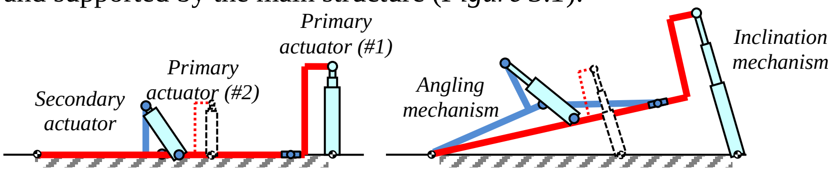

*Figure 3.1: Schematic side views of the platform in a rest configuration (*left*) or tilted and angled (*right*). The tiltable frame is red, the secondary structure, necessary to generate the angle between the half-platforms, is blue. The final project can have another primary actuator (#2) at half of the support frame, synchronized to the primary actuator (#1).*

Dynamic tests making use of this facility are organized as follows: after setting up an inclination of the plane (or of the two half-planes), an agricultural vehicle travels on it along complete circular paths, with several radii and at speeds comparable with the speeds used by that machine on the fields. A vehicle under test can travel on the two half-platforms both when they are aligned (i.e., they have the same inclination, thus forming a unique flat surface with an extension of 15×15 m; *Figure 3.2*), and when they have different inclinations and, therefore, there is an edge between them (*Figure 3.3*).
The *dynamic tests on a flat surface* are particularly interesting because, when a machine travels along a complete circumference, its longitudinal axis is lined up with the tangent at each point of the circular trajectory and, in particular, assumes all the possible angles φ between -180° and +180° with respect to the maximum slope direction of the support surface. Therefore, with a single closed path it is possible to test the same machine in correspondence with different angles φ. If an overturning occurs, it is associated with the plane slope α (responsible for the gravity force decomposition), with the angular position φ (corresponding to the inclination of the vehicle's longitudinal axis) but also with the turning radius *r* and the speed *v* (responsible for the centrifugal force intensity and for the weight transfer; *Figure 3.2*).
Dynamic tests on an angled surface are performed when the upper half-platform is horizontal (*Figure 3.3* left) and the lower half-platform inclined. The artificial edge divides each circular trajectory and simulates the sharp slope-changes that a machine can meet in the field, for example going out of rows in a field on a hillside (*Figure 3.3* right). This is a situation worthy to be inquired because of the impossibility for some vehicles (with a conventional or articulated frame) to fully comply with the inclined plane, leading to the loss of contact of a wheel (typically the most external wheel, in position C/C' of *Figure 3.3*, centre). This situation alters the vehicle's supporting polygon from a quadrilateral shape to a triangular shape, leading to a possible instability of the vehicle and triggering an overturning toward the external side of the turn.

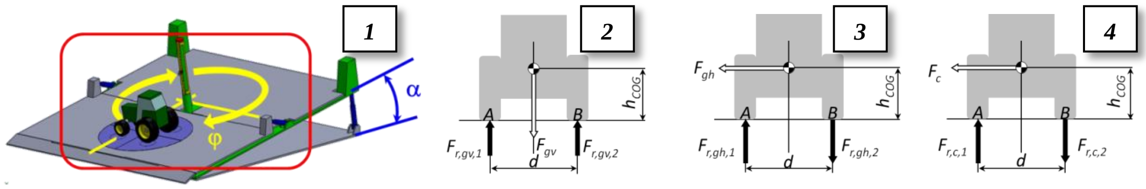

Figure 3.2: Dynamic tests on a flat surface use the whole plane of the tiltable platform (1); the angles that characterize the spatial position of the machine under test are also evidenced; effect of the gravity force decomposition (2, 3) and of the centrifugal force (4) on the reactional forces (not in scale) developed by the support in correspondence with the wheels of the same vehicle in the position shown in picture 1.

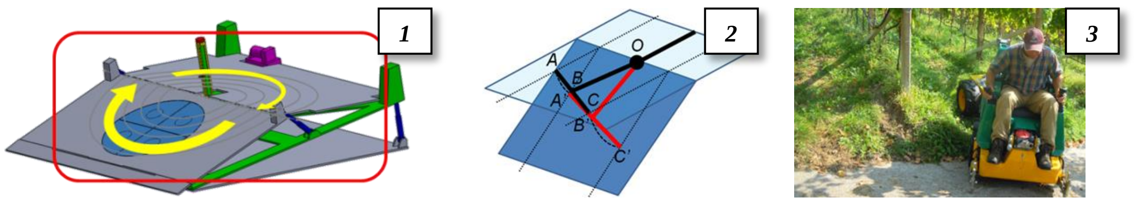

Figure 3.3: Dynamic tests on an angle surface use the whole plane of the tiltable platform (1); schematization of an articulated vehicle astride the edge (2), O is the articulation joint, the thick black/red lines are the vehicle frame in the horizontal/inclined plane; the front axle (ABC) is subjected to a double inclination (on the horizontal plane, to turn, and also due to the slope change); example of a small articulated tractor (3) undergoing the described situation (Mazzetto, Bietresato, Gasparetto, & Vidoni, 2013).

4. Conclusion

The proposed system is a tiltable and angleable plane with dimensions wide enough (15×15 m) to let an agricultural vehicle travel on it along complete circular paths, eventually with an

artificial edge in the middle of the trajectories. It allows simulating two important dynamic conditions that can lead a vehicle to overturn (critical surface harshness, excessive turning speed), letting the analysts study new active safety devices.
It will be installed within the "*Agroforestry Innovation Laboratory*" of the Free University of Bozen-Bolzano, located at the upcoming "*NOI - Technology Park*".

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CARTS – Canopy Adjusted Real Time Spraying

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Keywords: VRT, Spraying, Vineyards

Summary

The structural characteristics of the canopy are a key consideration for improving the efficiency of the spray application process for tree crops. However, obtaining accurate data in an easy, practical, and efficient way, and in-real-time, is an important problem to be solved. The main objective of the project CARTS is to develop a sprayer prototype and the respective algorithms in order to manage variable rate spraying in vineyards and other orchards. This prototype modifies the sprayed volume application rate according to the target geometry by using an algorithm based on the canopy volume inspired by the Tree Row Volume (TRV) model. Variations in canopy width along the row crop are electronically measured using several ultrasonic sensors placed on the sprayer and used to modify the emitted flow rate from the nozzles in real time; the objective during this process is to maintain the sprayed volume per unit canopy volume. Field trials already carried out at different crop stages in a vineyard indicated a good relationship between the applied volume and canopy characteristics. The potential pesticide savings were estimated to be at between 20% and 55% relative to the costs of a conventional application.

1. Introduction

Grapevine growth starts without any leaves and ends with a large canopy. The resulting leaf area to be treated can change from zero to over 23,000 m^2/ha each season. Therefore, plant protection products and volume application rates based on a fixed rate per hectare over-treat early season foliage, but may under-dose late season foliage (Siegfried et al., 2007). CARTS (Canopy Adjusted Real Time Spraying) project main goal is to develop a prototype that can measure in real time an apply a variable amount of liquid according to the canopy variability along the crop row in vineyards. This prototype must modify the sprayed volume application rate according to the target geometry by using an algorithm based on the canopy volume inspired by the Tree Row Volume (TRV) model. TRV is a simple and objective method used to determine the canopy volume in a hectare of orchard that can be applied to crops with different row spacing, tree sizes, ages and other factors (Scapin et al., 2005).Variations in canopy width along the row crop are electronically measured using several ultrasonic sensors placed on the sprayer and used to modify the emitted flow rate from the nozzles in real time; the objective during this process is to maintain the sprayed volume per unit canopy volume.

2. Materials and Methods

Field work is being carried out at Vinha do Casito, a vineyard belonging to Fundação Eugénio de Almeida (FEA) near Évora, Portugal (-7° 52' 36" W, 38° 32' 59" N). Row spacing is 2.5 m and distance between plants is 1 m. Trials were performed on two varieties (Trincadeira and

Aragonês). For each one, plants of high and low vigour were chosen, based upon Normalised Difference Vegetation Index (NDVI) and measured on previous year. NDVI presents a significant variation within the same field and variety witch reflects on canopy volume. Throughout the growing season canopies height and width were measured on four locations, combining varieties (Trincadeira and Aragonês) and vigour (high and low). TRV can be calculated by multiplying the following parameters: (1) tree average height in m, (2) tree average width in m, and (3) row length per hectare in m, which is determined by dividing 10,000 m^2 by the distance between rows in m (Sutton and Unrath, 1984, cit. by Scapin et al., 2005).

3. Results and Discussion

The leaf area development clearly follows an S-curve (Siegfried et al., 2007), as those represented in Figure 3.1, resulting from canopy measurements at sampling sites.

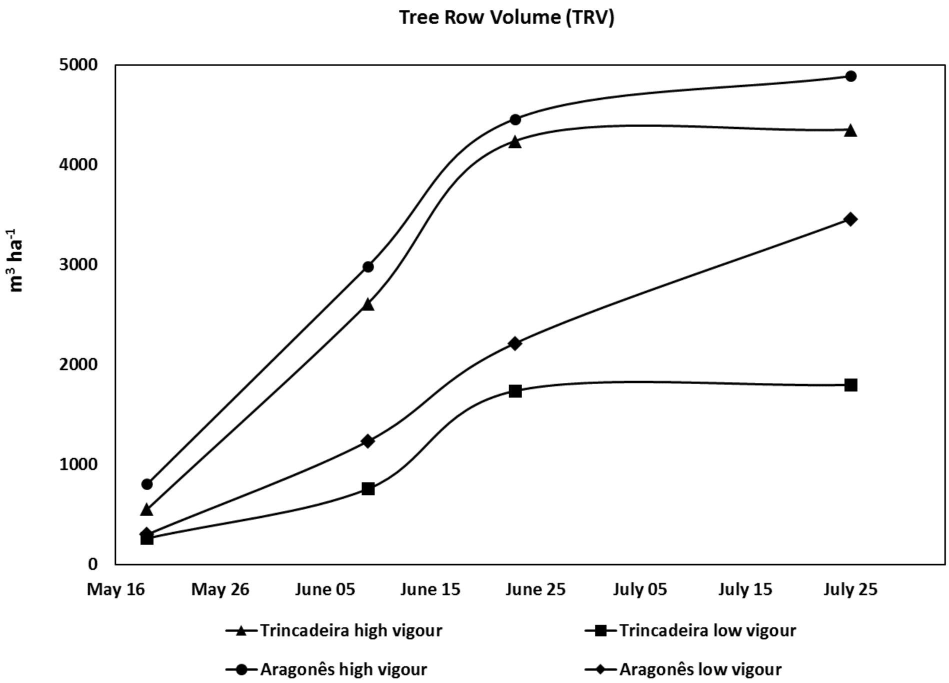

Figure 3.1: Tree Row Volume (TRV) variation over time at the 4 experimental sites.

Figure 3.2 shows the relationship between the volumes of applied product (Litres) and the canopy volumes measured at each sampling site (m^3) throughout the vegetative cycle. The red line indicates a reference value for this relationship, proposed by Gil et al. (2012) for this type of sprayers. It is possible to verify that the application efficiency hardly met the reference of Gil et al. (2012). As on May 19 the vegetative growth was still low, the "spray volume / canopy volume" ratio was calculated in two situations: (i) considering only the lower nozzles in operation (top nozzles closed); and (ii) considering all nozzles working (top and bottom opened). Nevertheless, in the areas of low vegetative vigour, at that time, the ratio between the spray volume and the leaves volume exceeded the reference value. In the first application, on May 19, only the Aragonês treatment, with high vigour, showed a suitable "spray volume / canopy volume" ratio because all other treatments presented a "spray volume / canopy volume" ratio always higher than the reference. In situations of low vegetative vigour, a value 3 times higher than the reference was found, thus showing a low application efficiency (over application). On June 9, the only treatment that approached the reference was the low-vigour Trincadeira variety, all the remaining treatments presented values lower than the reference (between half and 2/3 of the reference). On June 23 and July 25 all treatments were lower than the reference (close to 2/3 of the reference), showing a lack of application efficiency (under application).

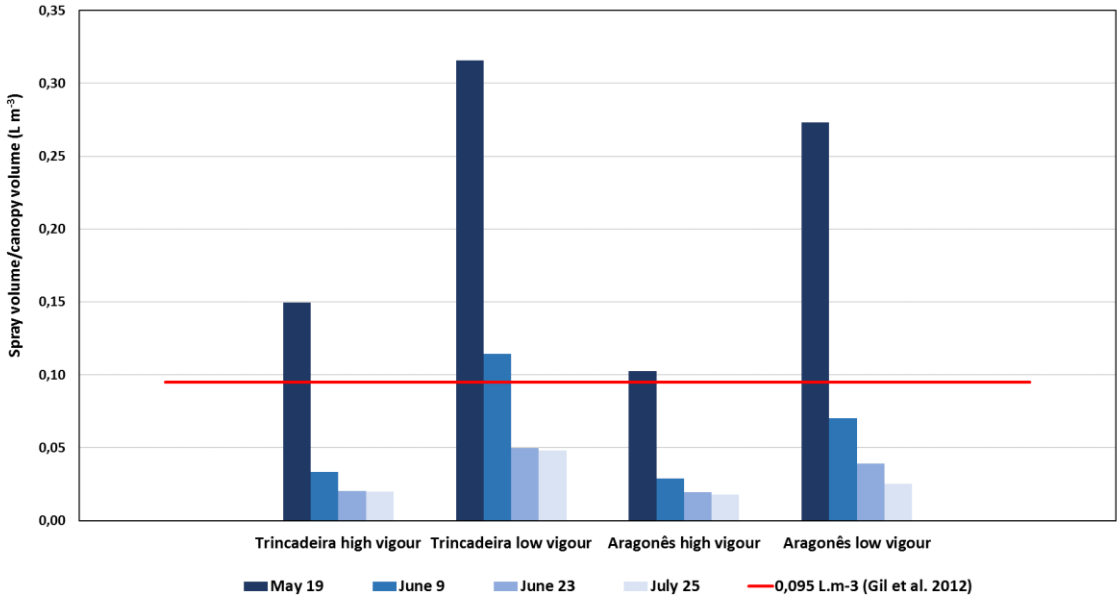

Figure 3.2: Relationship between volume of applied product (Litres) and canopy volume (m^3).

An efficient and effective spraying needs to ensure a correct "spray volume / leaf volume", but at the same time needs to consider that the sprayed leaves have to have the correct coverage of the sprayed product in terms of the quantity (droplet cover and deposition) but also in terms of quality (droplet Volume Median Diameter). Results show that droplet cover goes from 0 % to 30 % with a coefficient of variation normally above 80 %; droplet Volume Median Diameter (VMD) goes from ~100 µm to ~500 µm and the ratio between spray volume and canopy volume goes from 0.02 L m-3 to 0.32 L m-3. These huge variations happen because there are no fast and flexible systems reacting to site-specific needs without destroying the quality of spraying. There is a need of smart spraying systems (Figure 3.3) and because of that the CARTS (Canopy Adjusted Real Time Spraying) project was setup and was initiated in November 2015. The main objective of the CARTS project is to produce a spray equipment with capacity to measure the volume of leaves and adjust, in real time, the spray volume rate to be applied. To achieve this goal, the CARTS project brought together the Hexastep (Business leader: hexastep.pt), the University of Évora (Scientific leader: uevora.pt) and Micron (industrial leader: microngroup.com). With these consortium authors believe that in 2018 there will be available in the market a commercial differential sprayer for vines (Figure 3.3).

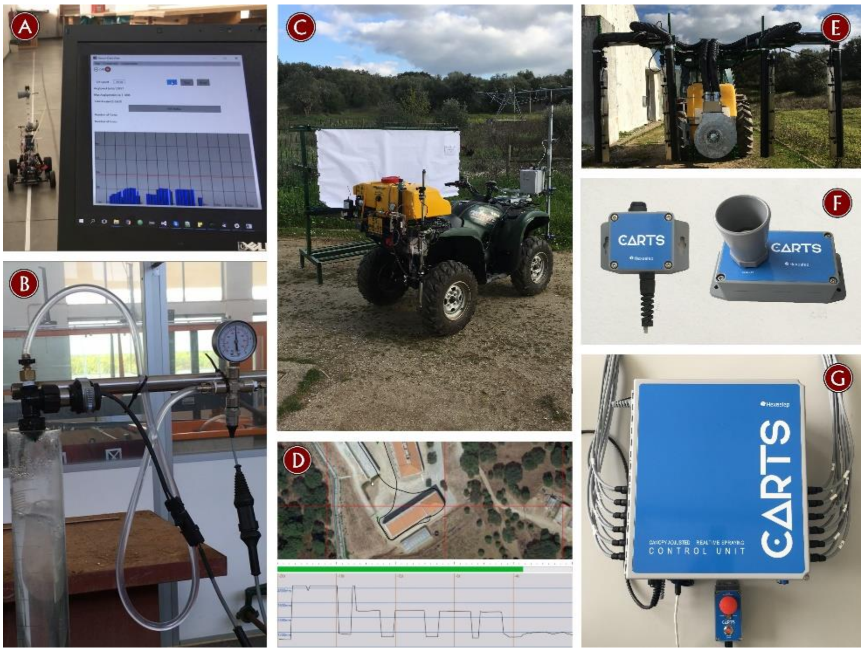

Figure 3.3: A –Mobile model with sensor capability; Volumetric estimation results displayed on the screen; B –Solenoid valve in operation, together with some hydraulic measuring instruments; C – Prototype coupled to light vehicle, with measurement and spraying capability; D – Prototype monitoring software, showing trajectory representation in conjunction with sensorial readings as a function of time; E – Sprayer used in large-scale prototype; F – Valve control module (left) and sensor (right); G –CARTS controller.

4. Conclusion

Large scale prototype is already being tested in the field and the team believes that in the end of the 2017 year a commercial model will be available.

Acknowledgments

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TOPIC 9

NATURAL RESOURCES AND ENVIRONMENTAL SYSTEMS MONITORING AND ASSESSMENT

Dielectric characterization of olive mill wastewater (OMW) contaminated soils by means of time domain reflectometry (TDR) technique

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Keywords: soil contamination, soil-OMW mixtures, dielectric models, time domain reflectometry

Summary
Olive mill wastewater (OMW) is an aqueous product of the industrial olive oil extraction process. Large quantities are generated in Mediterranean countries which produce 95-97% of the world's olive oil. The uncontrolled disposal, on the soil, of OMWs is a major environmental problem that affect soil and groundwater. To develop effective soil management techniques, characterization and identification of OMW-contaminated soils are needed. In recent years, several studies have been conducted both in saturated and unsaturated soils to detect different contaminants by means of time domain reflectometry (TDR) technique. This paper investigates the influence of OMW contamination on TDR measurement in a loam *Eutric Cambisol*.

1. Introduction

The olive oil industry is one of the most dominating agricultural sectors in the Mediterranean basin. Every year about 2 million tons of olive oil are produced, and this production is regularly increasing (Caputo et al., 2013; Sahraoui et al., 2015).
The extraction process of olive oil generates two by-products: i) a solid residue, and ii) the olive mill wastewater (OMW). This latter is an aqueous product which consists of a mixture of oil vegetation water and the water used in different stages of oil extraction (Colarieti et al., 2006; Sahraoui et al., 2015).
Due to their complex composition OMWs cannot be directly disposed into domestic wastewater treatment plants (Caputo et al., 2013). On the other hand, the mayor concern of this aqueous waste is really the lack of practical and useful solutions to their disposal which may constitute a serious environmental problem for Mediterranean producing countries (Kavvadias et al. 2014). Furthermore, the recycling of OMWs in agriculture may also cause potential negative effects on the physical and chemical soil properties, especially for long-term applications.
The problem of in situ evaluating the spatial and temporal distribution of OMWs represents a research topic of great interest, and nowadays it may be dealt with low-cost and non-invasive geophysical methods (Robinson et al., 2003; Comegna et al., 2013; Comegna et al., 2016), because OMWs significantly influence the dielectric response of the contaminated porous medium.
In order to justify our preliminary study, a series of laboratory tests have been conducted. Specific purposes include: i) dielectric characterization of OMW-water mixtures, and ii) dielectric characterization of OMW-contaminated soil samples.

2. Materials and methods

2.1 Soil and OMW properties

The soil investigated in this study was a loam *Eutric Cambisol* (IUSS Working Group WRB, 2006), located in southern Italy (sand 41.4%, clay 16.4%, silt 42.2%, porosity 0.52%, organic content 0.30 %, *pH* 8.40).
The OMW used in this research came from a continuous centrifugation system, and its principal chemical and physical properties are reported in table 1.

Table 1. Main physico-chemical properties of the OMW used in the experimentation.

Parameter	Value
pH	3.85
Electrical conductivity at 20°C (dS/m)	10.20
Dissolved oxygen: *DO* (mg/l)	0.23
Total organic carbon: TOC (mg/l)	6016
Total N (mg/l)	650
Chemical oxygen demand: COD (mg/l)	65000
Total poliphenols (mg/l)	1718

2.2. Experimental equipment

The experimental equipment is composed of a TDR unit (Tektronix 1502C cable tester) and a three-wire TDR probe, with wave guides 14.5 cm long, and an RG58 coaxial cable 2 m long. The reflected TDR signals are collected by a PC-based data acquisition system, and post-processed for apparent dielectric conductivity (ε_a) and apparent electrical conductivity (EC_a) calculation. Figure 1 gives a picture of the dielectric measurement system used in the experiment.

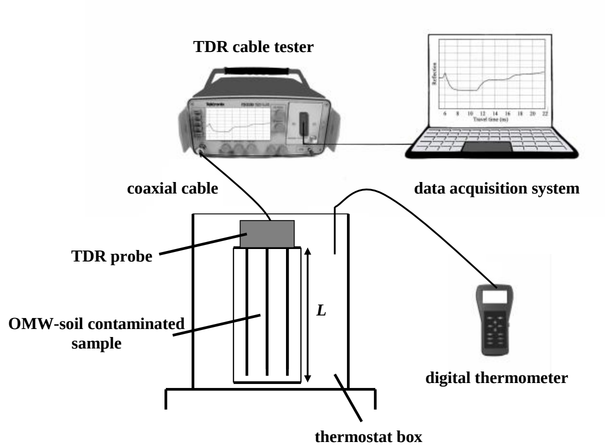

Figure 1. Experimental setup used in laboratory experiments.

2.3. Laboratory experiments

Two groups of experiments were performed in the laboratory. The first group of tests refers to dielectric measurements conducted on solutions obtained mixing known volumes of OMW and distilled water. The volume concentration of OMW (ϕ_{OMW}) was varied from 0 to 1.0 by 0.1 increments.

Table 2. Combinations of moisture volume (V_w) and OMW volume (V_{OMW}) for determined β values, and soil porosity ϕ.

θ_f	Volume of fluids (cm^3)	Relative volume of OMW in water: β					θ_f	Volume of fluids (cm^3)	Relative volume of OMW in water: β				
		1	0.75	0.50	0.25	0.10			1	0.75	0.50	0.25	0.10
0.05	V_w	0	13	27	40	48	0.25	V_w	0	66	133	199	239
	V_{OMW}	53	40	27	13	5		V_{OMW}	266	199	133	66	27
0.10	V_w	0	27	53	80	96	0.30	V_w	0	80	159	239	287
	V_{OMW}	106	80	53	27	11		V_{OMW}	319	239	159	80	32
0.15	V_w	0	40	80	120	144	0.35	V_w	0	93	186	279	335
	V_{OMW}	159	120	80	40	16		V_{OMW}	372	279	186	93	37
0.20	V_w	0	53	106	159	191	0.40	V_w	0	106	213	319	383
	V_{OMW}	213	159	106	53	21		V_{OMW}	425	319	213	106	43

In the second set of experiments, measurements of apparent dielectric permittivity (ε_a) and apparent electrical conductivity (EC_a) were contemporarily taken on soil samples containing mixtures with known different volumetric water content (θ_w) and volumetric OMW content (θ_{OMW}). Further, in the procedure adopted, the volumetric fluid content θ_f $(=\theta_{OMW}+\theta_w)$ and the relative volume of OMW in water $\beta\left(=\theta_{OMW}/\theta_f\right)$, were respectively varied from 0.05 to 0.40 (by 0.05 increments) and 0.10 to 1.0 (with steps of 0.25), in order to reach different levels of soil contamination. Overall there were 40 OMW-contaminated soil samples (table 2).

3. Results and discussion
3.1 Dielectric characterization of OMW-water mixtures

Figure 2 shows a series of TDR waveforms acquired in different OMW-distilled water mixtures.

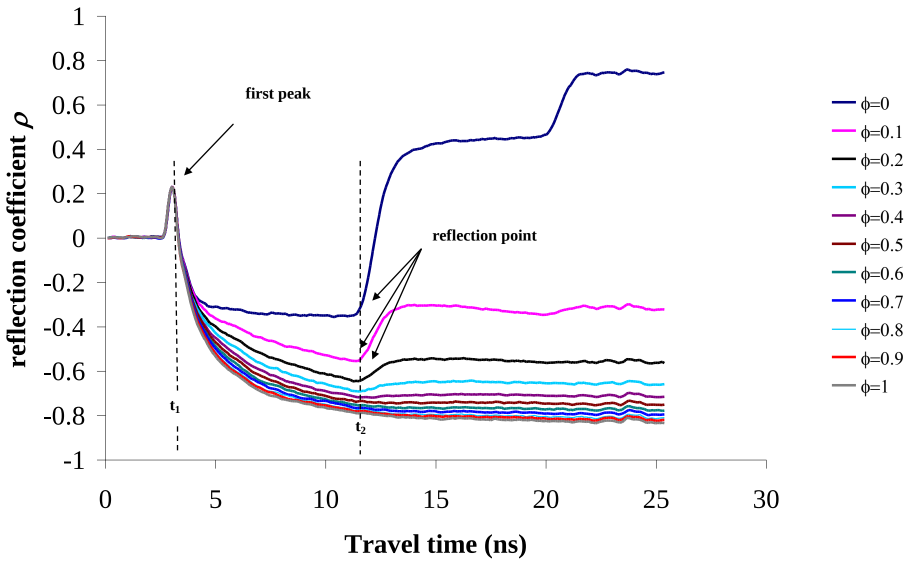

Figure 2. Reflection coefficient (ρ) versus travel time, for different volume concentration of OMW (ϕ_{OMW}) values.

The signal analysis in the time range t_1-t_2 (i.e. between the first peak and the reflection point), indicates partially equivalent travel times, thus similar permittivity values (ε_{sol}≈74-78). In this sense, the graph shows how analyzing the waveforms in the usual range t_1-t_2 does not allow any discrimination between volumetric OMW content (θ_{OMW}) and volumetric water content (θ_w). However at times larger than t_2, the TDR waveforms start to separate and the magnitude of the reflection coefficient (ρ), systematically increases as θ_{OMW} decreases.

3.2 Dielectric characterization of OMW-contaminated soil
Figures 3a and b show respectively the experimental ε_a vs θ_f and EC_a vs θ_f relationships, obtained for selected β values.
Figure 3a highlights that in the observed θ_f domain, the measured dielectric permittivity values of OMW-contaminated soil samples increases as the volumetric fluid content increases. Furthermore, for fixed θ_f values, the experimental data appear practically overlapped (except for θ_f =0.20, 0.35, and partially for 0.40), thus one may deduce that differences in β, which means differences in soil contamination levels, are not necessarily followed by significant ε_a variations. As a consequence, in all investigated cases, any relationship between ε_a and θ_{OMW} can be formalized. On the contrary the apparent electrical conductivity EC_a seems to be a more sensible dielectric property for characterizing OMW contamination in soils. As a matter of fact, figure 3b shows, that EC_a clearly increases with increasing the relative volume of OMW in water β, with a slope increasing as the β value increases.

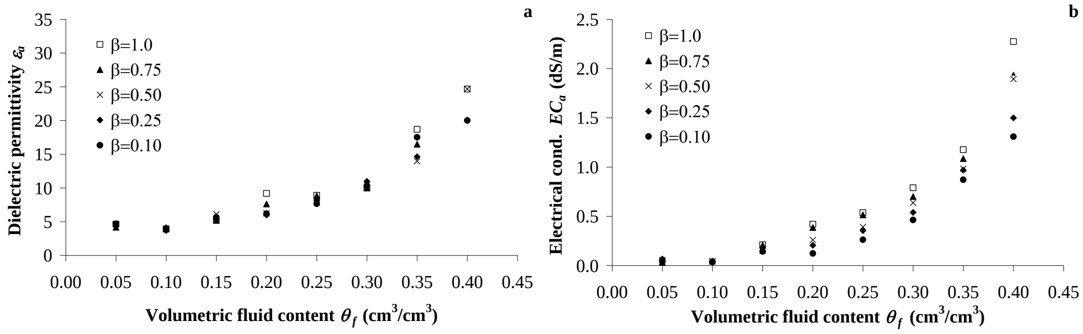

Figure 3. Effect of volumetric fluid content (θ_f) on a) apparent dielectric permittivity (ε_a), and b) apparent electrical conductivity (EC_a), of soil-water-OMW-air mixtures, for different β values.

4. Conclusions

In the present study, we conducted a series of laboratory-scale experiments on OMW soil contaminated samples. TDR measurements of both soil apparent dielectric permittivity (ε_a) and soil apparent electrical conductivity (EC_a) were taken within each investigated sample. The experimental framework was realized with the intention of accomplish, as much as possible, a full factorial plan of electromagnetic characterization of the OMW-contaminated soil samples in the $0.05 \le \theta_f \le 0.40$ domain.

The results showed that the presence of olive mill wastes in the soil influenced the dielectric behavior of the medium in terms of apparent electrical conductivity (EC_a), while the application of OMWs had a minor effect on the apparent dielectric permittivity (ε_a). The research developed can be considered a preliminary analysis using the TDR technique for characterizing the OMW presence in soil. Further experiments will be conducted to develop a dielectric model for θ_{OMW} estimation in soils.

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Time and frequency domain analysis of Solute breakthrough curves (BTCs) for transport parameter estimation in soils

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Keywords: solute transport, frequency domain, moments, estimate of parameters

Abstract
We consider two distinct approaches to estimate solute transport parameters in soils. The first is based on the moments' method, which is by far the most commonly used. The second requires the transport parameters to be determined by optimizing the quadratic differences between the theoretical frequency response, namely the Fourier transform of the *breakthrough curve*s (BTCs), and that estimated by the experimental data. Both the methods were used to analyze a plot-scale solute transport experiment. With respect to the calibration of the advective transport component u of the convection-dispersion equation (CDE), both the methods lead to the same estimate. This is explained by the fact that u is much less sensitive to experimental noise as it is related to the first-order moment of the BTCs. Instead, the dispersivity λ (which regulates the dispersion phenomenon) obtained through the frequency domain response was better than that obtained by the moments method. This difference is attributed to the build-up of the distortion effect due to the experimental errors in the estimate of the higher order moments.

1 Introduction and problem formulation

The study of solute propagation in soils is assuming ever-increasing importance due to the environmental protection issues, and the management of water resources. Both the theoretical and experimental progresses in the recent decades have enabled the formulation of conceptual models for prediction purposes (e.g. Severino and Indelman, 2004). In general, solute transport models are based on the description of a mean convective flow and a complex mechanism of solute particle diffusion/dispersion in the soil pores. By far the most established and widely used model is the convection-dispersion equation:

$$\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial z}=D\frac{\partial^2 C}{\partial z^2} \qquad (1)$$

where $C(z,t)$ represents the solute concentration (also termed *breakthrough curve*) measured at a certain depth z in time t, u is water velocity in the pores, and D is the hydrodynamic dispersion coefficient. The latter is commonly expressed as $D=D_0+\lambda u^{\alpha}$, D_0 [L^2/T] being molecular diffusivity, while λ [L] (termed *dispersivity*) and α [-] are empirical constants. The problem of identifying u and λ (also termed hydro-dispersive parameters) has been extensively treated (e.g. Comegna et al., 2001) by various methods and strategies. One of the most commonly used techniques for estimating hydro-dispersive properties is the moments method.

One of the main objectives in analyzing miscible flow tests consists in so-called data *filtering*, which in practice minimizes the effect of the random (typically accidental) noise. A very effective technique to handle measurement errors is based on using Fourier harmonic analysis and was proposed by Himmelblau (1970) and Gangwal et al. (1971). This method consists in performing parameter estimation, in the frequency domain rather than the time domain (e.g. Duffy and Gelhar, 1985; 1986), optimizing the sum of quadratic deviations between the response in frequency *measured* (i.e. estimated by measurements) and that obtained from equation (1).

This paper aims to analyse several miscible flow tests performed on a plot (Comegna et al., 2005) with the frequency response method and show that the estimate of hydro-dispersive parameters proves more accurate than what would be obtained by the classic method of moments.

2 Method formulation

Classically, moments M_n (with respect to time t) of order n are defined as follows (see e.g. *Papoulis*, 1965)

$$M_n(z) = \int_{-\infty}^{+\infty} t^n C(z,t)\, dt \tag{2}$$

The use of harmonic analysis to estimate u and λ entails application of Fourier transform

$$\tilde{f}(k) = \int dz\, f(z) \exp(-2\pi j k z) \qquad\qquad j = \sqrt{-1} \tag{3}$$

to the theoretical and experimental expression of moments. As regards the analytical expression $\tilde{M}_n$ of moments, this may be obtained by multiplying both the sides of (1) by t^n and integrating:

$$D \frac{d^2}{dz^2} M_n(z) - u \frac{d}{dz} M_n(z) = -n M_{n-1}(z) \tag{4}$$

Then, transforming (4) according to Fourier, we come up with

$$\tilde{M}_n(k) = \frac{n \tilde{M}_{n-1}(k)}{2\pi k} (2\pi k D + ju)^{-1} \tag{5}$$

Plugging n=1 into (5) and normalizing, then

$$\tilde{R}(k) = \frac{u^{-1}}{1 + (2\pi k \lambda)^2} \left(\lambda - \frac{j}{2\pi k} \right) \tag{6}$$

In the frequency domain, parameters u and λ will be determined by setting the following objective function:

$$\mathrm{O} = \sum_i \left| \tilde{R}_i^* - \tilde{R}(k_i) \right|^2 \tag{7}$$

at a minimum. In (7) the quantity $\tilde{R}_i^* - \tilde{R}(k_i)$ represents the deviation between the Fourier transform ($\tilde{R}_i^*$) of the measurement of R and the value of (6).

3 A brief description of the field tracer experiment

Tests were carried out on a sandy soil in the area of Ponticelli (Naples), on a 50m x 7m plot equipped with an irrigation system enabling both well-controlled boundary and a steady-state flow, conditions (for a more detailed description, see Comegna, 2006). The plot was first irrigated for 55 days with fresh water. We then applied to the whole plot surface a pulse of KCl (m=105 g/m^2).

The chlorine concentration $C(z,t)$ was measured at nine depths (z=10, 20, 30, 40, 50, 60, 70, 80, and 90 cm) and at increasing time intervals (t=97, 167, 263, 335, 407, 573, and 742 h). For each time t samples of disturbed soil were taken along set alignments using an Edelman sampler. Water content was determined with the gravimetric method; to determine the chlorine concentration the liquid part was extracted by filtration and on its subsequent titration using an appropriate concentration trasducer.

4 Discussion

By a first glance (figure 1a-1c) at the BTCs estimated by the moments method (solid line) and that of frequency response (dashed line), it is seen that both the methods allowed us to reconstruct the experimental curves pretty well. More precisely, both methods provide practically the same advective velocity u=0.16 cm/h. Furthermore, velocity u calculated as a relation between flow q=0.0417 cm/h and mean water content θ=0.35 (see Comegna, 2006, for more details) is lower, i.e. $u\approx$ 0.12 cm/h. However, this slight discrepancy falls within the range of variability in water content recorded during the test. Furthermore, another parameter tied to the convective component of model (1) is coefficient R which accounts for the delay due to adsorption at equilibrium, i.e., due to particularly rapid diffusions from and towards the stagnant zones. For the experiment at stake, the delay was practically negligible, i.e. $R \approx 1$, even given the fact that the particular soil pH conditions in Ponticelli, the potassium chloride proved sufficiently inert in terms of chemical adsorption.

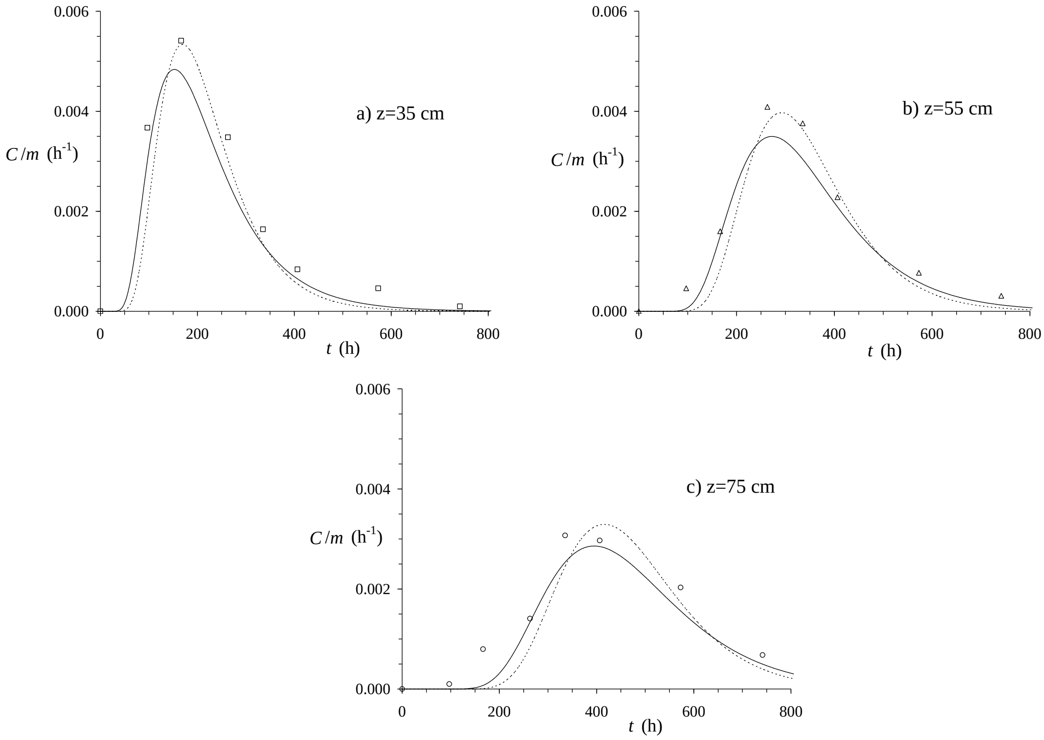

Figure 1. Comparison between experimental data (discrete points) and the breakthrough curves obtained with the moments method (solid line) and the frequency response method (dashed line) at depths of: a) z=35cm, b) z=55cm and c) z=75cm.

Since both methods lead to the same estimates of the convective component, any deviations from the value of u calculated from the flow and water content are likely to be attributed to effects of the spatial variability of hydraulic properties.
By analyzing the breakthrough curves at depths z=35, 55 and 75 cm (see figures 1a-c) the dispersive effect due to the crossing of the porous medium may be appreciated. In particular, the value (i.e. λ=4.3 cm) of dispersivity estimated with the classical method is greater than that obtained by the harmonic analysis (i.e. λ=3.0 cm). This is to be attributed to the fact that the Fourier transform (6) is calculated only for the first harmonics with the consequent "cut" of higher frequencies, which are generally associated with noise. Thus the effect of the Fourier transform of the experimental data is like a "low-band filter" which allows most of the true signal to be preserved (the latter being concentrated around the first harmonics) and the noise due to the experimental error to be held back (at least that characterized by greater frequency). The greater efficiency at estimating the dispersive component λ of the harmonic analysis method may be clearly observed (see figures 1a-1c).

5 Concluding remarks

An extremely important aspect in studying processes of solute propagation in porous media concerns the correct estimation of hydro-dispersive parameters to be used in mathematical models employed to describe such phenomena. In this paper we considered two methods (that of moments and frequency response) to estimate the properties of the convection and dispersion model, with both being applied to a real case. The methods supply practically the same result as regards estimation of the convective component of the process. This is due to the fact that, being essentially tied to the first-order moment, this parameter is a quantity which is relatively "scarcely affected" by measurement error.

To the contrary, we found a higher value of dispersivity λ on using the moments method compared with that obtained with the frequency response method. This discrepancy is to be chiefly attributed to the considerable sensitivity of the moments method towards higher-order terms. However, by the frequency response method we were able to obtain much more robust estimates of λ, the method being based only on the use of first-order moments, and hence less sensitive to noise.

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Removal performance and clogging investigation of an hybrid treatment wetland in Sicily

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Keywords: hybrid constructed wetland, clogging, geophysical methods, tracer test, hydraulic conductivity

Summary

Ttreatment Wetlands (TW_s) are green extensive systems, widely used to treat wastewater with different quality characteristics. Treatment processes occurring in TW_s may result in a gradual clogging of the substrate, with hydraulic fault and/or reduced treatment performance. The aim of this study was to analyze the hydraulic aspects and the performance of a hybrid treatment wetlands (hybrid-TWs), made of three beds in series, used as the tertiary treatment of the effluent of a conventional treatment plant at IKEA Store in Catania.

1. Introduction

Hybrid treatment wetlands (hybrid-TWs) can be applied in order to achieve higher treatment effects, as many of wastewater types are difficult to treat in a single constructed wetland unit, or the pollutants removal efficiency not satisfies the emission standards even more stringent (Masi et al., 2007). One of the most relevant process, which influences the life span of the TWs, is that of clogging, whose main effect is the reduction of the hydraulic conductivity at saturation of the TW porous media. Traditional approaches adopted to monitor the degree and impact of clogging in TWs are based on the hydraulic conductivity (Ks) measurements, tracer tests and physical-chemical characterization of the clog matter. Recent researches have shown that electrical resistivity tomography (ERT) technique can be very useful to investigate the geometry of subsurface flow TW_s as its internal structure and silting up and clogging processes (Casas et al. 2012). This study aims at evaluating the reliability of a hybrid TW system as secondary wastewater treatment system of the IKEA retail store in Eastern Sicily (Italy). In order to prevent the risk of system failure due to clogging, two different approaches based on: (i) the more traditional tracer test, and (ii) ERT technique, were implemented.

2. Materials and Methods

The hybrid-TWs consists of a horizontal subsurface flow bed (HF) and two vertical subsurface flow beds (VF1 and VF2) working in series. The first bed (I stage) is HF which removes organic matter and suspended solids. It has a surface area of about 400 m^2 and is planted for 2/3 with *Phragmites australis*, and for 1/3 with *Iris pseudacorus*, in order to control the expansion of the *Phragmites australis.* The second bed (II stage) is VF1, designed to further removal of organics and to nitrify ammonia to nitrate. VF1 has a surface area of about 580 m^2 and is planted with *Cyperus Papirus var. Siculus* and *Canna indica.* The porous substrate of VF1 is made of volcanic sand (5-15 mm) in the first 0.45 m with, while the remaining part until the bottom (0.30 m) is filled with coarse gravel (25–40 mm). The third bed (III stage) is VF2, which has the same design characteristic of VF1 (size, area, porous medium), but is planted with *Typha latifolia* and *Iris pseudacorus*. VF2 was designed for further removal of total nitrogen and microbiological parameters. Physical-chemical and microbiological analyses were carried out on wastewater samples collected at the inlet and at the outlet of each treatment bed. Clogging phenomena in HF was investigate through in situ measurements of hydraulic conductivity of the gravel bed (Ks) using the falling-head method (Pedescoll et al., 2009), flow paths visualization by means of tracer tests (Aiello et al., 2016) and geophysical electrical resistivity tomography (ERT) (Binley and Kemna, 2005).

3. Results and Discussion

Considering the general performances of the whole hybrid-TW, an improvement in wastewater quality was achieved due to the decrease in the concentrations of most physical-chemical and microbiological parameters (Figure 3.1). The most of the removal processes were obtained at the HF unit, most likely because the influent at that unit was more polluted than in the rest of the hybrid-TW. The mean removal of hybrid-TW were the follwing: 70% COD, 79% BOD5, 84% total suspended solids (TSS), 81% NH_4, 58% of total nitrogen (TN) and 4.0 Ulog of *E.Coli*. The hybrid-TW outlet concentrations always satisfied the national limits for discharge in superficial water (Legislative Decree 152/2006) and only partly have meet the more stringent limits for agriculture reuse (Ministerial Decree 185/2003).

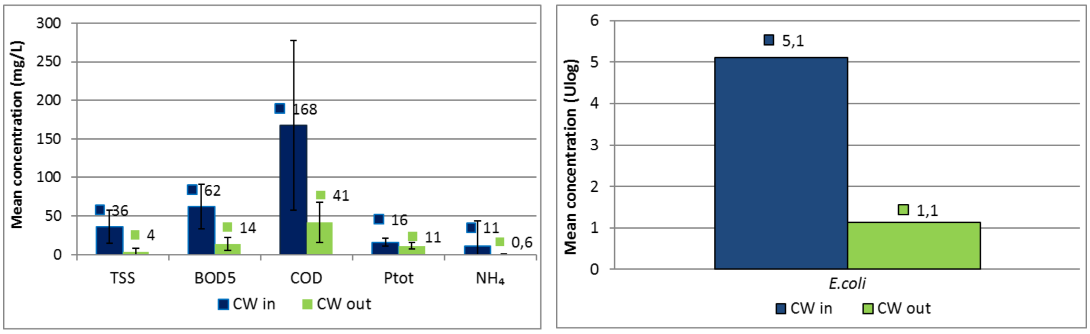

Figure 3.1: Mean of physicochemical and microbiological concentrations at the hybrid-TW

K_s measurements revealed a clear pattern (Figure 3.2) of hydraulic conductivity increasing going from the inlet (167.5 ± 103.9 m d^{-1} and 27.6 ± 10.0 m d^{-1}, in 2016 and 2017 respectively) to the central (390.5 ± 118.6 m d^{-1} and 135.5 ± 31.5 m d^{-1}, in 2016 and 2017 respectively) till to the outlet zone (252.8 ± 51.6 m d^{-1} and 118.6 ± 1.24 m d^{-1}, in 2016 and 2017 respectively) of the HF unit. In 2017, Ks values of the inlet zone were generally 1 order of magnitude lower than those of the middle and outlet zones, as a consequence of clogging of the granular medium that might be occurred in that HF area.

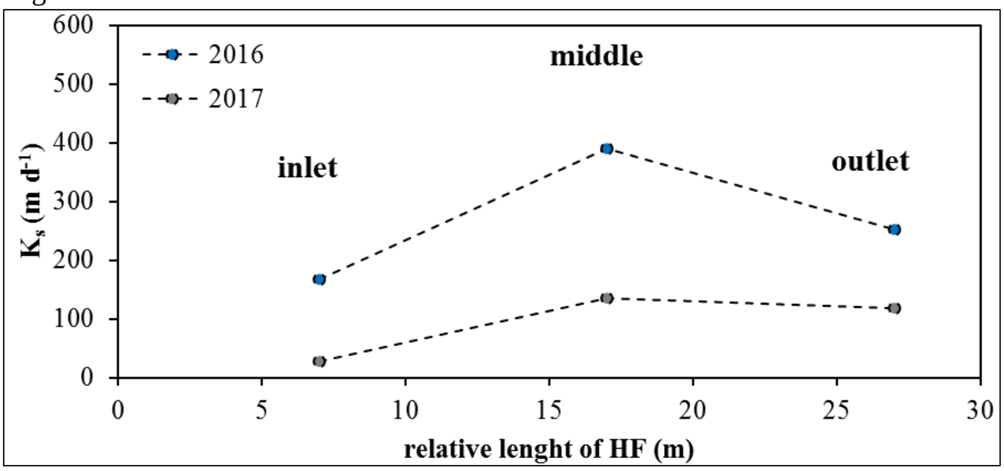

Figure 3.2: Saturated hydraulic conductivity (Ks) values at the different HF sampling locations in 2016 and 2017.

Sodium chloride (NaCl) was chosen for the tracer test in HF unit. The actual residence time, calculated on the basis of the first-moment analysis, was equal to 64 h, 24 h less than the nominal hydraulic residence time (nRT), thus indicating that the available HF volume is not fully utilized.
The breakthrough curve at the HF outlet (Figure 3.3) shows more than one peak, probably due to intermittent loading, with peaks happening at intervals of about 20 hours. The first peak of the tracer concentration time (t_p) was observed at 51.5 h and it is shorter than the nRT (88 h). The corresponding values of hydraulic efficiency (λ), calculated as the ratio between t_p and nRT, was 0.6 and it can be considered quite good according to Persson et al. (1999).

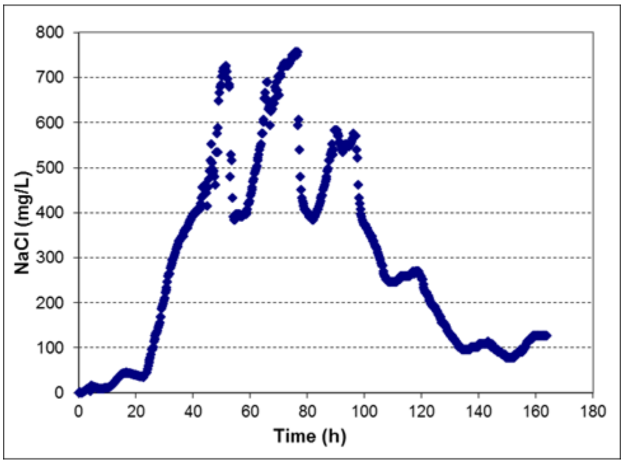

Figure 3.3: Tracer concentration (NaCl) at the HF outlet

Two-dimensional ERT profile surveys (named ERT1 and ERT2) were carried out in 2016 with the aim to identify electrical anomalies caused by a possible clogging of the HF unit (Figure 3.4). Overall between ERT1 to ERT2 slight difference (e.g. not statistically significant) in terms of ER values were observed; ERT1 and ERT2 had average electrical resistivity (ER) of 32 (±23) Ω m and 38 (±16) Ω m. Generally, in the first 3 m of transect line, both ERT1 and ERT2 showed the lower values of ER, thus indicating the presence of an area potentially clogged.

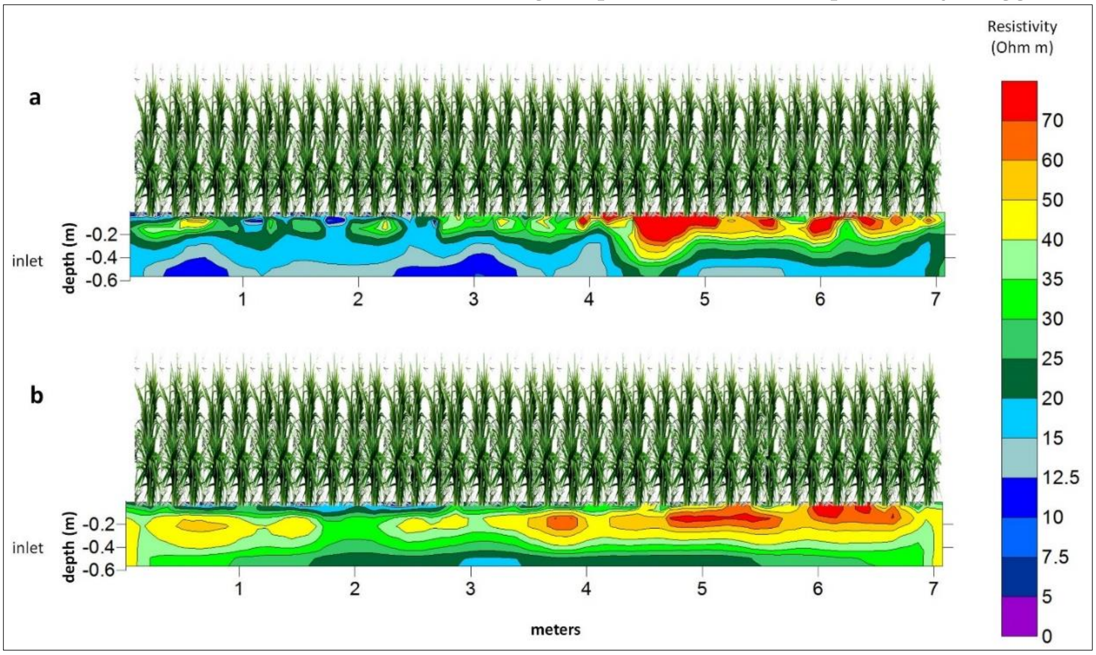

Figure 3.4: ERT data acquired in the HF unit in 2016; ERT1 (a) and ERT2 (b)

4. Conclusion

The hybrid-TW system of the IKEA store in Catania has efficiently removed the main pollutant concentrations (e.g. physical-chemical and microbiological) entering the system and has showed a great capability to manage the high wastewater load variability.
To assess the clogging risk of the TW system, methods based on Ks measurements, tracer tests and ERT provide useful information. Some of these methods are time consuming and may cause some disturbance of the TW beds, the minimally invasive ERT techniques could be a valid alternative, allowing reliable results.

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Identifying suitable sites for underground dams using GIS: a case study in North-East Brazil

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Summary
In arid and semi-arid areas, where rainfall tends to be erratic and unpredictable, concentrated in a few intense storms, water scarcity is a looming threat to water security. Water security is turning into a priority and it can be achieved only through the collection, conservation and wise use of the available water resources. Water harvesting, defined as the concentration and collection of floodwater or rainwater runoff for multi-purpose use, can ensure water availability for domestic and agricultural use. In water scarce areas, the selection of the best sites for the construction of water harvesting structures is often based on farmers' traditional knowledge. Starting from the necessity of strengthening and complementing traditional knowledge in the definition of the best sites, a methodology for the assessment of suitable sites for underground dams construction using spatial multi-criteria analysis is proposed. Spatial data, as slope, rainfall, soil texture and curve number were used. As weighting technique, the analytic hierarchy process (AHP) has been used. The proposed methodology shows promising preliminary results for an early planning to identify suitable sites for underground dam construction.

1. Introduction

The effectiveness of water harvesting in improving yield and reliability of agricultural production has been shown by a large number of studies (Rockström & Falkenmark, 2015). The basic principle behind water harvesting is to capture rainwater falling in a certain area at a certain time, reallocating it over time and within new scenarios (Critchley, 1991); in this way it will ensure water availability not only for domestic and agricultural use, but also for livestock and small-scale industries as well as ecosystem sustenance, aquifers recharge and erosion control. Furthermore, a key element for the implementation of water harvesting methods is represented by the selection of potential sites. A large number of approaches have been developed for water harvesting siting; Geographical Information System (GIS) represents a useful tool in combination with remote sensing, hydrological modelling or both. Nevertheless, in most of the arid areas the selection of the best sites where to realize rainwater structures is almost completely based on the traditional knowledge of local people. Construction of underground water dams (figure 1.1) in the Alagoas region, in North-East of Brazil, has been carried out for ten years by the local NGO, named Cactus.
The selection of the best sites for the realization of the structures is totally founded on information that local population derives from its own life experience and it could require up to six months. Thus, the objective of this study is to create a procedure that allows the integration of scientific based method with local knowledge criteria in selection of the best sites for water harvesting structure.

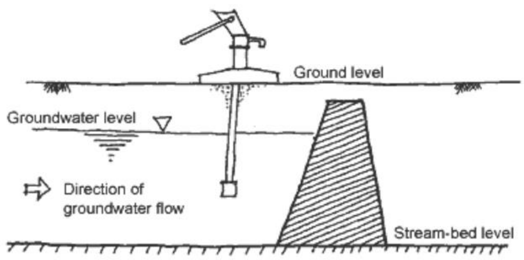

Figure 1.1 Underground dam scheme (VSF, 2006)

Therefore, a GIS based Multi Criteria Decision Analysis (MCDA)(Zionts, 1979) approach is proposed. The approach allowed to integrate and transform spatial data (input) in the decision (output) map, where qualitative information of individual themes and features are converted into quantitative values, by constructing a pairwise comparison matrix. The methodology has been tested on two underground dams' pilot sites, and a more detailed focus has been realised on the surface upstream drainage basin from pilot sites. The analysis of NDVI time series of the area was realised to cross check the siting procedure and to test its validity as indicator for siting procedures.

2. Materials and Methods

2.1 Study area

The study was carried out on a portion of the Alagoas region called *sertao*, in the North-East of Brazil, where the construction of water harvesting structures has been going on since ten years; *sertao* is characterized by a semi-arid climate and a mean annual precipitation between 250 and 500 mm. Moreover, precipitations are confined to a short rainy season that extends from January to April. Rainfall is extremely erratic and in some years the rains are minimal, leading to catastrophic drought. The region is characterized by the existence of a dense network of temporary rivers (Montenegro & Ragab, 2012).

2.2 Methodology

The Multi Criteria Decision Analysis were performed in QGIS environment using the Weighted Linear Combination (WLC) decision rule. Four factors were selected in order to accomplish the analysis: annual rainfall (average monthly rainfall data from 1960 to 2006), slope, soil texture and Curve Number (CN). Then, each factor was reclassified into normalized classes. Normalized reclassification is shown in Table 2.1.

Then, the weights of the themes and their features were assigned and normalized using the Analytic Hierarchy Process - AHP as described by Drobne & Lisec (2009). A pair wise comparison matrix was built, then the relative weights were obtained by calculating the principal eigenvector of the matrix, normalised by the sum of its elements. To perform pairwise comparison, it was decided to consider Texture moderately less important than Rain, CN moderately less important than Texture and Slope moderately less important than CN. Table 2.2 shows the results of relative weights calculations. Then, through the raster calculator, WLC score was calculated as:

$$S = 10 \cdot \sum_i C_i \cdot W_i \tag{2.1}$$

Where Ci is the value of the i-th criteria (rainfall, texture, CN or slope) and W_i is its relative weight. Hence, a suitability map with values ranging from 0 (not suitable area) to 10 (very suitable area) was obtained.

Table 2.1: Input parameter reclassification

Parameter	Rating	Reclassification weights
Rainfall (mm)	≥500	1
	≥300 <500	0.66
	≥100 <300	0.33
	<100	0
Texture	Sand	1
	Medium	0.5
	Clay	0
CN	>0 <30	1
	>30 <40	0.66
	>40 <70	0.33
	>70 <100	0
Slope (%)	<3%	1
	>3% <5%	0.66
	>5% <10%	0.33

	>10%	0

Table 2.2: Pairwise comparison and weights

	Rainfall	**Texture**	**CN**	**Slope**	**Weight**
Rainfall	1	1.67	2	2.5	0.400
Texture	0.6	1	1.43	1.25	0.240
CN	0.5	0.7	1	1.11	0.186
Slope	0.4	0.8	0.9	1	0.173

In addition, the comparison analysis of NDVI (Normalized Difference Vegetation Index) values before and after the construction of two dams was carried out for assessing the fluctuations in vegetation occurring with changes in soil moisture, due to underground dam construction, considering a time span from 2003 to 2010.

3. Results and Discussion

The obtained suitability map shows that the two analyzed underground dams fell within suitable areas, confirming a good site selection through traditional knowledge criteria. In order to further investigate the suitability level of the watersheds of the two dams analyzed, the pixels belonging to the two underground dams basins were reclassified into three classes (Al-Adamat, Diabat, & Shatnawi, 2010), assigning 1 to the ones with value from 0 to 3 (Not allowed class), 2 to pixels with value from 4 to 6 (Least suitable class) and 3 to pixels with value from 7 to 10 (Suitable class). Then, for each watershed the percentage of pixels belonging to the class 1, 2 and 3 was calculated. The results show that there are no pixels in class 1, Not allowed, for both the cases.
Moreover, the NDVI time series comparison shows the presence of healthy vegetation after the underground dam construction, testifying an increase of water presence. According to the literature (Jeyapprabha, 2014) an higher value of NDVI (darker pixels) means higher level of suitability of the site for a dam. This assumption is based on the fact that where the areas are red there is a large number of healthy plants, meaning availability of water in the background and, therefore, that the soil is capable of retaining the water. Thus, it is possible to affirm that NDVI procedure can validate the results obtained with WLC, since the two areas were suitable for the construction of underground dams.

4. Conclusions

Starting from the necessity to strengthen and complement traditional knowledge in the definition of the best sites for underground dams, an instrument was created that is simple, because it is based on the few data available, as well as free, since it is completely developed using open source softwares. The use of MCDA procedure called Weighted Linear Combination allowed to perform a multi criteria analysis, combining weighted factors to obtain a suitability map. The application of the algorithm obtained to the data collected in Brazil, showed an equal suitability of both the sites considered.
Further validations of WLC results have been proceeded through NDVI (Normalized Difference Vegetation Index). Standing that an higher value of NDVI (darker pixels) means higher level of suitability of the site for a dam (Forzieri, Gardenti, Caparrini, & Castelli, 2008), it is possible to affirm that the results obtained through this procedure could validate those obtained through WLC. More studies should be carried out on other sites, but these first results can be considered promising for the integration of local knowledge use in the procedure selection of optimal sites for underground dam construction.

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Rainwater harvesting monitoring through Remote Sensing in Jordan

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Keywords: NDWI, NDVI, Drylands, Sentinel-2

Summary
The use of remote sensing and GIS in water management took a new turn as these techniques have been utilized in new approaches of assessment, management and monitoring of water harvesting interventions. This study focuses on the monitoring of Mankat Alwithar dam in the Mafraq Governorate by using latest Sentinel-2 multi-spectral imagery. Three images of the area from different years (2015 to 2017) were downloaded and an analysis of the NDWI and NDVI was made for the dam and the surrounding area, in order to assess which index could be more suitable. The study showed that the vegetation cover around the dam, monitored through NDVI, was scarce, while the water surface extension was clearly identifiable through NDWI.

1. Introduction

Water scarcity is one of the biggest challenges that the Kingdom of Jordan is facing nowadays. This is due to the natural aridity that characterizes the region, as well as to a high rate of natural population growth, together with huge arrivals of refugees. Hence, Water Harvesting (WH) represents a valid solution to the problem of water shortage in the country (von Mayrhauser, 2012). A key aspect for the implementation of water harvesting methods is represented by the selection of the best sites (Ammar, 2016).
Vegetation health is a key indicator for the effectiveness of WH interventions, as it can be expected to improve when additional water is retained in the soil. The Normalized Difference Vegetation Index (NDVI) is a numerical indicator used to determine the vegetation health through the spectral reflectance measurements, acquired in the visible (red) and near-infrared regions (Deering, 1978).

$$\mathrm{NDVI} = \frac{\mathrm{Xnir} - \mathrm{Xred}}{\mathrm{Xnir} + \mathrm{Xred}} \tag{1.1}$$

Where Xnir is the reflectance of the target in the near infrared wavelength and Xred is the reflectance in the red band. The NDVI is based on the properties of healthy vegetation, which has a high absorbance/low reflectance in the visible portion (photo synthetically active region) of the electromagnetic spectrum while having a high reflectance at the near infrared wavelengths, ranging from −1 to +1, where values near 0 indicate little to no healthy vegetation while negative values typically correspond to snow/ice cover under clear skies, or to cloudy conditions (Case, 2014). Also the changes in the collected water can be a good indicator of the effect of the use of water harvesting systems, considering both the differences in the water stored in the soil and in lakes or ponds. Normalized Difference Water Index (NDWI) is used to monitor changes in water content of the target, using the green reflectance (Xgreen) and the near infrared reflectance, as proposed by Gao in 1996.

$$\mathrm{NDWI} = \frac{\mathrm{Xgreen} - \mathrm{Xnir}}{\mathrm{Xgreen} + \mathrm{Xnir}} \tag{1.2}$$

NDWI can range from -1 (bare land) to 1 (high water depth). The main goal of this paper is to test NDVI and NDWI as monitoring indicators for WH by using latest Sentinel-2 multispectral imagery, in order to get a better knowledge about remote sensing adoption for watershed planning in arid, data scarce and regions.

2. Materials and Methods
1.2 Study area
The study was carried out on the northern of Jordan, in the Al Mafraq Governorate, for the Mankat Alwithar dam (Figure 2.1). The site is located at the coordinates (32°24'44.94''N 36°06'43.17''E)

Figure 2.1: The Mankat Alwithar dam (Google Earth).

The rainy season starts in November and ends by early May. The climate of this Mediterranean basin is also characterized by cool rainy winters and hot dry summers. The mean annual minimum and maximum temperatures in the west are 12.3 °C and 23.1 °C, respectively. The mean annual minimum and maximum temperatures in the east are 9.3 °C and 24.0 °C, respectively (Ozdogan, 2010).

2.2 Methodology
Sentinel-2 images were downloaded, free of charge, from ESA Open Access Hub (https://scihub.copernicus.eu/dhus/#/home). Multi-year satellite images were used to monitor the effect of differences in water retained in the soil due to water harvesting interventions. The work was on three of the images that represented the dam area in the best way and the changes in the water surface and vegetation between the years 2015 and 2017. Changes in vegetation, due to increased water retained in the soil due to water harvesting interventions, can therefore be measured by differences in the NVDI calculated from satellite images. The changes in water in the area were studied by analysing the NDWI (Figure 2.2 and 2.3).

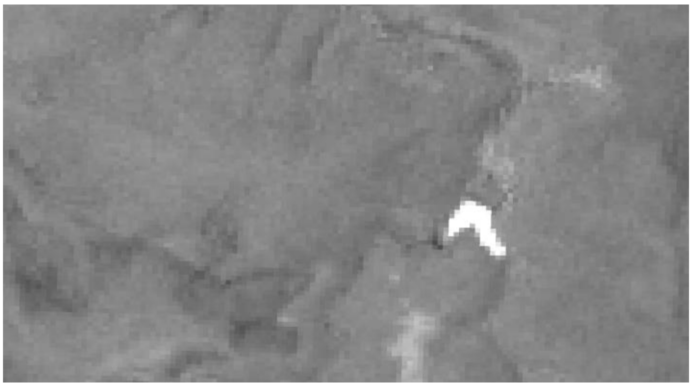

Figure 2.2: NDWI of the study area

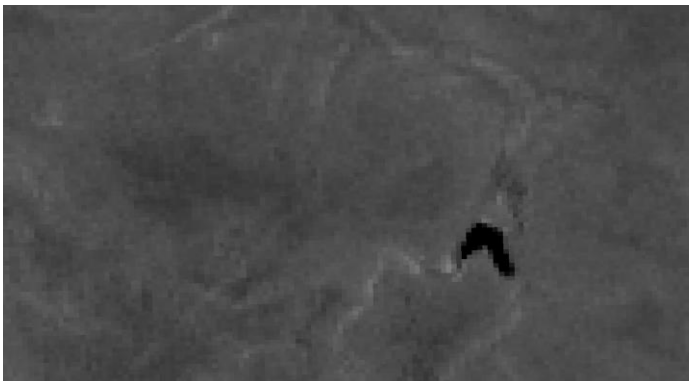

Figure 2.3: NDVI of the study area

3. Results and Discussion

The analysis and monitoring of the photos showed a very low vegetation in the area and the NDVI values were ranging between 0.09 to -0.08.
On the other hand, NDWI images showed a marked variation between the values of the pixels within the dam and the bare soil. A threshold analysis, realized by calculating, for each image, the number of pixels in the area that showed a NDWI value higher than a given threshold, was realized, in order to identify the water surface area. For all the three images under study, the analysis showed small changes of the water surface for high changes in the threshold, indicating a solid identification procedure for monitoring the amount of water present in the dam. The same analysis was realized considering NDVI images, but calculating the number of pixels, and thus the area, below a certain threshold, since the NDVI of water bodies is usually negative. The results were not encouraging, given the confusion between water pixels and other areas with generically low NDVI.
In the framework of this analysis, Sentinel-2 imagery offered offers great resolution (10m for red, green and near infrared images). Besides that, Sentinel-2 offers a wide range of applications for WH monitoring and planning, thanks to the availability of 12 spectral bands with a resolution ranging from 10 to 60 m. In addition to this, in the context of very arid climates like Jordan, the common problem of cloud cover for visible wavelength remote sensing will be less relevant.

4. Conclusion

The work provided useful insights on the use of NDVI and NDWI as indicators for monitoring water harvesting structures in arid climates like the Kingdom of Jordan. NDWI showed better results, by detecting clearly the extent of water bodies, while the traditional use of NDVI for vegetation monitoring was not possible due to the aridity of the terrain. The attempt of detecting water bodies with NDVI showed results not at the level of NDWI. However, the use of Sentinel-2 imagery allowed to identify clearly a small water body like the Mankat Alwithar dam, given its high resolution of 10 m.
The results of the study indicate the suitability of the use of Sentinel-2 monitoring for water harvesting, and the promising adoption of NDWI. Further developments of the analysis should focus on the application of the methodology to new case studies, to test NDWI for the detection of water content of subsurface water harvesting systems (sand dams) and to assess the suitability to the use of remote sensing monitoring for multiple water harvesting structures, to support water management planning.

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Leaf Area Index from Landsat-8: review and comparison of existing algorithms applied to mixed agricultural and forest areas.

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Summary
The use of remote-sensed data in agriculture and as source of input data for hydrological modeling has become very important in recent years. In particular, several methodologies have been developed to quali-quantitatively investigate the vegetation condition, leading to the setup of different vegetation indexes. Among them, Leaf area index (LAI) is one of the most important quantity governing the physical and biological processes of plant canopies and soil water consumption.
In this study, we present a comparison of the most popular models used to retrieve LAI applied in a study area located in Capitanata region (Southern Italy), where five dominant land use classes have been analyzed in their space-time variability.

1. Introduction
The Leaf Area Index is an important vegetation biophysical parameter, defined as a ratio of leaf area to unit ground surface area *(Watson, 1947)*. This index is related to several vegetation exchange processes, providing information on changes in productivity or climate impacts on ecosystems. In literature it is possible to find many algorithms to its retrieval *(Viña, 2011; Ganguly, 2012)*. The choice of the model to use become thus crucial for any kind of application.
The following research aims to compare different models of LAI, undergoing the following steps: first, through the USGS archive we selected a sample of images acquired by Landsat-8 satellite, from 2013 to 2016, with 30m of spatial resolution. Subsequently, we carried out a classification of soil based on different uses, which led to the identification of five land use classes. Then, images were preprocessed through Envi and Matlab softwares, in order to isolate a particular sub-region and apply correction of cloudiness and radiometric calibration.
Therefore data processing consisted of vegetation indices calculation: NDVI (Normalized Difference Vegetation Index) *(Rouse et Al., 1974)*, WDVI (Weighted Difference Vegetation Index) *(Clevers, 1988)*, and EVI (Enhanced Vegetation Index) *(Liu and Huete, 1995)*. Then, LAI algorithms were chosen and applied. Finally, multi-temporal statistical analysis was carried out to evaluate the most performing models for every land cover category, according to existing experimental data.

2. Materials and Methods
The acquisition of the satellite images was obtained through the use of USGS resources EarthExplorer and LandsatLook Viewer. The formerly selected area corresponds to the WGS 84/UTM zone 33N, referring to, respectively, WRS-2 Path/Row 188/31 and 189/31. After the first selection, the sample underwent a pre-processing phase in order to manage the cloudiness, apply the radiometric calibration (Top of Atmosphere Reflectance) and select the same ROI (Region of Interest) on every scene. In particular, a ROI of 21 km x 21 km was chosen, on the basis of its variety in land cover and soil use, as well as the availability of previous studies conducted in the given area.
Before the analysis, a subdivision of the land cover and soil use was performed within the ROI, by means of a thematic map and a classification table. Five predominant land uses were selected: Forest, Mediterranean shrubland, Wheat crops, Pasture, Olive grove.
Therefore, an extensive literature review was performed, leading to the choice of six algorithms to be tested: 1. LAI-WDVI *(Clevers, 1989)*, 2. LAI-EVI *(Boegh et Al., 2002)*, LAI-NDVI: 3.

Beer *(Baret et Al., 1989)*, 4. Caraux-Garson *(Caraux-Garson et Al., 1998)*, 5. Peterson *(Peterson et Al., 1987)*, 6. Nemani-Running *(Nemani and Running, 1989)*, as summarized by Table 2.1. The parameters appearing in some models (i.e. LAI based on Beer's law and LAI function of WDVI) were calibrated based on previous studies conducted in compatible areas, as illustrated by Table 2.2.

Table 2.1: Models of LAI employed in the analysis.

Index	LAI	Model	Type
NDVI	$-0.39+6*NDVI$	Caraux-Garson	Linear
NDVI	$-\frac{1}{k}\ln\left(\frac{NDVI_{can}-NDVI}{NDVI_{can}-NDVI_{back}}\right)$	Based on Beer's law	Non-Linear
NDVI	$0.65e^{\frac{NDVI}{0.34}}$	Nemani-Running	Non-Linear
NDVI	$\left(0.52\left(\frac{NDVI+1}{1-NDVI}\right)\right)^{1.715}$	Peterson et Al.	Non-Linear
WDVI	$-\frac{1}{\alpha}\ln\left(1-\frac{WDVI}{WDVI_{\infty}}\right)$	Clevers	Non-Linear
EVI	$3.618*EVI-0.118$	Boegh	Linear

Table 2.2: Calibration of the parameters of LAI based on Beer's law

Parameter	Forest	Mediterranean shrubland	Wheat crops	Pasture	Olive grove
k	0.47 *(Bréda, 2009)*	0.212 *(Gigante et Al., 2009)*	0.17 *(Gigante et Al., 2009)*	Monthly calibrated *(JRC)*	Monthly calibrated *(JRC)*
$NDVI_{can}$	Global max. increased with $\varepsilon = 0.0001$ for every area				
$NDVI_{back}$	Local min.	Local min.	Global min.	Local min.	Local min.
α	0.39 for every area *(Vanino et Al.,2015)*				
$WDVI_{\infty}$	Global max. increased with $\varepsilon = 0.0001$ for every area				

Our research included a sample of 34 images. For each image, six LAI maps have been generated. A statistical analysis was performed on the available dataset through Matlab software. In particular, the analysis covered three test cases: i) for each land use class, the six LAI patterns during 2014 (the only year with at least one image per month); ii) for each LAI model, the pattern of the five land use classes; iii) for each land use class, the LAI trend in July and in December within the period 2013-2016.

3. Results and Discussion

The employment of the reference data on support of our results was set up as follows: for forest, we considered the results accomplished in *(JRC)* and (Iacobellis et Al., 2015), for Mediterranean shrubland and pasture, we took the dataset available in *(NASA Land Data Assimilation Systems)*, for wheat crops we were supported by the studies conducted in *(JRC)* and *(Iacobellis et Al., 2015)*, for olive grove, because of the unavailability of a complete dataset, we relied on the results obtained in *(Cermak et Al., 2007)* and *(Iacobellis et Al., 2015)*.

To appreciate the performances of the six LAI models, three metrics were considered: a) the seasonal trend during the year and b) the bias with respect to literature values; and c) the statistical dispersion of each class.

The study valued the performances of models for each land category, to identify the ones which best approximated the reference data, and the performances of each model for all the categories, to ratify whether a given model would branch its answers out according to zones with different traits.

The results can be summarized as follows: for the year 2014, every model showed a good and diversified response to different soils, except of LAI-WDVI, which also exhibited a low range of values, being suitable to describe olive grove only, and, generally performing poorly in the application in zones with high expected values of LAI. LAI-EVI showed, in every case, an

inadequate range of values, characterizing, although not outstandingly, the Mediterranean shrubland only. For the LAI-Beer, a high sensitiveness to the calibration parameters was recognized, along with conspicuous fluctuations and values not always in line with literature. This model characterized in an admissible way forest and wheat crops only but, to be considered promising, it strongly needs to be recalibrated with a set of parameters as specific as possible.
Peterson's model resulted highly accurate for wheat crops, performing quite correctly in pasture as well, while it showed an unsatisfactorily high and fluctuating range of values for Mediterranean shrubland, olive grove and, especially, forest.
Finally, Nemani-Running and Caraux-Garson models performed accurately for all land use classes except of olive grove. In particular, the former promisingly approximated reference data for pasture and Mediterranean shrubland, and, subsequently forest; the latter performed reliably in forest and Mediterranean shrubland, secondary, in pasture and, eventually, in wheat crops.

4. Conclusion

This research laid the foundations for a further characterization of the examined zone and the trends highlighted in the observation time span.
The most suitable LAI models, estimated through the comparison with experimental or literature data, and valued by means of given metrics, were identified: without a specific ground-truth calibration, the best performing model is the Caraux-Garson along with the Nemani-Running. All other methods evidence a high sensibility to the surrounding soil and to the empirical parameters used.
Further analysis may consider the use of a larger sample of images, including other satellites and expanding the period of observation. Also, it could be useful to examine other aspects related to soil and vegetation, such as rainfall, soil moisture, temperature, etc. Additionally, a parameter recalibration of LAI based on Beer's law is needed. Finally, it would be crucial to enhance experimental data in support of the analysis.

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The production of traditional pasta: a case study in Tuscany

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Keywords: Life Cycle Assessment, environmental sustainability, pasta production

Summary
The major pasta industries have started to evaluate the impact of their production through the Life Cycle Analysis (LCA) or the Environmental Product Declaration (EPD®), according to ISO 14040 and 14025 standards. In this work a production chain of a traditional pasta was investigated and compared with some commercial and conventional products. Results indicate that the traditional pasta may cause impacts of 1.160 kg of CO_2eq emissions and 11.360 of MJ of fossil energy consumption per each kg of dried pasta produced, without considering the phases of distribution and domestic cooking.

1. Introduction

The major pasta industries have started to evaluate the impact of their production through the Life Cycle Analysis (LCA) and, in some cases, even through the Environmental Product Declaration (EPD®), according to ISO 14040 and 14025 standards, making information on the environmental impact of pasta production widely available. For smaller producers instead this process is not always easy to access, especially for niche products such as those made from traditional processes or old wheat varieties, so there is scarcity of this data in the reference databases for environmental analysis also because systems of food production are strongly national or site specific.
The scope of this work is therefore to make a detailed analysis of the life cycle of the entire process of high quality pasta production following the traditional process and with the use of an old wheat variety in an Italian agricultural farm.

2. Materials and Methods

The present work developed a cradle-to-gate LCA for the production of traditional pasta. Particularly, a comparative LCA was implemented with the purpose of highlighting the main differences between the production of traditional and commercial/conventional pasta as well as the most critical steps from an environmental point of view together with possible solutions aimed at reducing their impact. The analysed chain of pasta production included the following stages: durum wheat cultivation, milling of durum wheat to obtain semolina, pasta production and packaging, transportation and wastes management. The distribution phase from the producing industry to the final user was neglected, whilst the domestic cooking was simply estimated. The inventory data were collected in three firms located in Central Italy: Montepaldi farm (Firenze, Tuscany, Italy) for wheat cultivation, Molino Silvestri (Torgiano, Umbria, Italy) for wheat milling, Pastificio Artigianale Fabbri (Strada in Chianti, Tuscany, Italy) for pasta production. Then the pasta is commercialized with the Montepaldi brand. Using these data, an LCA according to the ISO 14040 standards was carried out. The food chain was modelled through the Gemis® software, setting a functional unit of 1kg of dried pasta. Particularly the whole system was modelled considering the annual production of 1,500 kg of dried pasta that is the pasta marketable, even if the produced amount is equal to 1,788 kg. Data were referred to the annual production of the Montepaldi pasta: the agricultural data concern the year 2012, whilst other phases concern the year 2011. Anyway no differences in term of production yield, input and output quantities were observed in these two years, therefore no criticisms were highlighted in the modelling process. Figure 2.1 illustrates the main inputs, the agricultural operations and the outputs, i.e. the product and the residues taken into account in the present work for the LCA development.

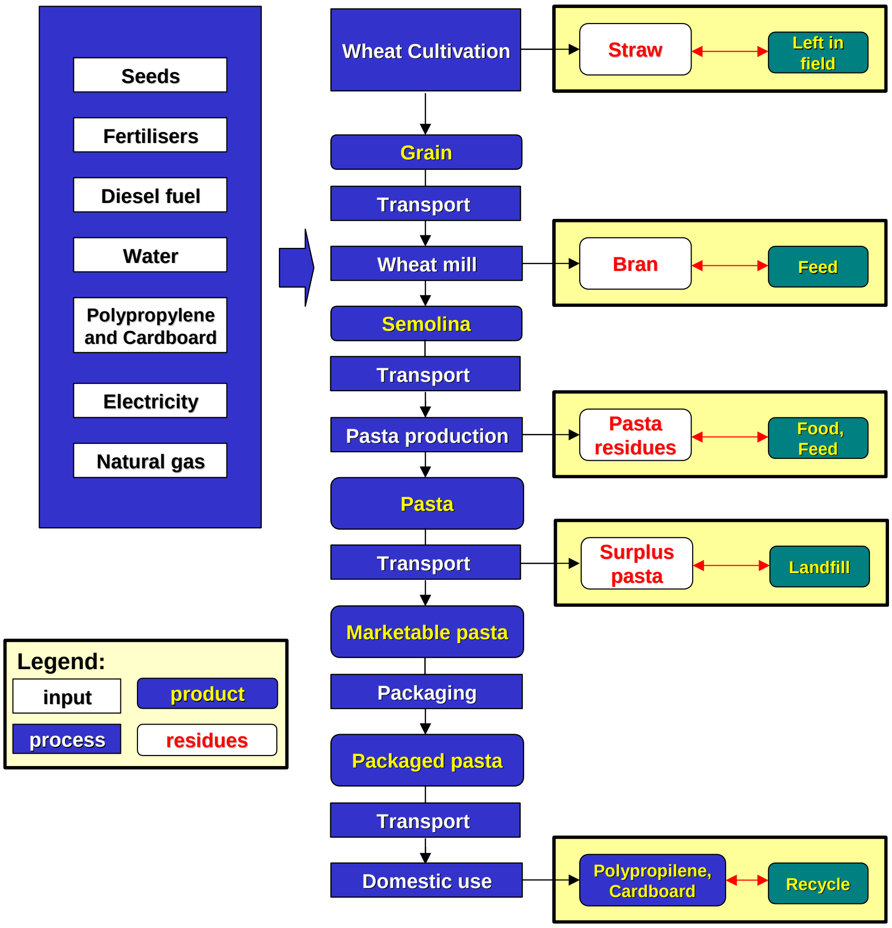

Figure 2.1 - System boundaries of the production of traditional pasta for the Life Cycle Assessment implementation.

However, the adopted approach provides several exclusions for the data collection and the inputs estimation:

- materials needed for construction and maintenance of machines and equipments as well as construction materials of farm buildings and machines (Chiaramonti and Recchia, 2010);
- no transports associated to fertilisers and other agrochemicals delivered to the farm were considered;
- depuration treatments of the wastewater of the production plants;
- energy and resources consumptions due to the administrative activities;
- the ink consumption and the printing for the packaging of the product.

The methodology was applied for determining the following environmental pressures: the effects on the global warming through the quantification of the CO_2 equivalent emissions (CO_2eq) taking into account the carbon dioxide (CO_2), the methane (CH_4) and the nitrous oxide (N_2O) emissions and using the Global Warming Potential GWP100 factors (IPCC, 2001) and the primary energy consumption through the Cumulated Energy Utilisation (CEU), representing the fossil energy required for extracting, manufacturing and disposing raw and auxiliary materials.

3. Results and Discussion

Tables 3.1 and 3.2 report the inventory data of the Montepaldi system: the first one concerns the inputs whilst the second one illustrates the outputs.

Table 3.1: Inventory data referred to 1 kg of pasta for the inputs of the Montepaldi system.

Input	Unit	Value
Seeds production	kg	0.114
P_2O_5 fertiliser production	kg	0.044
N fertiliser production	kg	0.017
Drinking water	kg	17.735
Diesel fuel	MJ	4.395
Electricity	MJ	0.922
Natural gas	MJ	11.334
Polypropylene for wheat big bag	kg	0.007
Polypropylene for pasta packaging	kg	0.017
Polypropylene for semolina packaging	kg	0.014
Cardboard packaging	kg	0.208

Table 3.2: Inventory data referred to 1 kg of pasta for the outputs of the Montepaldi system.

Output	Value [kg]	End of life
Marketable pasta	1.000	Consumption for food
Surplus pasta	0.192	Waste disposal (landfill)
Wastewater	5.593	Depuration plant
Steam	0.490	Atmospheric emission
Straw	2.533	Left in field
Bran	0.434	Feed
Pasta residues	0.083	90% for food; 10% for feed
Polypropylene	0.041	Recycling
Cardboard packaging	0.194	Recycling

Concerning the inputs, the amounts of fertilisers are very reduced because in the Montepaldi farm only one fertilisation is carried out. The water consumption is mainly due to the washing of equipments and machines (31.9%) as well as the domestic cooking (56.6%). The quantity of the water needed for the pasta production is confirmed by the values reported in (BREF, 2006) and ranging between 22 and 30 kg per 1 kg of semolina. For the domestic cooking, data were collected from (Bevilacqua et al., 2007; Ruini et al., 2009). For the milling no fossil energies are used except the diesel fuel needed for the forklift truck. Moreover the diesel consumption for the agricultural operations (2.048 MJ) results lower than this illustrated in other studies (EPD De Cecco, 2011), because of the reduced number of operations for wheat cultivation. Anyway the huge energetic requirement is due to the transports (3,405 MJ): even if from the pasta production plant to the Montepaldi farm only a distance of 19 km is accounted, 12 travels are necessary for moving the produced pasta. Table 3.3 reports the environmental impacts for the Montepaldi system. The LCA results show emissions of 1.160 kg of CO_2eq per kg of dried pasta produced and 1.982 kg if the domestic consumption phase is considered. Results highlighted values lower than those accounted in the EPD® of Barilla (1.332 kg per kg of pasta) and De Cecco (1.490 kg per kg of pasta kg per kg of pasta). Similar considerations can be achieved for the CER that results lower than the amounts accounted for Barilla or De Cecco pasta (11.360 MJ kg^{-1} vs 16.000 MJ kg^{-1} and 12.973 MJ kg^{-1} respectively). Concerning the CO_2eq emissions the main critical phases are the wheat cultivation (31.3%) and the pasta domestic consumption (41.5%). Even if for the CEU results the domestic cooking represents the 53.7% (16.651 MJ per kg of dried pasta) of the total fossil energy consumption (28.011 MJ per kg of dried pasta). The diesel fuel is the second resource needed and could be reduced through the logistics optimisation.

Table 3.3: LCA results referred to 1 kg of pasta for the Montepaldi system.

	CO_2eq emissions [kg]	CEU [MJ]
Diesel fuel consumption	0.367	5.033
Electricity consumption	0.115	1.527
Natural gas consumption	0.819	15.038
Seed consumption	0.038	0.140
N-fertilisers use	0.114	0.871
P_2O_5-fertilisers use	0.061	0.809
Water consumption	0.007	0.104
Polypropylene use	0.085	2.226
Cardboard packaging	0.165	2.220
Straw emissions	0.211	-
Total without domestic use	1.160	11.360
Total	1.982	28.011

4. Conclusion

The results have highlighted that the analysed traditional chain causes lower environmental impacts than those associated with the industrial chains. Critical points are the transports between the firms and in the distribution phase, together with the final use of the product. Moreover, results indicate that the traditional pasta may cause impacts of 1.160 kg of CO_2eq emissions and 11.360 of MJ of fossil energy consumption per each kg of dried pasta produced, without considering the phases of distribution and domestic cooking.

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Life cycle assessment and environmental evaluation of agricultural mechanisation: potentiality, unsolved issues and possible interactions

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Keywords: environmental impact, machinery field operations, SCR and EGR

Summary
This study shows how the LCA approach applied to agricultural field operations can be a useful tool to evaluate the performance of different technologies applied to machinery, finalised to the reduction of the environmental impact of agricultural systems. Three different cases were investigated: the first two concern the use of tractors adopting advanced technologies for pollutant emissions reduction (i.e. EGR and SCR) and the last considers the machinery used for the seedbed preparation for arable crops, carried out using different soil tillage equipment.

1. Introduction

Agriculture is responsible for a considerable environmental impact and mechanisation is related to a share of these negative effects. Although in the last decades standardised and extensively accepted methods for environmental impact assessment were developed, their application to mechanical field operations is still limited. This is mainly due to the difficulties for inventory data collection characterised by site and time variability and to the carefulness of machinery manufacturers that are developing concerns about farmers' perceptions. Nevertheless, without the possibility of assessing the impact it is impossible to quantify the reductions achievable with new machines and innovations in technologies.
This study is focused on the application of Life Cycle Assessment (LCA) approach to the environmental impact assessment of machinery field operations. In detail, the aim of this study is twofold: 1) to show how LCA can be a useful tool to analyse, from an environmental point of view, the different machinery field operations; 2) to discuss limits and unsolved issues of this approach applied to mechanisation, aiming to the identification of possible solutions.

2. Materials and Methods

The Life Cycle Assessment (LCA) is a standardised method adopted worldwide for quantifying the potential environmental impacts of processes for products or services during their whole life cycle, using a holistic approach. There are four steps in LCA, the second of which is the Life Cycle Inventory (LCI) data collection, where the flow of materials and energy from the studied systems and the environment are identified and quantified. These data cannot be always directly measured, depending on several variables, such as pedo-climatic (e.g. soil texture and water content), site-specific (e.g. field shape, slope) and logistic (e.g. annual working time) conditions. To overcome this problem, specific databases have been developed for retrieving data. However, it must be considered that the processes available in the databases only rarely take into account the same pedo-climatic and logistic conditions. As a consequence, they do not allow to achieve affordable results. The processes can be modified and made more reliable using measured data or further information estimated with models able to take into account the site-specific characteristics. Thus, in this study, the LCA approach was applied to three cases:
<u>Case 1</u> - A harrowing carried out in a sandy-loam soil with a rotary harrow (10 cm depth, 3 m width) coupled with tractor A (max power 82 kW, minimum specific fuel consumption 225 g/kWh, not equipped with EGR, emission stage Stage 2, 66.2 g CO/ha, 40.284 kg CO_2/ha; 229.6 g NO_X/ha) and B (max power 82 kW, minimum specific fuel consumption 238 g/kWh, equipped with EGR, emission stage Stage 3A, 56.3 g CO/ha; 43.299 kg CO_2/ha; 134.4 g

NO_X/ha). In detail, EGR works by recirculating a portion of the engine's exhaust gas back to the engine cylinders. This dilutes the O_2 in the incoming air stream and provides gases inert to combustion to act as absorbents of combustion heat, to reduce peak in-cylinder temperatures and as a consequence the NOx generation. This happens because NOx is produced in a narrow band of high cylinder temperatures and pressures. Nevertheless, EGR shows some disadvantages: the main of them is a reduction of the engine efficiency, i.e. an increase in specific fuel consumption of 4-10% (Volvo, 2010); an increase of 5% was considered in this study.

Case 2 - A 35 cm depth ploughing carried out on a medium textured-clayey soil with a 4-furrows plough coupled with tractor C (158 kW, specific fuel consumption 200 g/kWh, equipped with SCR, emission stage Stage 3B, AdBlue® consumption 4% vol/vol) and D (152 kW, specific fuel consumption 213 g/kWh, not equipped with SCR, emission stage Stage 3A). Details about the field tests carried out can be found in Pessina and Facchinetti (2013). The SCR (Selective Catalytic Reduction) converts in molecular nitrogen and water the NOx, using ammonia (NH_3) as reducing agent. The reducing agent is carried on board of the tractor as AdBlue®, an aqueous solution containing 32.5% urea. In this after-treatment system, the urea injected in the exhaust gas stream is converted to NH_3 through the process of thermolysis and hydrolysis. Respect to EGR, the adoption of SCR highlights some advantages, such as higher specific power output, improved engine life and a lower specific fuel consumption, due to an increase in fuel efficiency ranging between 4 and 5% (Maiboom et al., 2009; Volvo, 2010). Nevertheless, AdBlue® is consumed. In this case, LCA was used to evaluate if, from an environmental point of view, the reduction of pollutants and the increase in fuel efficiency offset the environmental impact related to AdBlue® consumption.

Case 3 – Three different alternative solutions for seedbed preparation of arable crops (e.g. maize) in medium textured soils of Northern Italy were compared. A 35 cm depth primary tillage and a secondary tillage (8 cm depth) were taken into account. Each solution, carried out by means of different machines (Table 1), considers a proper coupling between the tractor and the implement.

Table 1: Composition of the three compared seedbed solutions.

Solution	*Primary Tillage*	*1st secondary tillage*	*2nd secondary tillage*
A	*Disc plough*	*Spring tine harrow*	*Spring tine harrow*
B	*Disc plough*	*Rotary harrow*	---
C	*Mouldboard plough*	*Spring tine harrow*	*Rotary harrow*

Secondary data about diesel and liquid urea production as well as tractor and implement manufacturing, maintenance and disposal were retrieved from Ecoinvent 3 (Weidema et al., 2013). The energy consumption for the production of 1 kg AdBlue® was 0.07 kWh of electricity and 1.71 MJ from natural gas.

Life Cycle Impact Assessment was carried out using the ReCiPe Midpoint method (Goedkoop et al., 2008) for the following impact categories: climate change (CC), ozone depletion (OD), terrestrial acidification (TA), freshwater eutrophication (FE), marine eutrophication (ME), photochemical oxidant formation (POF), particulate matter formation (PM), metal depletion (MD) and fossil depletion (FD).

3. Results and Discussion

Table 2 reports the comparison for the harrowing carried out with a tractor not equipped with EGR (Stage 2) and the one equipped with EGR (Stage 3A). The reduction of nitrogen oxides emissions achieved with the EGR allows considerable benefits for the environmental categories deeply affected by these pollutants (TA, POF, ME and PM), but also a worsening of the environmental results for CC, OD and FD, due to the slightly higher fuel consumption in respect to Stage 2.

Table 2: Results for the harrowing carried out with the tractor equipped or not with EGR.

Impact category	Unit	Tractor A Stage 2	Tractor B Stage 3A	Δ%
CC	kg CO_2 eq	56.59	59.02	+4%
OD	mg CFC-11 eq	8.827	9.245	+5%
TA	kg SO2 eq	0.235	0.184	-22%
FE	kg P eq	0.006	0.006	0%
ME	kg N eq	0.012	0.009	-30%
POF	kg NMVOC	0.344	0.251	-27%
PM	kg PM10 eq	0.109	0.092	6%
MD	kg Fe eq	3.877	3.885	0%
FD	kg oil eq	17.386	18.162	+4%

The environmental comparison between the ploughing carried out with tractor C (Stage 3B) and tractor D (stage 3A) is reported in Table 3. The use of AdBlue® has a negligible effect on the evaluated impact categories (<2% - data not shown), but allows to reduce considerably the environmental impact affected by NOx and NMVOC emissions (i.e. TA, ME, POF, PM), while, for the other impact categories, the reduction is almost completely related to the reduction of fuel consumption.

Table 3: Results for ploughing carried out with the tractor equipped or not with SCR

Impact category	Unit	Tractor C Stage 3B	Tractor D Stage 3A	Δ
CC	kg CO2 eq	151.22	157.50	-4%
OD	mg CFC-11 eq	24.690	25.746	-4%
TA	kg SO2 eq	0.289	0.772	-63%
FE	kg P eq	0.0091	0.0092	-1%
ME	kg N eq	0.0099	0.0432	-77%
POF	kg NMVOC	0.345	1.215	-72%
PM	kg PM10 eq	0.1159	0.369	-69%
MD	kg Fe eq	5.675	5.769	-2%
FD	kg oil eq	47.27	49.22	-4%

Concerning the case 3, Figure 1 shows the comparison among the three different seedbed solutions. Solution B with two secondary tillage operations shows the highest impact for almost all the evaluated impact categories. Nevertheless, it is interesting to underline that for FE and ME, the impact is similar to the one of solution C, in which only one harrowing is performed. Between solutions A and C, A shows the best results for seedbed preparation, even if primary tillage has a higher impact.

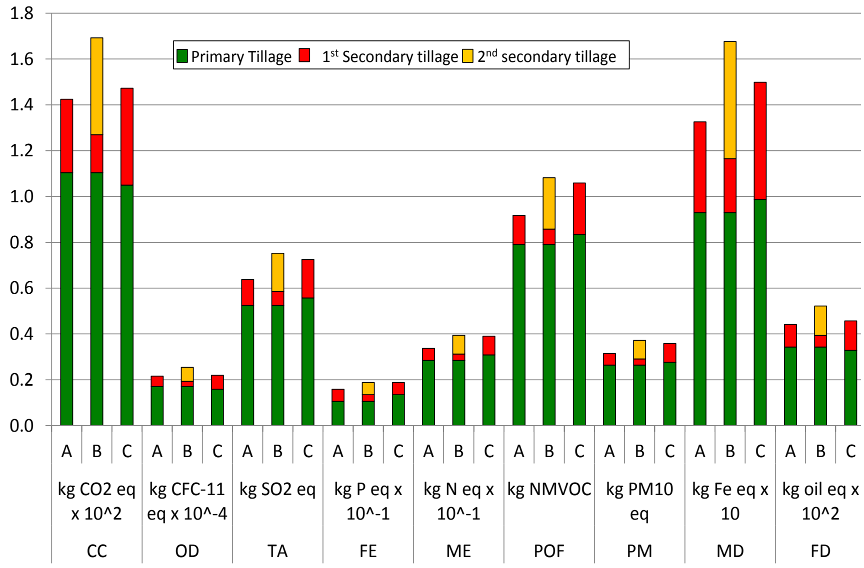

Figure 1: Comparison among the different solutions for the seedbed preparation.

4. Conclusion

The outcomes of this study show how the LCA approach can be useful to highlight, from an environmental point of view, the performances of different mechanical solutions in agricultural field operations, as well as the benefits arising from the development and application of new technologies. As shown for the comparison between tractors equipped or not with EGR, not in all the cases the introduction of new technologies allows to achieve environmental benefits for all the evaluated impact categories. For what concerns the assessment of mechanised operations, the use of reliable local data (such as concerning working time, fuel, lubricant and tyres consumption, type and age of tractors, emissive stage and combustion emissions) represents the key aspect, because these parameters deeply affect the environmental results.

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Developing a new tool for assessing environmental emissions of tillage operation

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Keywords: LCA, Environmental emissions, Agricultural practices, Tillage

Summary
In order to assess the environmental impacts of agri-food systems, life cycle assessment (LCA) based approaches have been extensively applied to different food products. The results of such kind of studies often indicate that the agricultural phase, and especially tillage operation, is the most impacting life cycle stage of such systems. During this stage, emissions of agricultural field operations can contribute largely to the various impact categories. However, these operations have received relatively scant attention in LCA studies and the available databases of LCA software do not provide sufficient data for accurately calculating pollutant emissions of agricultural operations. The objective of this study is to develop a new tool for estimating more detailed and specific datasets for analyzing environmental emissions associated with tillage practices in different conditions. This paper estimates diesel fuel and lubricant consumption and also depreciated weight of tractors and implements using existing formulations. Different scenarios were identified by considering tillage operations by different operational parameters, namely working speed, field efficiency, working width, soil condition, tractor power and tractor type. Overall, this new tool will allow LCA practitioners to develop more specific and precise environmental analyses of tillage operations for agri-food systems.

1. Introduction

The Life Cycle Assessment (LCA) methodology typically includes four phases consisting of goal and scope definition, inventory analysis, life cycle impact assessment, and interpretation of the results. Since the inventory fulfilment is complex and time consuming, often, precompiled datasets from commercial databases are used to complete the inventory accounting (Mousavi-Avval et al., 2017a, Notarnicola et al. 2017).
In LCA of agri-food systems, the agricultural stage is responsible for notable environmental emissions, such as climate change, acidification, eutrophication, ozone depletion and mineral and fossil resources depletion (Mousavi-Avval et al., 2017b). In spite of the important contribution of field practices to the environmental profile, the available datasets concerning such agricultural practices are not sufficiently detailed to effectively model the emissions in different field conditions. The local characteristics are difficult to obtain, to measure or even to implement in a database (Bengoa et al., 2014).
A review of the literature revealed that there is some scientific literature on investigating fuel consumption and environmental emissions of agricultural operations in realistic operational conditions (Lindgren et al., 2010; Lindgren and Hansson, 2004). However, most of them are experimental works dealing with specific machines and in specific conditions. Lovarelli et al. (2017) developed a tool to support the completion of an inventory reliable for local conditions of agricultural operations. However, the selected parameters were considered based on an experimental work in the Po Valley area located in Northern Italy and these parameters are not easily measurable as they require detailed information about the operation that is not available in general.
The objective of this study is to introduce a new tool for quantifying the inventory of tillage operations by mouldboard plough. Primary tillage operation is a basic operation and, even if considerable technical developments have already been reached, tillage is one of the most

frequent environmental hotspots of the agricultural phase of agri-food product systems (Fusi et al., 2014; Lovarelli et al., 2017).

2. Materials and methods

In this study fuel and lubricant consumption during primary tillage operations are calculated and associated to environmental emissions, together with those of fuel and lubricant in the production stage. Moreover, the depreciated weight of tractor and ploughing machines are estimated. In order to calculate fuel consumption during the tillage operation with a mouldboard plough, the drawbar power and power take-off (PTO) requirements were calculated based on the ASAE standards (ASAE, 2006). Furthermore, fuel and lubricant consumption were estimated by considering available and required power in different conditions.
Draft is defined as the force required to pull an implement in the horizontal direction of travel. To calculate the draft requirement, both the functional draft (soil resistance) and the draft required to overcome rolling resistance of the implement are included.
For tillage tools operated at a depth, draft depends upon soil texture, depth, and geometry of the tool. Typical draft requirements can be calculated as follows (ASAE, 2006):

$$\mathrm{D} = \mathrm{F_i}[A + B(S) + C(S)^2]WT \quad (2.1)$$

where D is implement draft; F is a dimensionless soil texture adjustment parameter (F_1=1.0, F_2=0.70, F_3=0.45); i = 1 for fine, 2 for medium and 3 for coarse textured soils; A, B and C are machine-specific parameters. These parameters vary based on the type of machine for different operations. For example, for ploughing with mouldboard plough these parameters are as: A=652, B=0.0, C=5.1; however, they don't vary based on different types of mouldboard plough; S is field speed, km/h (7 km/h for operation with mouldboard plough); W is machine width, (0.3 m for a furrow of mouldboard plough); T is tillage depth in cm.
To convert draft requirement into drawbar power requirement, the speed of the operation needs to be considered. After calculating the drawbar power requirement, the PTO power requirement can be calculated based on the drawbar performance of tractor.
To determine the diesel fuel consumption by a tractor operating under a range of load conditions, over a period of time, equation (2.2) was applied (ASAE, 2006):

$$\mathrm{SFC_{diesel}} = 2.64\mathrm{X} + 3.91 - 0.203\sqrt{738\mathrm{X} + 173} \quad (2.2)$$

where SFC_{diesel} denotes specific diesel fuel consumption for a specific operation, in L/kWh; X is the ratio between the equivalent PTO power required by tillage operations and the maximum available power from the PTO.
By considering the rated engine power, P in kW, specific lubricant consumption, in L/h, is calculated using equation (2.3) (ASAE, 2006):

$$\mathrm{SLC_{lubricant}} = 0.00059P + 0.02169 \quad (2.3)$$

In this study six parameters were considered: width of ploughing, tractor power, field condition, depth of tillage, soil condition, and tractor type. Also, different possible values for each of these parameters were considered. These parameters are presented in Table 1.

Table 1: Parameter Selection

Parameter level	Tool	Width	Tractor power (kW)	Field type	Depth	Soil condition	Tractor type
1	Moldboard Plow	Small	Less than 60	Open field	Shallow depth	Firm	2WD
2	Moldboard Plow	Medium	60-86	Orchard	Medium depth	Medium	MFWD
3	Moldboard Plow	Large	86-112	-	Deep	Soft	4WD
4	Moldboard Plow	-	More than 112	-	-	-	Track

Some scenario examples:
Implement/Width/Tractor power/Field type/Depth/Soil condition/Tractor type (**Bolded** word indicates the changed parameter of that scenario compared to the first one)

111111- Moldboard Plow/Small/Less than 60/Open field/Shallow depth/Firm/2WD
111112- Moldboard Plow/ Small/Less than 60/Open field/Shallow depth/Firm/ ***MFWD***
111121- Moldboard Plow/ Small/Less than 60/Open field/Shallow depth/ ***Medium*** */2WD*
*111211- Moldboard Plow/ Small/Less than 60kW/Open field/****Medium depth****/Firm/2WD*
*112111- Moldboard Plow/ Small/Less than 60kW/****Orchard****/Shallow depth/Firm/2WD*
*121111- Moldboard Plow/ Small/****60-86 kW****/Open field/Shallow depth/Firm/2WD*
211111- Moldboard Plow/ ***Medium****/60-86 kW/Open field/Shallow depth/Firm/2WD*
*342334- Moldboard Plow/****Large/More than 112 kW/Orchard/Deep/Soft/Track***

3. Results and discussion

In order to develop a LCI of tillage operations, fuel consumption, lubricant consumption, depreciated weight of tractor and mouldboard plough were estimated.

To calculate fuel consumption, six parameters were considered. By taking into account all of the parameter levels, 864 different scenarios were simulated. For the tillage operation, draft and power requirements were calculated by operational parameters of the implement; the available power was calculated by considering engine power and efficiency rate. Consequently, the *X* parameter, which is the ratio of equivalent PTO power required by tillage operation to the maximum available one from the PTO, was estimated. By considering possible scenarios of suitable match between tractor power and required power, scenarios with X value between 0.4 and 0.9 were considered as possible solutions. Finally, from the 864 scenarios, 410 were found to be suitable solutions, 152 scenarios were not suitable solutions, and 302 were found to be not possible. Fig. 1 presents fuel consumption values for the 410 scenarios for tillage operations with a mouldboard plough. Diesel fuel consumption ranged from 12.6 to 76.0 L/ha, with the average of 34.15 L/ha.

By taking into account the 410 possible scenarios, lubricant consumption for tillage operation of one hectare with a mouldboard plough was calculated. Lubricant consumption ranged from 0.05 to 0.24 L/ha, with the average of 0.12 L/ha, and standard deviation of 0.04 L/ha.

By considering the 410 possible scenarios, the depreciated weight of the tractor and the mouldboard plough were estimated and the results revealed that the depreciated weight of the tractor ranged from 0.18 to 0.71 kg/ha, with the average of 0.36 kg/ha. The depreciated weight of the mouldboard ranged from 0.46 to 0.60 kg/ha, with the average of 0.53 kg/ha, and standard deviation of 0.07 kg/ha.

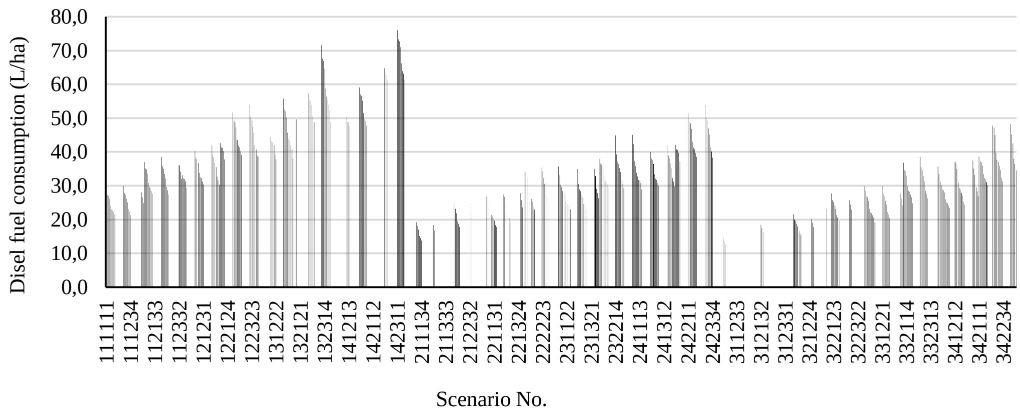

Figure 1: Diesel fuel consumption for 410 scenarios for tillage operation

4. Conclusions

In this study the LCI of tillage operations in different conditions was conducted. Totally, for 410 scenarios of tillage operation, fuel consumption, lubricant consumption, and depreciated weight of tractors and mouldboard plough were estimated. The results revealed that in tillage operations with a mouldboard plough with different operational parameters there are large variations. With this tool it is possible to customise the agricultural inventory and adapt it to specific conditions.

This approach also allows for a more accurate estimation of materials consumption that supports interpretative analyses aimed at improving the environmental performance of the system under study.

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Carbon storage assessment in Valle Camonica forest ecosystems: the first step to promote a local voluntary carbon market for climate change mitigation

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Keywords: Forest inventory, Forest Typology, Carbon storage, Carbon pools, Voluntary Carbon Market, Climate change mitigation

Summary
Voluntary Carbon Markets (VCMs) are currently developed worldwide. In Italy, the scientific aspects concerning the processes of greenhouse gas (GHG) emissions and storage in forest ecosystems were investigated but, up to now, there are only few existing experiences that give an economic value to such processes. Thus, the objective of this study was to propose an innovative approach to estimate the total stored carbon in Valle Camonica (Lombardy Region) forest ecosystems, also taking into account stored carbon variation over time due to improved forest management practices. First results obtained show that living biomass (aboveground and belowground) is an important carbon pool because it can stock about the 80% of the total stored carbon ($2.2 \cdot 10^6$ tons and $2.7 \cdot 10^6$ tons, respectively). To achieve a higher carbon storage, improved forest management practices, such as conversion of aged and/or abandoned coppice to tall trees and/or reduction of cutted wood biomass volume, can be adopted. Such additional stored carbon could be converted in carbon credits that could be certified and marketed in a local VCM, which is the starting point for a local low-carbon emissions economy. Moreover, with improved forest management practices, more wood biomass per hectare can be obtained. This additional biomass could be cut and used for energy purposes, supporting the reduction of fossil sources use and, thus, contributing to an indirect environmental local decarbonisation and a multifunctional forest resources utilization as well.

1. Introduction

The positive role played by forest ecosystems in climate change mitigation is politically and scientifically recognized worldwide. Because the issue of increasing the greenhouse effect is one of the most important key elements in raising public awareness, VCMs are currently developed worldwide. This form of exchange is promoted both by public and private sectors and the offer is often generated by a spontaneous demand, driven by ethical and social motivations, not imposed by binding targets, as is normally the case of regulated markets[1]. To establish local VCMs is a key element for sites characterized by extensive forest areas, potentially able to generate carbon credits, which represent the exchange units to promote GHG neutralization actions, linked with environmentally impacting local goods (products and/or services). Processes of GHG emissions and storage in forests through VCMs were investigated also in Italy, but only few experiences were conducted to give an economic value to such processes. Valle Camonica seems to be suitable and ready for the development of a local VCM, thanks to the fact that there are: (i) extensive forest areas, (ii) lots of forest inventory data collected in Forest Plans (FPs) and (iii) many manufacturing activities and a well-developed economy.

The objective of this study was to propose an innovative approach to estimate the total stored carbon in Valle Camonica forest ecosystems. The tool, based on present situation, give also the possibility to analyze future scenarios resulting from improved forest management practices.

2. Materials and Methods

Up to now, because of data availability, only public forest areas were taken into account. The first step was the collection of the most important forest inventory data related to each forest particles (total: 2027) classified in each of the 45 FPs of Valle Camonica: (i) particle location (inside or outside the "Adamello Regional Park"), (ii) forest typology (classification unit which includes trees subjected to the same evolutionary pressure and pedoclimatic conditions) and possibly its variants (total number of forest typologies and variants: 66), (iii) forest government (coppice or tall trees), iv) forest function (such as productive, protective, naturalistic and recreational), (v) forest area (ha), (vi) growing stock volume (m^3), (vii) current wood increment ($m^3 \cdot year^{-1}$) and (viii) eventual wood biomass cut ($m^3 \cdot year^{-1}$). Data were organized in a MSExcel database in which each particle represents a record. Such database is structured in 4 different scenarios: (A_1, BAU_N) Business As Usual, to analyze the carbon storage occurred from 1984 (starting year of the oldest FP) to 2016 (current situation), (A_2, BAU_F) BAU in future, to assess, from 2017 to 2029 (deadline year of the most recent FP), the carbon storage variation due to the simply trees cut, (B_1, SST_N) Sustainable, to evaluate the carbon storage from 1984 to 2016 in the case of application of improved forest managements practices, (B2, SST_F) Sustainable in future, identical to the A_2 scenario, but based on improved forest management practices.

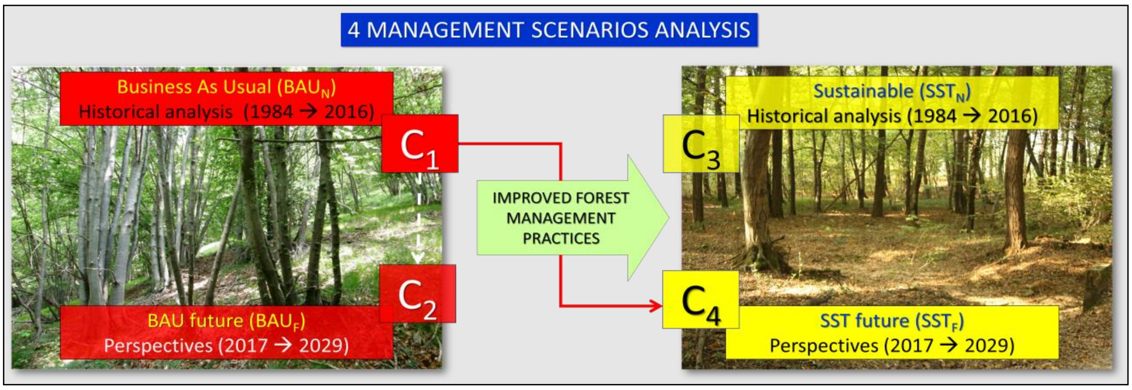

Figure 2.1: representation of the database for the estimation of the total stored carbon in Valle Camonica public forest areas. Coppice (left) can be converted in tall trees (right) to increase wood biomass volume per hectare and thus carbon storage capacity.

Within each scenario, for each forest particle, growing stock volume of the current year (GS_n; m^3) was calculated, starting from growing stock volume in the previous year (GS_{n-1}; m^3), adding the current wood increment (I_n; $m^3 \cdot year^{-1}$, assumed constant and independent of trees age), and subtracting losses due to eventual wood biomass cut in the current year (H_n; $m^3 \cdot year^{-1}$):

$$GS_n = GS_{n-1} + I_n - H_n \tag{2.1}$$

Growing stock losses due to natural mortality were not taken into account. If data on current wood increment were not available from FPs, specific values based on weighted averages and bibliographic information were used[2]. Starting from GS_n, stored carbon at the end of the timeframe and its variation over time were estimated in 4 different carbon pools: (i) aboveground biomass (C_{ab}; t) (ii) belowground biomass (C_{bb}; t), (iii) dead wood (C_{dw}; t) and (iv) litter (C_{li}; t) applying the general methodology defined by the Intergovernmental Panel on Climate Change (IPCC)[3,4,5]:

- $C_{ab} = GS \cdot BEF \cdot WBD \cdot C_f$ (2.2)
- $C_{bb} = GS \cdot WBD \cdot R \cdot C_f$ (2.3)
- $C_{dw} = GS \cdot BEF \cdot WBD \cdot DMCF \cdot C_f$ (2.4)
- C_{li}: estimated applying different linear relations, reported in the EU Project *"CArbon and NItrogen cycling in Forest ecosystems (CANIF)"*, according to the type of forests (coniferous, broadleaves and rupicolous forests)

where:

- GS = growing stock volume (m^3);
- BEF = biomass expansion factor (total aboveground biomass volume on growing stock volume);
- WBD = wood basic density ($t_{dm} \cdot m^{-3}$);
- R = root-shoot ratio (belowground dry biomass on growing stock dry biomass);
- DMCF = dead mass conversion factor (dead wood dry matter on aboveground biomass dry matter);
- C_f: dry matter carbon fraction (stem of different tree species).

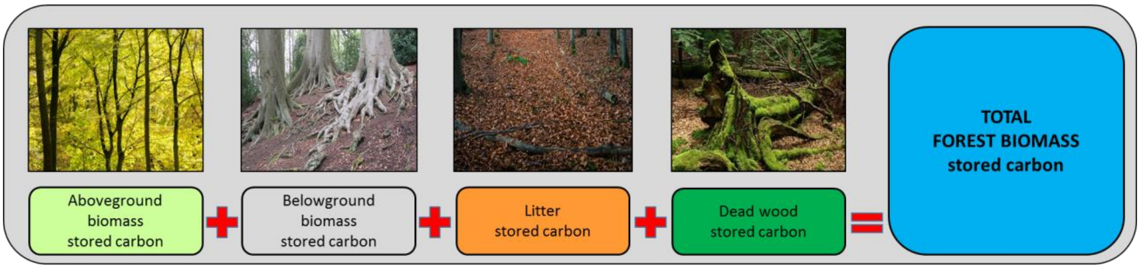

Figure 2.2: Forest carbon pools taken into account for biomass carbon storage estimation.

According to the "*Italian National Inventory Report for Forest Land Carbon Pools to UNFCCC (NIR 2006, 2007)*", specific values of BEF, WBD and R were used. Dead wood stored carbon was estimated applying a DMCF average value of 0.17 (as indicated by IPCC for deciduous and evergreen forests ecosystems). For each forest typology, specific values of C_f were used; if not available, general values[6] of C_f = 0.508 (coniferous) and C_f = 0.477 (broadleaves) were taken into account.
The sum between the total stored carbon in aboveground biomass (C_{ab}; t) and the total stored carbon in belowground biomass (C_{bb}; t) gives the total stored carbon in living biomass (C_{lb}; t), while the sum between the total stored carbon in dead wood (C_{dw}; t) and the total stored carbon in litter (C_{li}; t) gives the total stored carbon in dead biomass (C_{db}; t).
Finally, for each forest particle, the sum between the total stored carbon in living (C_{lb}; t) and dead biomass (C_{db}; t) gives the total stored carbon in biomass (C_{tb}; t):

$$C_{tb} = C_{lb} + C_{db} \tag{2.5}$$

By Aggregation, the total stored carbon in Valle Camonica public forest areas was estimated.

3. First results and Discussion

Up to now, only the first scenario (A_1, BAU_N) was computed. Results show that, in 2016, total stored carbon (forest areas: 36740 ha; growing stock: $6.7 \cdot 10^6$ m^3) achieves approximately $2.7 \cdot 10^6$ tons; about the 80% of such carbon ($2.2 \cdot 10^6$ tons) is stored in living biomass (aboveground and belowground). Taking into account forest government, about the 88% of the total carbon ($2.4 \cdot 10^6$ tons) is stored in tall trees (forest areas: 31200 ha; growing stock: $6.1 \cdot 10^6$ m^3), while the remaining 12% ($3.1 \cdot 10^5$ tons) is stored in coppice (forest areas: 5540 ha; growing stock: $5.3 \cdot 10^5$ m^3). Moreover, taking into account forest particle location, about the 60% of the contribution to the total carbon stock ($1.7 \cdot 10^6$ tons) comes from particles which are outside the Adamello Regional Park, while the remaining 40% ($1.0 \cdot 10^6$ tons) comes from particles that are inside the Park.

4. Conclusion

By the described approach, it was possible to estimate the total stored carbon in the public forest areas of Valle Camonica in the current year (2016) taking into account the contribution of 4 different carbon pools. The next step of the study will concern the analysis of the total stored carbon variation in case both of current and improved forest management practices, such as conversion of aged and/or abandoned coppice to tall trees and/or reduction of cutted wood biomass volume. Such practices are generally connected with a higher carbon storage. This additional stored carbon can generate credits that could be certified and marketed in a local

VCM, which is the starting point for a local low-carbon emissions economy. Moreover, with improved forest management practices, more wood biomass per hectare can be obtained. This additional wood biomass could be cut and used for energy purposes, supporting the reduction of fossil sources use and, thus, contributing to an indirect environmental local decarbonisation and a multifunctional forest resources utilization as well. At last, another important aspect that will be analyzed concerns the estimation of the total stored carbon in private forest areas (about 23560 ha).

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Monitoring mangrove forest in the South coast of Sancti Spíritus province (Cuba) through Landsat 8-OLI images.

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Keywords: mangrove forest, remote sensing, monitoring

Summary

In the coastal zones of tropical and subtropical regions, fragile ecosystems like deltas, mangrove forest and swamps, among others, are widely diffused. The National Hydrographic Basin Council of Cuba promotes the river basins as basic unit for an integrated management of hydric resources aiming to maximize social and economic wellbeing, without implicating negative impacts on vital ecosystems. This research, part of a wider PhD project carried out at UNIVPM of Ancona, has focused on Zaza River basin (Central region of Cuba) where, as consequence of an inefficient management of water resources to meet agricultural and civic needs, the mangrove forest suffers a significant decay. For the environmental services that mangrove forest offers, supporting ecological equilibrium in coastal areas, the monitoring of mangroves is a very important goal to promote an effective sustainable management of hydric resources at basin level. Specific objectives of the research are: 1) characterise environmental issues affecting the mangrove forest. 2) analyse relationships between phenology and spectral behaviour of species shaping the mangrove forest. 3) experiment an effective approach in mapping the mangrove forest by using RS techniques. This way it could be defined a methodological model for monitoring environmental diseases of mangroves in all costal area of Cuba island.

1. Introduction

In Cuba, hydrographic basins are the functional basic units for programs and plans aiming to integrate the management of natural resources with economic and social development. Among natural resources, water is an essential components of wellbeing and productivity. For the Caribbean small islands (e.g. Cuba, Grenada, Antigua-Barbuda) freshwater shortage is a serious problem because water supply is depending on rainwater, mainly. To fight this risk the implementation of an Integrate Water Resources Management (IWRM) approach at river basin level should be the more useful strategy to manage water resources in a sustainable way so achieving long-term social, economic and environmental benefits (GWP, 2000). Unfortunately, the sectoral approaches in water resources management have dominated and are still prevailing at world level. This leads to a fragmented and uncoordinated management of hydric resources (GWP, 2000) and related impacts. Furthermore, in fragile ecosystems (deltas, mangrove forest, swamps) of tropical and subtropical coastal zones, impacts generated by water deficits are dramatically increasing because of anthropogenic global warming (IPCC, 2001). In Cuba, human activities have generated multiple environmental problems within hydrographic basins as consequence of deterioration and depletion of natural resources (deforestation, biodiversity erosion, degradation of soils, water pollution). A loss of stability in natural ecosystems and cultural landscapes has derived (González et al., 2012). If we consider that hydrographic basins of Cuba host very sensitive ecosystems, such as in coastal zones, this condition is particularly negative and small environmental changes can generate significant negative impacts. It is the case of mangrove forests, fragile ecosystems of tropical and subtropical climates associated at deltas and coasts. Temperature, salinity, sediment and energy conditions in these ecosystems must be keep optimal to maintain a good ecological equilibrium. The mangroves are defined, according to Feller and Sitnik (1996), as a set of tropical trees and shrubs which grow in the inter sea zone, constituted by 16 families with 40 to 50 species approximately. By using special devices for breathing, viviparity and long term germinative power mangroves can grow in extreme conditions of aquatic and saline environment, muddy and unstable. The forest of mangroves is an high specialized open ecosystem of great importance in the ecology of coastal zones (Cintron et al., 1980), which dies abruptly when one of parameters of its environment is modified. Mangroves are linked with terrestrial ecosystems by fluvial systems, delivering nutrients and exporting detritus. The alteration of the natural flows of nutrients brings serious alteration in the structure and productivity of such ecosystem. That is why the tropical coasts, for such small they can be, are the first places where detect the variation of water flow (Blasco, 1991) as consequence of climate change or incorrect management of water at basin level. For these reasons, monitoring the ecological state of mangrove forest is an important ecological goal (Blasco et al., 1998; Gilman et al., 2008). Frequently, Remote Sensing techniques are used to this purpose (Kuenzer et al., 2011). Unfortunately, up today in Cuba only environmental and phenological variables of mangroves have been considered by applying traditional investigation tools (Menéndez et al., 2006). The focus of this study was appointed on the mangrove forest in the Southern coast of province of Sancti Spíritus (central region of Cuba) which is suffering human impacts due to irrational managing of hydric resources at basin level and natural impacts caused by hurricanes and tsunamis. A multitemporal set of Landsat – 8 OLI images and the Multiple Endmember Spectral Mixture Analysis (MESMA) methodology (Roberts et al., 1998; Somers & Asner, 2013) were used to analyse spectral behaviour of mangrove species, with the aim to improve the mangrove forest mapping.

2. Materials and Methods

The study area is located in the central region of Cuba within the Zaza River basin, the second basin for extension (2413 km^2) in the island, which is characterised by several environmental issues, as well as for the economic and demographic importance. The remotely data set was made by ten multispectral images Landsat – 8 OLI (path: 14 / Row: 45) ranging from November 2014 to December 2015, selected from the Geological Service of the United States (http://earthexplorer.usgs.gov/). A sub-set of spectral bands, with a ground resolution equal to 30 m x 30 m, was processed to convert radiance into reflectance and generate geometric correction into UTM, Zone 17 N system. In particular the band 2 (0.452 – 0.512 µ), the band 3 (0.533 – 0.590 µ) and the band 4 (0.636 – 0.673 µ) in the VIS region; the band 5 (0.851 – 0.879 µ) in the NIR region; finally the band 6 (1.566 – 1.651 µ) and the band 7 (2.107 – 2.294 µ) in the SWIR region were selected. Ground truth of mangroves species (*Rhizophora mangrove, Avicennia germinans, Laguncularia racemosa, Conocarpus erectus*) were collected on August and September 2015 through field surveys in 61 plots of 10 m x 10 m each one, according to the Cuban "Protocol for monitoring the mangrove ecosystems" (Menéndez et al., 2006). Plots were selected within the deltaic zones of Jatibonico del Sur river, Agabama river, Zaza river (Southern coast of Sancti Spiritus province). To describe spectral behaviors of mangrove species the average response (at 95% of confidence) of pure pixels for each species and all Landsat selected bands (VIS, NIR and SWIR) were elaborated. This allowed to get more light on the spectral behavior of each mangrove specie in relation with phenology and climatic season.

Finally, using the VIPER tool (Roberts et al., 2007), the MESMA methodology was applied to the February 2015 Landsat image, which represents the dry season, and to July 2015 Landsat image, representing the rainy season. Also a multitemporal image of 2015 (February, March, May and July) was processed by MESMA. This allowed to generate a series of fraction images, according to this methodology, related to monotemporal images or multitemporal image. The fraction images were used firstly in a qualitative way, assembling several RGB compositions with aim to visualize the spatial distribution of each fraction (class) within the study area. Secondly, a basic segmentation method (density slice) was applied to each fraction image (mono and multitemporal, classes number ranging from 4 to 8) for analyzing through the traditional Confusion Matrix technique the accuracy corresponding at different level of purity (or mixing) of different species of mangrove. This allowed to obtain very interesting results in order to the spectral separability among the different species

3. Results and Discussion

The first results of this research has been the description of the spectral behaviour of the three species of mangrove considered in the study (Red Mangrove or *Rhizophora mangrove,* Black Mangrove *or Avicennia germinans*, White Mangrove *or Laguncularia racemose* plus *Conocarpus erectus)* in the VIS, NIR and SWIR spectral regions. In the VIS spectral region there are not evident differences among the species, while in the NIR region the Red Mangrove and the White Mangrove in the SWIR regions have shown significant differences from others cover types (the other two type of mangroves, other vegetation, forest with all species of mangrove). Secondly, it was possible to relate the spectral behavior of all species of mangrove to the different climatic seasons and phenological stages. In the dry season (e.g. February) all species show more elevated values of reflectance in VIS region, while reflectance values go below in the rainy period (e.g. July). An opposite situation can be observed in the NIR region, mainly for Red Mangrove, whose reflectance become higher in the rainy period when flowering, fructification and new leaves production are particularly active. The main result from the application of MESMA methodology concerns the good separation obtained for Red Mangrove with respect to other coverages. An accuracy more than 80% for fraction of pixels of Red Mangrove with a good level of purity has resulted from the Confusion Matrix performed on the multitemporal image classified in 8 classes. Furthermore, interesting results were obtained for torbid water or water with suspended sediments. MESMA methodology seems be able to put in evidence the distribution of sediments in the marine areas of deltas, this phenomena being related to rain seasons and water resource management model in all the hydrographic basin .

4. Conclusion

This research has allowed to unique results in the panorama of mangrove forest detection by Landsat 8-OLI images in the South coast of Cuba. In particular, the analysis of spectral behavior of the three species of mangrove considered in the study has leaded to distinguish the Red Mangrove from others mangroves. Furthermore the application of MESMA methodology has given more support at previous result, leading at significant level of accuracy in mapping mangrove forest and red Mangove separately. This is very important, because Red Mangrove represents the most fragile ecosystem within mangrove forests, the first barrier which has to fight with many natural and human impacts. Actually, this study is in developing phase and needs more studies and field experiments, but the first results obtained are very promising, mainly for the Cuban environment.

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The use of Unmanned Aerial Systems (UAS) for wildlife monitoring

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Keywords: Monitoring, UAS, RPAS, Wildlife

Summary
This work represents a first experimental approach to estimate the density of Roe deer (*Capreolus capreolus*) populations through innovative technologies. Therefore, we present opportunities and limits of surveys made by Unmanned Aerial Systems (UAS) (or Remotely Piloted Aircraft Systems: RPAS) for the study of wild ungulates.

1. Introduction

There are many methods to estimate wild ungulates populations. One of these is represented by observations from vantage points usually employed in medium-low covered forest areas. This method can give useful information but it is subject to some limitations, such as the risk of double counting and the necessity of a high number of operators due to the small size of the observable areas. Such limitations could be reduced integrating the method with the use of Unmanned Aerial Systems (UAS).

This study reports some experiences carried out mainly to check the suitability of UAS use in the specific case of monitoring of Roe deer, in particular:

- the possibility to identify animals in open areas in relation to the type of camera, the flight altitude and the type of vegetation cover;
- the possible disturb caused to animals by the noise emitted from the rotors of the aircraft and the flight altitude;
- the extension of the analyzed surface area at dusk as it is the most suitable time for wildlife detection.

2. Materials and Methods

This work refers about the experimentation conducted in a protected area with a high density of Roe deer (Parco Mediceo di Pratolino - Florence) and in the absence of disturbing elements.

The Aircraft used was a Yuneek Q500+ quadcopter equipped with a CGO2+ gimbal camera and it is characterized by a flying time of about 20 minutes.

Figure 2.1: The Aircraft used for surveys

The first experimental phase concerned the definition of technical parameters useful to characterize the research system. For this purpose, the acoustic emission of the aircraft (dB) and pics of the underlying soil area were recorded at intervals of 10 m up to 70 m above the ground.

In the second phase, operating flights were carried out on an area of around 90,000 m^2 consisting of seven contiguous open areas separated by hedges and woody plants.

Flights were made at dusk when roe deer go in open spaces for feeding.
The flight parameters were: height of the flight from 40 to 60 m with the speed of the aircraft approximately 3 m/s. Every flight was conducted in an average time of about 10-15 minutes.

Figure 2.2: The study area

3. Results and Discussion

The results about the relief of UAS noise intensity are shown in the table 3.1.

Table 3.1: UAS noise intensity

UAS NOISE INTENSITY (dB)					
Height (m)	1st trial	2nd trial	3th trial	4th trial	**Mean**
0	60	58,3	56	57	**57,8**
10	62	62,9	62,5	63	**62,6**
20	59,5	57,5	56,5	60	**58,4**
30	52	50,9	53	56	**53,0**
40	50	50,5	51,5	56	**52,0**
50	48,5	48	47,5	50,3	**48,6**
60	47	47,5	49,5	47,5	**47,9**
70	44	45,5	43,5	46	**44,8**

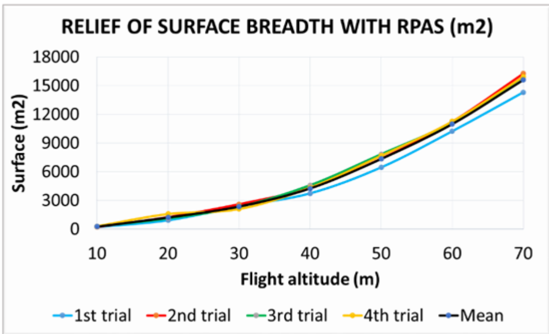

Figure 3.1: UAS Surface breadth

The analysis of the videos has allowed to verify that the shooting field amplitude grows about 2.000 m^2 for each 10 m of flight height: at an altitude of 50 m the area covered by each frame is about 9.000 m^2 while at 60 m is around 11.000 m^2.

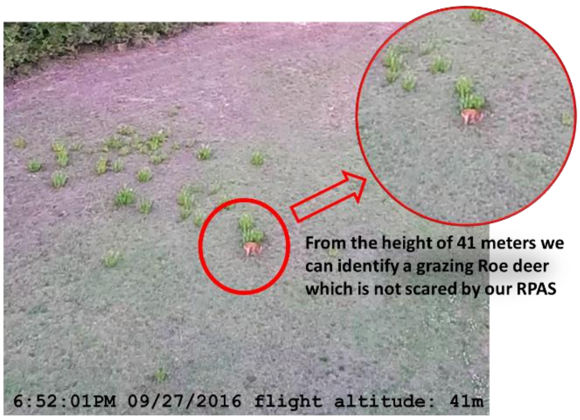

Figure 3.2: A Roe deer shooted by UAS

The ability of UAS to fly over the natural visual barriers (land orography, trees, hedges, etc.) allowed to conduct a census over all the study area, despite its size. Using this procedure, a small number of operators can scan a much wider area in comparison to the traditional observations from the ground. In fact, only two operators can do all the flights in an average time of about 10-15 minutes.
The analysis of the aerial pics taken at dusk from 40 to 60 m has identified many Roe deer grazing in different open areas and has verified the absence of any alarm reactions to the passage of the aircraft.

4. Conclusion

In conclusion, the comparison between the traditional method of census by vantage points and the census by UAS showed the many advantages that use of drones can have in the monitoring of wildlife.

Table 4.1: Comparison between census with UAS and census from vantage points.

CENSUS WITH UAS		CENSUS FROM VANTAGE POINT	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
High shooting area	Potential disturbance of Roe deer for the noise	Low disturbance of Roe deer	Low observable area
Ability to overcome natural obstacles	Patent requirement for the pilot	Operations allowed everywhere	Disability to overcome natural obstacles
Low number of operators	Operations influenced by weather conditions	Low influence of the weather conditions	High number of operators
Low operational timing			High operational timing
Objectivity of results			Subjectivity of results
Reduction of double counting			Possibility of double counting
Easy to repetition of the census			Census carried out by unqualified person
Possibility of the flight mission programming			
Census carried out by qualified person			

Further developments include the use of an experimental custom quadcopter designed and manufactured to specification, with autonomous flight on waypoints uploaded from a pc and equipped with a thermographic camera.

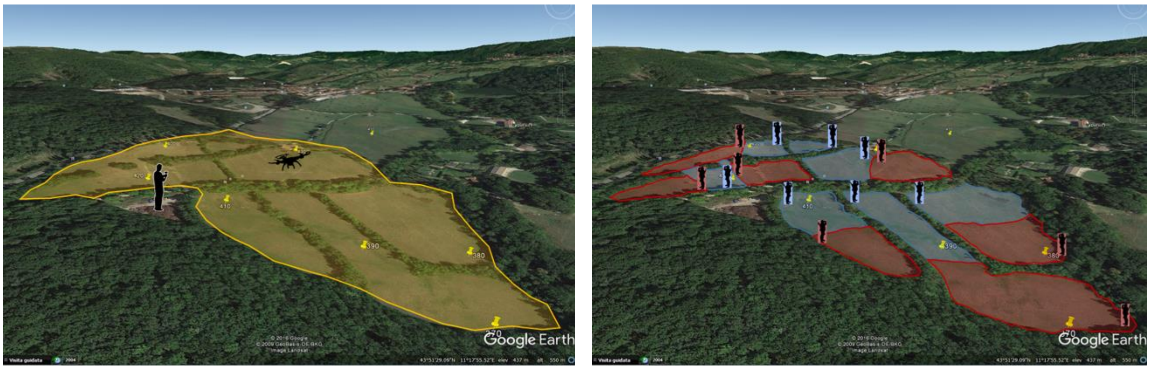

Figure 4.1: With "census by UAS", a small number of operators can scan a much wider area in comparison to the traditional observations from the ground.

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Land use change multi-approach assessment in a interregional context in South Italy

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Keywords: Land use change scenarios; spatial-multicriteria decision analysis; landscape metrics; ecosystem services

Summary
According to international and EU policies, complementary approaches for landscape and environment values assessment, in land use planning, are an essential prerequisite on a supra-regional scale. Study area is an internal mountain area, between Campania and Molise regions. In this context, appropriate management policies and land use change (LUC), in favour of bio-energy crops, concur to create new opportunities. Main advantage of this LUC is to mitigate negative trends such as erosion risk, socio-economic problems and environmental impacts. The work presents a possible physical-mathematical approach for pragmatic determination of the predictable environmental effects, starting from three LUC scenarios, through Ecosystem Services (ES) and Landscape Metrics (LM) assessment approaches. While the ES assessment shows benefits of bioenergy crops, LM assessment arises risks mainly related to land fragmentation. Integrated assessments enforce for further investigation on LUC aimed to evaluate corrective and mitigation measures that would be applied.

1. Introduction
Marginal lands are critical in terms of management and development policies related mainly to their low value. This land category may also include areas subject to different jurisdictions, such as "border areas". The Matese area is part of two regional administrations; it is an internal area, a mountain area, recognized as a " less-favoured areas " (EC n.1257, 1999), but it has also a high environmental, historical and landscape value; so it is representative of many Italian Appennine contexts. Policies to support employment and environmental sustainability may help to create new opportunities and new development perspectives in these areas, in accordance with the European political (European Parliament, Directive 2009/28/EC) which drives for renewable energy sources, biomass and energy crops. Previous studies developed LUC scenarios building methods (Verburg et al., 2008) to assess environmental impact (Costanza, 2008; MEA, 2005). In this paper we present a scenario-based multi-approach assessment (through empirical analysis, simulation models and objective diagnosis) in order to investigate the likely LUC impacts in terms of ecosystem services and landscape metrics. The aim is to highlight the close connection between structural characteristics of landscape pattern together with biodiversity and functional quality of ecosystems, as decision makers support already in the *ex-ante* evaluation stage.

2. Materials and Methods
2.1 Study area
Study area (120,000 hectares) extends between Campania and Molise Regions, in four Provinces and 35 Municiplities, but it has a unitary common historic and landscaping character, "Sannio region" (Figure 2.1). There are one Campania regional park (Matese Regional Park), sixteen SIC and four ZPS (Figure 2.2) to highlight the environmental value of the study area and claim for a special attention to possible impacts consequent of development and transformation

policies. Study area shows a trend towards a depopulation process. The population concerned amounts to 88,304 inhabitants (census data 2011), with a provincial decrement in the last thirty years, of 4-5% (with the exception of the province of Caserta); the employed are over 50 thousand, of which 8% in the primary sector.

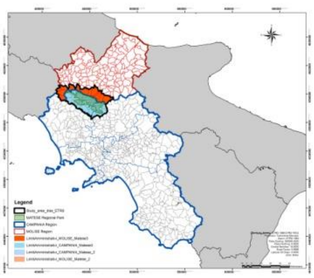

Figure 2.1: Study area

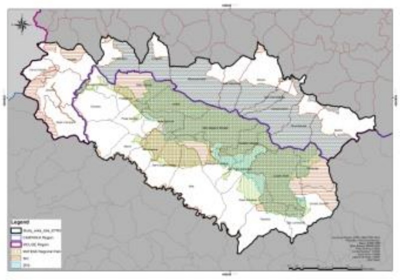

Figure 2.2: Protected areas

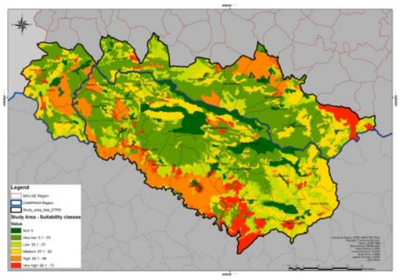

Figure 2.3: Suitability map

2.2 Methodological approach

The methodological approach encompassed three steps: 1) LUC scenarios building; 2) LUC scenarios assessment, through Ecosystem Services (ES); LUC scenarios assessment, trough Landscape Metrics.

In the first step, land use change (LUC) suitable areas were processed (ILWIS software), through Spatial-MultiCriteria Decision Analysis (Malczewski, 2006), taking into account both environmental and socio-economic land components (Cervelli et al., 2016). Suitability map (Figure 2.3) allowed to identify the more suitable of changes areas. This map constitute the basis for three scenarios building: Scenario 1, i.e current situation or no-change scenario; Scenario 2, where LUC areas were compared with the most suitable areas for specific bioenergy crops (giant reed, thistle, poplar); Scenario 3 where areas were supposed in a progressive state of abandonment. The second step assessed the Ecosystem Services value (which includes all ES categories), referred to each scenario. In particular, total ES monetary value was processed, starting from ES value identification for each land use/cover class, derived from Corine Land Cover of 2012 (CLC12) and from context variables, according to Scolozzi method (Scolozzi et al., 2012). All land cover class monetary values are updated starting from Scolozzi's study (Cervelli et al., 2017). Finally, in the third step, the landscape pattern analysis was performed using three landscape metrics, calculated at the class level by FRAGSTAT software: i) Number of Patches (NP), that is the simple measure of the extent of subdivision of the patch type; ii) Patch Density (PD), that is a limited but fundamental aspect of landscape pattern; iii) Landscape Division Index (DIVISION), that is based on the cumulative patch area distribution and is interpreted as the probability that two randomly chosen pixel in landscape are not situated in the same patch of the corresponding patch type (McGarigal, 2012).

3. Results and Discussion

LUC scenarios building sorted out three possible land configuration, resulting from different policies and driving forces. Scenario 1 (Figure 3.1) describes the current situation. Scenario 2 hypothesizes bioenergy crops distribution (Figure 3.2) It encompasses 23,000ha, 16% of which are devoted to giant reed (Arundo donax), 61% to thistle and lastly 23% to poplar. Scenario 3 describes, in the same areas of Scenario 2, a possible abandonment configuration (Figure 3.3): in principle, current class of CLC12 "Land principally occupied by agriculture areas" changes into "Pasture"; "Permanent and Annual crops areas" changes into "Land principally occupied by agriculture"; "Non-irrigated arable land", "Pasture", "Transitional woodland shrub areas", "Sparely vegetated areas", "Burnt areas" changes into "Sparely vegetated areas".

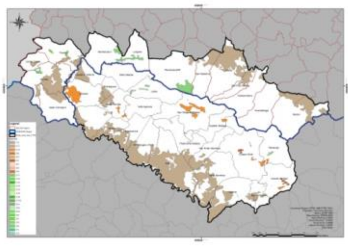

Figure 3.1: LUC areas: Scenario 1 - No change

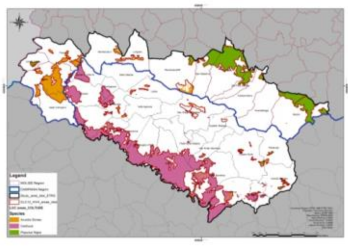

Figure 3.2: LUC areas: Scenario 2 - Bioenergy crops

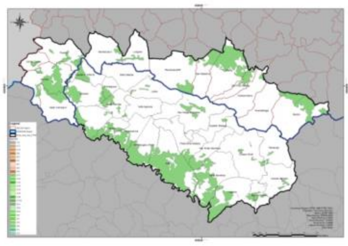

Figure 3.3: LUC areas: Scenario 3 - Abandonment

LUC Scenarios assessment through Ecosystem Services monetary value shows higher ecosystem value in Scenario 1 (about 2,900€/ha/y) then ES value assessed in other parts of the Campania Region (for example: SIR Litorale Domizio-Flegreo Agro Aversano developed under the LIFE Ecoremed Project, summing to about 1,700€/ha/y). Scenario 2 and 3 show a modest but interesting ES value increase (+5%), for the first one, and decrease (-3%) for the second, respectively (Table 3.1). The results also reflect trends highlighted through InVEST software, through habitat quality module and erosion risk (Cervelli et al., 2017), in the same area.

Table 3.1: Total ES monetary values(mv)

		CLC12 classes (level 2)												ES mv (M€)
		11	**12**	**13**	**21**	**22**	**23**	**24**	**31**	**32**	**33**	**41**	**51**	
Sc 1	**Area (ha)**	18	513	85	21892	4488	3196	15213	53231	18007	1522	199	284	
	ES mv (M€)	22	12	10	12027	4688	532	14868	306169	2999	73	3382	892	345671.5
Sc 2	**Area (ha)**	18	513	85	480	4488	20490	15181	58555	17981	402	197	284	
	ES mv (M€)	22	12	10	437	4685	2849	14875	333101	2990	48	3362	891	363282.8
Sc 3	**Area (ha)**	18	513	85	480	4463	3109	15208	53237	18001	23079	199	284	
	ES mv (M€)	22	12	10	309	4661	518	14859	306201	2990	341	3382	891	334195.9

Finally, landscape metrics have allowed to evaluate opportunities and risks associated with LUC scenarios, in terms of land structure (Table 3.2): in particular, PD and NP metrics highlight the trend of a substantial landscape heterogeneity, for scenarios 2 and 3, raising also risk of networks loss among patch types. Division metric is comparable in all scenarios.

Table 3.2: Landscape Metrics results

SCENARIOS	NP	PD	DIVISION
1	621	0.5148	0.9476
2	4196	3.4785	0.9447
3	4962	4.1135	0.9479

4. Conclusions

The need to take action on marginal context, can be an opportunity to economic, environmental and social recovery. This reasearch shows that the multi-approach assessments is a valid tool to support agricultural development policies and it is also appropriate to analize LUC impacts useful for hypotize mitigation measures. Scenarios building and LUC impacts environmental assessment become a dynamic and structured tool to boost the landscape image, to have positive impacts to the environment and to provide landscape care.

Acknowledgment
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TOPIC 10

BIOSYSTEMS ENGINEERING AT URBAN AND SUBURBAN SCALE

Alternative methods for weed control in urban areas

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Keywords: flaming, steaming, bio-herbicides, Taraxacum officinale

Summary
Weed control is always a difficult task in urban hard surfaces and the use of chemical herbicides is not always allowed by the public institutions and is often unwelcome by the citizens. Thus the objective of this research is to the test flaming, steaming and bio-herbicides as safe and sustainable alternative methods for weed control in urban areas. *Taraxacum officinale* was selected as ideal experimental weed. It was treated with flaming, steaming and acetic acid solution. *T. officinale* was sensitive to all the different treatments when treated in the earlier development stage, despite the dose adopted. Steaming was the most effective treatment, flaming did not completely kill the plants and the effect of the acetic acid was in between. According to the results obtained in this experiment, steaming, flaming and acetic acid showed to be effective in the control of *T. officinale*. Moreover, the results highlighted that all the three methods could be used within an integrated weed management approach.

1. Introduction
Weed control is always a difficult task in urban hard surfaces and the use of chemical herbicides is not always allowed by the public institutions and is often unwelcome by the citizens. Thus the objective of this research is to the test flaming, steaming and bio-herbicides as safe and sustainable alternative methods for weed control in urban areas. Weeds are generally controlled using herbicides or trimmers in urban areas (Benvenuti, 2004). However, herbicides cause environment contaminations and are dangerous for human health while trimmers cause damage to the surfaces and project stones and other objects causing damage to things and people (Rask et al., 2007). Thus, the use of flaming, steaming and bio-herbicides can represent a safe and sustainable alternative (Raffaelli, et al., 2013; Rask et al., 2013).

2. Materials and Methods
Taraxacum officinale was selected as ideal experimental weed because is common and difficult to eliminate (Fig. 2.1). Their seedlings sensitiveness (grown in pots) was tested using three different treatments:
- open flaming with a specific test bench (Fig. 2.2);
- steaming with professional electric steam generator (power 2.4 kW; flow rate 3.12 kg h^{-1}) equipped with a lance with a proper cylindrical diffuser (Fig. 2.3);
- acetic acid solution (20%)

Each method was tested using three different doses:
- flaming: 31, 52, and 156 kg ha^{-1} of LPG;
- steam: 2032, 4063 and 8126 kg ha^{-1};
- acetic acid solution: 75, 150, 300 kg ha^{-1}

The treatments were tested on two different weed development stages, 3-4 leaves and 10-12 leaves. Weed number and weed leaf area were assessed.

Figure 2.1: Taraxacum transplanted in pots before treatments.

Figure 2.2: Flame weeding on Taraxacum.

Figure 2.3: Steaming on Taraxacum and steam generator.

3. Results and Discussion

T. officinale was sensitive to all the different treatments when treated in the earlier development stage, despite the dose adopted. The later stage showed a variable resilience depending on the dose. The resilience is virtually due to the totipotent cells in the crown. Steaming was the most effective (plant mortality close to 100%). Flaming did not kill the plants but affected significantly their development. The results of the acetic acid were in between the other two treatments.

4. Conclusion

According to the results obtained in this experiment, steaming, flaming and acetic acid showed to be effective in the control of *T. officinale*. Moreover, the results highlighted that all the three methods could be used within an integrated weed management approach.

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Bees as biological indicators of air quality in a urban context

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Keywords: air quality, bees, atomic absorption, lead, nickel, cadmium concentrations

Summary

The aim of this research, supported by the municipally district of Milano, was to evaluate the air quality in Milano during the EXPO period, through the study of pollutants measured on bees, as bioaccumulators, reared in a beehive in the urban territory.
A beehive located in the Triennale area, in Milano, was considered. The trial was conducted since May to October 2015. Every two days, bees found dead in the beehive were collected and took to the ASL Prevention Laboratory to evaluate the concentration of Lead, Cadmium and Nickel on bees body through atomic absorption analysis. In the same period, data about atmospheric dust (PM_{10} and $PM_{2.5}$), levels of Lead, Cadmium and Nickel, measured by the nearest control unit in the town (through gravimetric method), were daily downloaded from the ARPA website. To evaluate the effect of atmospheric pollutants measured on bees body and to estimate the animal ability to work as a biological pollution indicator, data were pooled and submitted to variance analysis (Proc GLM, SAS 9.24).
Environmental data showed a clear relationship of PM_{10} and metals in the air. The comparison between atmospheric and animal data has revealed a tight relation, with linear dependences for animals and atmosphere, when the concentration of atmospheric lead exceeded the value of 4 ng/m^3, bees "carried" about 0.7 mg/kg of lead, when the lead atmospheric concentration was higher than 15 ng/m^3, lead on bees body was more than 0.9 mg/ kg ($y=0.1006x + 0.573$, R^2 0.98). A similar relationship was also detected for Nickel concentration, 2.1 ng/m^3 of atmospheric Ni corresponded to 0.3mg/kg of Ni on bees ($y=0.062x + 0.2618$, $R^2=0.98$).
The comparison of these data, particularly the concentrations of lead and nickel, has shown that these animals could serve as environmental "low cost" sentinels to assess the air quality in a city like Milan, where concentrations of fine particles and pollutants can induce serious health problems to citizens.

1. Introduction

Bees (Apis mellifera L.) can be considered as an environmental quality indicator, for their worldwide usage for honey production, pollination and their wide-ranging foraging behavior (Bromenshenk et al., 1986). They collect water, nectar, pollen and various particulates, with an impressive "pickup" frequency, within an area of about 3 km from the beehive (Raeymaekers et al., 2006). Bees ethological and morphological characteristics make them excellent ecological detectors, they are ubiquitous, do not have great eating needs, their body covered with hair work as collectors of the materials and the substances in the surrounding in the atmosphere, soil, vegetation and water.
Many studies have been performed on honey bees capacity to be indicators for pollutants in the atmosphere (Crane 1984, Van der Steen et al., 2015, Conti et al., 2001). A recent study by Van der Steen (2012). These experiments indicated that adult honeybees can serve to detect temporal and spatial patterns in environmental concentrations of a wide range of heavy metals which the bees may take up from all environmental compartments: vegetation, soil, air and water (Bromenshenk et al., 1985; Porrini et al., 2003).

The aim of this research, supported by the municipally district of Milano, was to evaluate the ability of Honeybees as bio-accumulators to indicate the levels of pollutants (dust and some heavy metal) in Milano during the EXPO period.

2. Materials and Methods

A beehive located in the Triennale area, in Milano, was considered. The trial was conducted since May to October 2015. Every two days, bees found dead in the beehive were collected and took to the ASL Prevention Laboratory to evaluate the concentration of Lead, Cadmium and Nickel on their body through atomic absorption analysis. In the same period, data about atmospheric dust (PM_{10} and $PM_{2.5}$), levels of Lead, Cadmium and Nickel, measured by the nearest control unit in the town (through gravimetric method), were daily downloaded from the ARPA website. To evaluate the effect of atmospheric pollutants measured on bees body and to estimate the animal ability to work as a biological pollution indicator, data were pooled and submitted to variance analysis (Proc GLM, SAS 9.4).

Figure 2.1:The beehive located in the Triennale, in Milano during the EXPO period

3. Results and Discussion

Environmental PM_{10} and $PM_{2.}5$ did not reach considerable concentrations in the EXPO period, as shown by Figure 3.1. Environmental data showed a clear relationship of PM_{10} and metals in the air. The comparison between atmospheric and animal data has revealed a tight relation, with linear dependences for animals and atmosphere.

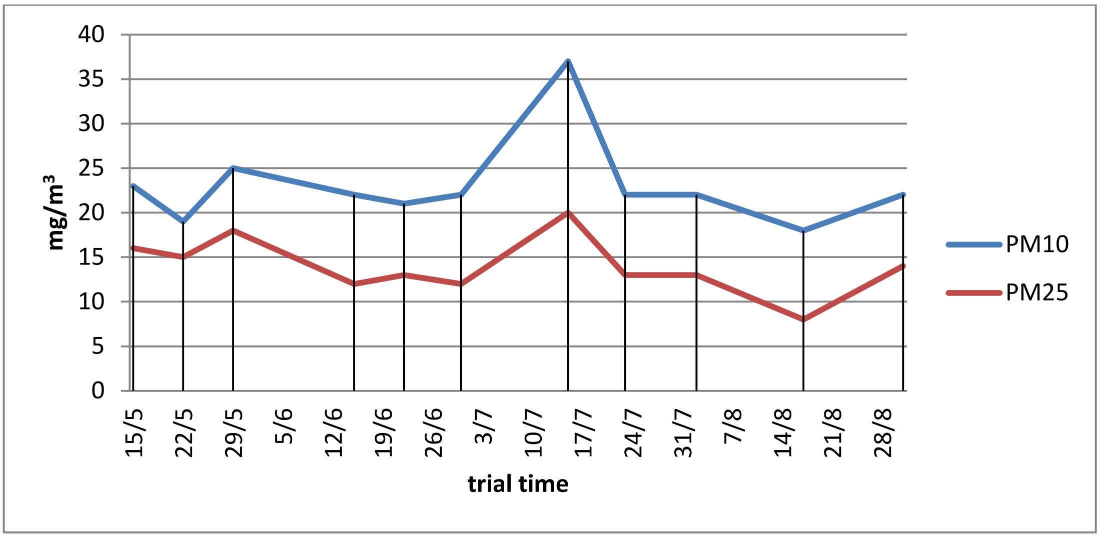

Figure 3.1: Mean daily values of PM_{10} and $PM_{2.5}$ concentrations in Milano during the Expo Period in 2015

Concentrations of heavy metals in the atmosphere, previously classified in three ranges (see Figure 3.2 and Figure 3.3), showed a clear relation with metals found on honeybees.

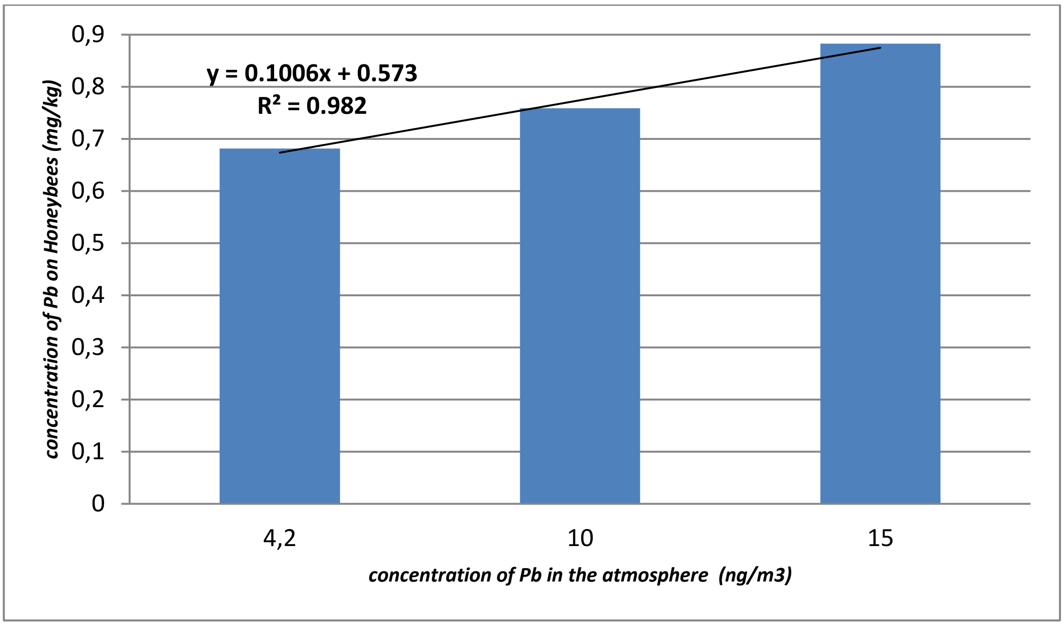

Figure 3.2: Relationship between concentration of Pb (ng/m3) in the atmosphere and detected on Honeybees

When the concentration of atmospheric lead (Figure 3.2) exceeded the value of 4 ng/m^3, bees "carried" about 0.7 mg/kg of lead, when the lead atmospheric concentration was higher than 15 ng/m^3, lead on bees body was more than 0.9 mg/ kg (y=0.1006x + 0.573, R^2 0.98).

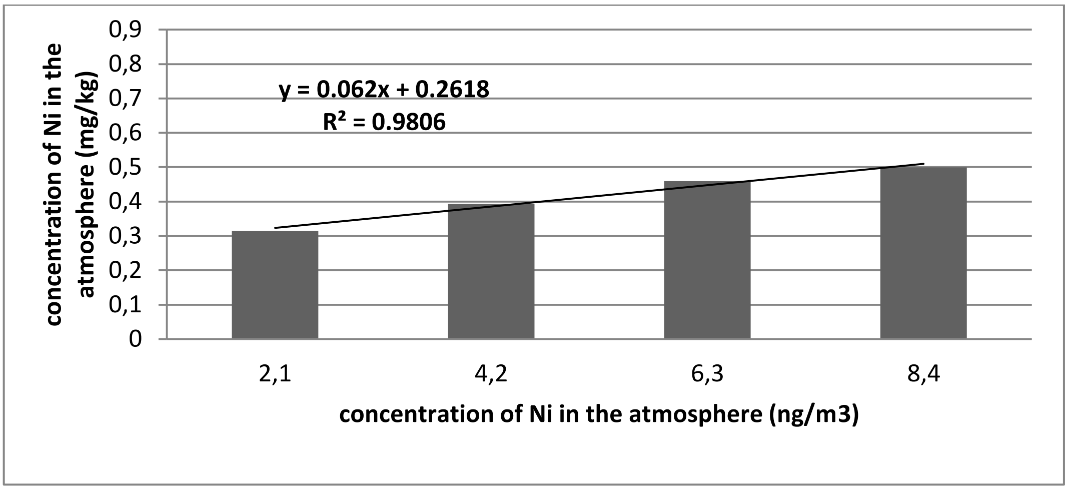

Figure 3.3: Relationship between concentration of Ni (ng/m3) in the atmosphere and detected on Honeybees

A similar relationship was also detected for Nickel concentration (Figure 3.3), 2.1 ng/m^3 of atmospheric Ni corresponded to 0.3 mg/kg of Ni on bees (y=0.062x + 0.2618, R^2=0.98).

4. Conclusion

The comparison of these data, particularly the concentrations of lead and nickel, has shown that these animals could serve as environmental "low cost" sentinels to assess the air quality in a city like Milan, where concentrations of fine particles and pollutants can induce serious health problems to citizens.

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Biosystems engineering for cooperation projects with developing countries

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The knowledge of Dr. Achille Sigliuzzo was the occasion for some teachers from the DISAAT Department participating in the CPS (Interdepartmental Development Cooperation Center) University of Bari "Aldo Moro" to be involved in two small cooperation projects in Kenya. Dr. Sigliuzzo, after many years of working on agronomy and agricultural infrastructures, has carried out many cooperation projects in Africa and shared with the CPS his network of contacts and knowledge. Participation in these cooperation projects has allowed to enrich the cultural and human baggage of the participants. On two trips to Kenya, it was possible to observe the reality of a developing country, its agriculture and its agricultural infrastructure. As is always the case for cooperation projects, beyond the technical and cultural aspects, the human factor was of equal importance. New friends in Africa have made it possible to get in touch with realities and life experiences that are very different from those in Western Countries and this represents the greatest achievement. Although small projects are concerned, the CPS has implemented works that actually support the populations of the Meru district (Kenya). The DISAAT Department has shared its technical and scientific knowledge to construct a pedestrian bridge over the river Kitheno. Following the success of this initiative, it was also possible to realize a potabilizer with the prevailing support of the Apulia Region, which has funded both projects. The Catholic Diocese of Meru, through Mr. Andrea Botta, provided the project with logistical support that was crucial to the success of the projects.

Cooperation Project "Construction of a Pedestrian Bridge on the Kitheno River" Meru District (Kenya) (code R / 4/4/2009). Project duration: 32 months; Start Project 18/09/2009; End of project 18/05/2012. **Cost of the project:** 47500 €. **Partners:** Apulia Region, Interdepartmental Research Center for Development Cooperation (CPS) University of Bari, Catholic Diocese of Meru.

Motivation of the project

"Meru Herbs" is an association of officinal herb producers, operating in the Meru District (KENYA) on the right and left bank of the Kitheno River over an area of over 5000ha with the support of the Catholic Diocese of Meru (Blank , H. G, et al., 2002). The Association is made up of about 500 farmers' owners, with a total irrigated area of 500ha. Thanks to the funds of "Italian Development Cooperation", since the mid-1980s, a rural aqueduct was built on the river. The Association carries out its activities under the auspices of the Diocese of Meru and, with elective bodies, provides for the management of irrigation networks and the transformation and marketing of agricultural products grown by members who are certified organic and exported throughout the world by chain of fair trade sales. Meru Herbs is a cooperative that produces teas, carcades, camomiles and jams (Becchetti L. and Costantino M., 2008). Over the years, trunks transported by the river flood have destroyed the pedestrian crossing three times (fig.1). Cultivators on the left bank of the river, to go to the agricultural processing center, used very dangerous wooden walkways (fig.2) or had to go a long way.

	
Fig.1: Destruction, caused by floods, of the pedestrian bridge over the river Kitheno near the Meru Herbs center	Fig.2: Temporary wooden bridge used for crossing the river Kitheno

The project had the purpose of building a new secure bridge, insurmountable by the waters, which it can be used by farmers and the local population. The destruction of the bridge over the river Kitheno has revealed the lack of knowledge of the problems of river regimentation and stabilization of the banks and shores.

Agriculture in the Meru District

The Meru Herbs Factory is located in Kenya in the province of Tharaka, which has recently become a County. The District of Tharaka Nithi County extends for 2638.8 km^2. Daily average temperatures range from a minimum of 11 °C to a maximum of 25.9 C with a maximum of 40°C. Rainfall varies between 200 mm and 800 mm per year. Tharaka has a bimodal pluviometric regime with long rains in March-May and short rains from October to December. This thermal and pluviometric trend makes the county a sub-arid region, causing drought and food shortage. Consequently, the County's poverty level is 65% and the main sources of support are agriculture, sheep farming and mining (stone and sand). Despite the difficulties due to the climate and the lack of agricultural technology, the district demonstrates a modest attitude towards extensive agricultural productions. Farmers produce fruit and vegetable products that are unrelated to irrigation requirements such as sorghum, millet, eye beans, grams, peas, sweet potatoes, cassava, corn and cotton. Farmers, in addition to bananas and mangoes, produce vegetable products for Meru Herbs Factory, which transforms them, giving the finished product high added value and high global quality. Farmers operating in the Meru Herbs Factory district have diversified their production to meet the needs of the Factory. They have not distorted their agricultural culture and practice consociate crops to avoid the use of fertilizers. The availability of water thanks to the Nguru Gariwe Water Project (NGWP) project enables the production of plants with high efficiency and quality with high irrigation requirements. Meru Herbs, besides producing products of undeniable quality, has a high social value, acting as a social cushion and at the same time supporting more than 1200 families working in the fields, valorizing the territory, and avoiding the abandonment of agricultural land. District farming respects the standards of organic certification to which Meru Herbs Factory adheres but, at the same time, agricultural productions are not very efficient. The efforts made by farmers turn out to be too high with respect to the obtained production, this phenomenon results in a difficulty in the management of orders commissioned by Meru Herbs Factory.

Rural Buildings and Agricultural Infrastructures in the Meru District

In the Meru district, the aqueduct has provided every farmer with an irrigation grip and today many family-run farms exist. Agricultural productions have the problem of transporting on land paths that are deteriorated by the passage of trucks (fig. 3). The problem is mainly felt in the dry season. Near the main road, farmers give their products to transport in urban areas and markets and sorting centers have arisen (fig. 4). Despite these issues, farmers have built rural housing and animal shelter. These are used for the production of meat and for the fertilization of soils, since agricultural productions are exclusively biological. The buildings are made of wood and mud, brick and mud, brick (figg. 5,6). The windows are in iron without glass and only with insect net. The wood is rarely used as a building material because it attacked by termites.

Fig.3: Rural viability in the meru district

Fig 4: Banana collection center.

Fig.5: shelter for animals, made of wood and mud.

Figure 6: building type of blocks of stone

Activities carried out for the project

Hydrological study: Using hydrological data and cartography provided by the Diocese of Meru, an hydrological study was carried out on the basin of the Kitheno river. According to the rainfall, the full flow in the sections of the river affected by the bridge construction was calculated. River section relief: River section relief: Technical staff of Dept. DISAAT, which was at Meru Herbs, carried out river inspections and decided to move the bridge to a more downstream section that provided greater stability, compatibility with the existing vegetation and which easily connects with existing and planned traffic in the future.

	
Fig.7: laying of concrete of the piles of the bridge	Fig.8: Assembly of the bridge

In addition, they have detected graphically the section of the river where the bridge was built. Bridge design: The Bridge and its foundations (fig.7) was designed based on the reliefs made. The bridge is in metal wire mesh; foundations have hydrodynamic shape and are made of reinforced concrete . Gabions and cliffs to prevent the erosion of the bridge piers were realized.
Seminar activity of the University of Bari at Meru Herbs: During the trips to Kenya, the teachers involved in the project conducted seminar on the cultivation of chamomile and tomato and experimental parcels covered with shaded nets were prepared. A further seminar focused on river regimentation with naturalistic engineering works such as cliffs and gabions. Bridge construction: After the design phase, the works were entrusted to the Salesian community of the nearby town of Embu (Kenya), which has accomplished it in 6 months. The metal parts were made to Embu, welded and assembled at the construction site (figg. 7,8). Inauguration of the bridge: The day 17 April 2012, the ceremony of the inauguration of the pedestrian bridge over the river Kitheno took place in the presence of civil authorities, religious representatives and representatives of the University of Bari.

	
Fig.9: Commemorative plaque applied to the bridge	Fig. 10: Opening Ceremony

Cooperation Project: Installation of a Drinking water purifier for the Meru aqueduct (KENYA) cod. R / 4/2/2012 Project duration: 24 months; September 2012 - end of project September 2014. Cost of the project: 16,850 €. Partner: Puglia Region, Interdepartmental Research Center for Development Cooperation (CPS) University of Bari, Catholic Diocese of Meru.

The aqueduct under management to "Meru Herbs", distributes water to approximately 5,000 local residents (including two schools) although it is a rural aqueduct. From the surface, the water passes through settlers (Figures 36, 37) and then directly into the distribution pipes. Thanks to the constraints on the territory, water does not present any type of pollutant, but the waters are turbid for the presence of clay and silt and cause gastro-intestinal disturbances especially among children. The CPS of the University of Bari, proposed the construction of a purification plant that provides drinking water at Meru Herbs and the neighboring village. The Meru Herbs provided for its installation according to the required flow rates. The Apulia Region has funded the work.

	
Fig. 11: Sedimentation tanks for water supply	Fig.12: Drinking water purifier, main unit

The project was completed in September 2014 with the implementation of two potable waterers, one of which is serving the Meru Herbs production and the other serving the community.

Conclusion

Projects have shown that devoting a small part of our time to co-operation is beneficial to others and increases our knowledge and experience. The Biosystem Engineering sector can provide decisive support to the agriculture of emerging countries that require efficient, sustainable and self-sufficient development models. The projects carried out show how small works in countries where drinking water, electricity, viability and health services are insufficient can greatly improve the quality of life. The small cost of the two projects can be an invitation to seek sources of funding to be devoted to cooperation in the developing countries. Moreover, the projects were an opportunity for reflection and social and human growth for all participants.

Personnel of dept. DISAAT who has supported the projects: Prof. Giacomo Scarascia Mugnozza, Prof. Pietro Rubino, Eng. Giovanni Russo, PhD Dott. Lorenzo Vecchietti, Prof. Francesco Gentile. Other participants in the projects: Eng. Sergio Castellano (University of Foggia)

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For interested people, visit the Meru Herbs website: http://meruherbs.it/# and download the file: Botta A. 2013, Story of a Bridge. http://meruherbs.it/wp-content/uploads/2014/02/Strory-of-a-bridge.pdf

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