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Welcome to XII Conference AIIA – Palermo Italy, September 19-22, 2022

On behalf of the Italian Association of Agricultural Engineering, we warmly welcome you to the XII AIIA International Conference: “BIOSYSTEMS ENGINEERING TOWARDS THE GREEN DEAL. Improving the resilience of agriculture, forestry and food systems in the post-Covid era”.

AIIA 2022 Conference proposes a dynamic and innovative approach aimed at increasing cultural and scientific exchanges among different Italian and international researchers with particular regard to those coming from the Mediterranean areas.

The organization of this International Conference was possible thanks to the help and care of many colleagues: we thank the authors and the members of the Organizing and Scientific Committees.

We wish you stimulating and productive days, as well as a fascinating stay in the city of Palermo.

On behalf of the Organizers

Prof. Giuseppe Giordano
(AIIA President)

Prof. Pietro Catania
(AIIA Secretary)

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Natural Fibers Reinforcement for Earthen Building Components: Valorization of a Low-quality Sheep Wool Fiber

Monica Parlato, Francesca Valenti, Simona Porto

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Spatio-temporal variability in throughfall at the hillslope scale in a mountain beech stand

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Throughfall variability, interception, temporal stability, hillslope, Mediterranean forest

Understanding the role of forests in modifying water inputs via rainfall interception is fundamental for a correct understanding and simulation of catchment scale runoff generation and changes therein as a result of land use or climate change. Despite many studies at the stand scale, still little is known about the role of hillslope topography and the associated tree stand characteristics on throughfall spatio-temporal variability. Therefore, this work aims at better understanding the dominant factors on throughfall variability and on the temporal persistence of throughfall spatial patterns along a transect on a steep hillslope characterized by differences in tree size and density.

The measurements were taken in an experimental hillslope near the outlet of the Lecciona catchment (0.3 km²), Tuscany Apennines, Central Italy. The study hillslope is roughly 110 m long and 60 m wide, has a mean slope of 25°, and is predominantly covered by beech trees and sparse oak trees. A grid of 126 throughfall collectors was installed in July 2020 across three subplots. In November 2021 a line of five automatic rain gauges connected to gutters was installed to increase the collection area on the hillslope. Throughfall from the grid collectors was manually measured approximately monthly. The rain gauges record data at a 5-min resolution.

The 27 manual measurements revealed a large temporal variability in interception (mean: 24%, standard deviation: $\pm 31\%$), reflecting the seasonal precipitation pattern of Mediterranean areas and tree phenology. The spatial variability in interception was also high and reflected the spatial variability of the stand: interception was higher for the lower plot, characterized by a lower tree density and larger tree sizes than the upper plot ($32\pm 28\%$ and $20\pm 32\%$, respectively). Statistical analysis also showed that the spatial variability for each subplot was higher in the dormant season than in the growing season, suggesting an important role of branch morphology and stemflow.

The temporal stability analysis revealed that the most temporally-stable and representative measurement points were located on the extended transect that, overall, captured the different tree characteristics along the hillslope well.



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Future forestry surveys will be conducted to measure tree characteristics (such as diameter height, and Leaf Area Index) to assess their effect on the spatial variability of throughfall. Moreover, the high-resolution data from the five automatic gauges will be used to assess their representativeness compared to the manual grid and to test and validate an interception model at the hillslope scale.

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Seasonal meteorological forcing controls runoff generation in a Mediterranean mountain catchment

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Keywords. Runoff; Seasonality; Forest; Mountain catchment; Hydrological response

Abstract. Hydrological processes in Mediterranean climates featuring an increment in the frequency of dry periods are being increasingly studied. However, our knowledge on how the seasonality in meteorological forcing controls runoff generation in mountain, forested catchments in the Mediterranean area is still rather poor. In this context, this work aims at better understanding the role played by seasonal variability in meteorological forcing on the hydrological response of a small catchment in central Italy.

The Re della Pietra experimental catchment (2 km², 650-1280 m asl) is located in the Tuscan Apennines, and, on average, receives 1180 mm of precipitation/year unevenly distributed through a wet (November-May) and a dry period (June-October). Forest cover is close to 100%, consisting mainly of beech trees, with minor oak trees and conifers. The equipment includes a weather station, four stream gauges (0.3 – 2 km²), soil moisture probes at two depths, stream electrical conductivity probes in three stream sections, three groundwater wells, nine sapflow sensors and 12 multiparametric tree probes.

Results from 2021 showed that runoff response to rainfall was rapid throughout the year at all spatial scales but long hydrograph recessions were observed during the wet period, and high peaks with flashy response occurred in the dry period. Soil moisture clearly responded even to small rain events and showed a strong seasonal behaviour as well, with a coupled response and very similar values at both depths in the wet season, and a decoupling in the dry season. Conversely, groundwater table responded only to major events (>10 mm).

During the wet period, event water proportion in the stream estimated through electrical conductivity was higher in the headwaters, then becoming similar at all scales during the dry period, when pre-event water dominated. Diel fluctuation patterns in streamflow were observed at all scales in summer and were consistently time-shifted compared to sap flow



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and stem radial variation of beech trees, revealing a strong influence of evapotranspiration on runoff generation.

Overall, these results provide new and useful insights on the seasonality of hydrological response of Mediterranean mountain catchments at different spatial scales.

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Investigating the interaction between snowmelt runoff and road network in the occurrence of hillslope instabilities affecting a landslide-prone mountain basin through a multi-modeling approach

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Keywords: snowmelt, road network, landslide, GIS, modelling

Abstract

The presence of roads is frequently linked with the occurrence of land degradation processes such as landslides and erosive dynamics, especially in steep slope mountain areas. In this regard, the use of Airborne Laser Scanning (ALS)-derived high-resolution topographic data allowed to better represent landscapes and related physical processes at the basin-scale. Furthermore, the implementation of topographically-based hydrological models also increased our possibilities to simulate water overland flows and investigate the occurrence of specific soil degradative phenomena. Snowpack melting plays a primary role in altering superficial water dynamics in mountain landscapes, but accurate investigation about the interaction between snowmelt-runoff and human infrastructures such as roads and trails in the occurrence of hillslope failures is still obscure. This research aims therefore to assess the relationship between snowmelt-runoff, road presence and terrain instabilities affecting a landslide-prone steep slope mountain meadow (northern Italy). The detection of snowmelt overflows alteration due to the presence of the road, as well as its relation with the activation of a shallow landslide were performed through an innovative multi-modeling approach. In this regard, the role of the road in altering snowmelt-runoff was investigated both considering its presence and assuming its absence by a novel Digital Elevation Model (DEM) editing procedure. Different hydrological and slope stability models were interactively implemented, starting from pre-event ALS-derived DEM in order to compute predictive simulations at the basin scale. Results attested the key role played by the road in altering snowmelt runoff pathways, as well as their combined contribution in the foreseen activation of the observed shallow landslide. Starting from on-field observations conducted after the landslide triggering (2020), the *Area Under the Receiver Operating Characteristic* curve (AUC-ROC) and the Cohen's kappa-index were elaborated to assess the accuracy of instabilities predictions. AUC-ROC and Cohen's κ respectively resulted around 0.9 and 0.6. This work could be a useful tool for planning specific mitigation interventions able to reduce the occurrence of similar risk scenarios, also providing suggestions for developing and promoting efficient sustainable actions for mountain landscapes.



Hydrological effects of prescribed fire and mulching with fern residues in Mediterranean forest areas

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Keywords. Water infiltration, soil water repellency, surface runoff, soil erosion, soil properties.

Abstract. Prescribed fire is a feasible practice to reduce the wildfire risk in the Mediterranean forest areas. However, the changes in soil properties and vegetation removal can lead to negative impacts on the hydrological response. Mulching has been proposed as an effective post-fire management technique to avoid these impacts. Several studies have analyzed the effects of prescribed fires and mulching on soil hydrology, showing that these impacts are of different magnitude and often contrasting. To integrate this knowledge, this study has evaluated the short-term effects of the prescribed fire and post-fire mulching using fern on the hydrology of soil in three forests (pine, chestnut and oak) of Southern Italy. Rainfall simulations have been carried out to estimate the water infiltration, and experimental plots have been installed to measure the surface runoff volume and soil loss under natural precipitations throughout one year. The soil water repellency (SWR) and the main chemical properties of the forest soils have been also determined immediately after the fire and one year after. The study has demonstrated that, under simulated rainfalls, the prescribed fire reduces the infiltration rates compared to the unburned soils. Mulching is not able to contrast this reduction, which, however, disappears some months after the fire. Immediately after the fire, the runoff (+150-375%) and erosion (+100-800%) significantly increase in all forest stands after natural precipitations. The pre-fire runoff and erosion rates restored after five months. Soil mulching with fern was effective to limit these increases (reductions in the runoff coefficients and soil losses by 30 to 80%). The prescribed fire significantly changed the main chemical properties of soils. In particular, SWR was detected in the pine and oak forests. Mulching with fern was unable to limit these changes, which however were generally transient. Overall, the experimental investigation has shown that, in the studied Mediterranean forests, post-fire management actions, such as the soil cover with a cheap mulch material as fern residues, are needed effective to control the short-term increases in surface runoff and soil erosion after prescribed fires.



Runoff and recharge in Piemonte

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Keywords. Water, runoff, flood event, hydrological processes

Abstract.

Both agricultural and forest hydrology topics have been treated in the scientific works of the group at the University of Torino. This work presents some main papers which can show the path followed by the group. The first paper is 50 years old, the second is 30 years old, the third 7 years, and the last was published in 2022. All papers have results that are still useful in the field of runoff studies.

We start from a forest hydrology paper of Merlo (1973) where it is presented a procedure to calculate peak discharges from mountain catchments proposed by Tournon. In that paper Merlo did a very comprehensive analysis of thousands of hydrographs in 9 catchments (between 30 and 170 square kilometers) in Piemonte, and in close by areas of Liguria and Emilia Romagna.

The calculation procedure presented in that paper is used up to now in many flood evaluation and can be found in several textbooks (e.g.: Greppi, 1999; Ferro, 2006). It is an example of “science for management”, in this case of the risk of flooding. The very detailed analyses of Merlo (1973) can be discussed in light of the literature of 50 years, which is particularly abundant in this topic. Some points can be linked to the talk of Jeff Mc Donnell “Which future for catchment hydrology?”, held in the Agricultural Hydraulics Department of Firenze in 2019. In that occasion he presented a very inspiring review about the runoff theme in relatively small catchments.

Another paper which can be cast in the Mc Donnell’s framework is the one of Ferraris and Acutis (1994), presented at the AIIA conference of Milano, about twenty years after the Merlo’s paper. This is instead a typical “positive science”, where the authors collected experimental hydrographs from agricultural hillslopes in the Piemonte plain. They are 0.4 hectare catchments, with a uniform very mild slope. The data were well reproduced by optimizing only two parameters in a finite difference numerical solution of the kinematic wave, together with a Yves Parlange equation of soil infiltration.

The next paper, the one of Canone et al. (2015) is again in the line of the work about soil moisture of Yves Parlange, and more specifically of his friend Randel Haverkamp. The latter worked in the group in Turin for the years 2008 and 2009 and died few months ago in France. The Institute of Agricultural Hydraulics, now named Labflux, in this paper was in between the “science for management” and the “positive science”, providing guidelines for managing the surface irrigation on borders, the most spread method in Piemonte. Three farms were



monitored and a model was used to fit the data and to simulate different scenarios of real world irrigation.

It is in the frame of “positive science” that still the group is doing research in the Critical Zone Observatories field, with several experimental installations. One has a 25 meters high eddy covariance mast and cosmic ray apparatus in a forest, and another is at 2600 meters asl with hydrological fluxes measurements. The new issue will be to see if the discharge data collected in the different mountain catchments, together with stable isotopes data will allow to follow the inspiring talk of Mc Donnell previously cited.

However the activity of “science for management” issues is continuing now. It has been published very recently a study for the Water Authority with the objective to forecast the recharge of the aquifers around Turin: in Brussolo et al. (2022) the time series from 1959 and the simulations to 2050 are presented, calculating the actual evapotranspiration both in the past and in the future with a model. The temporal and spatial variability of past time series of recharge is shown.

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Hydrological and sediment dynamics in two Mediterranean intermittent rivers

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Keywords. Hydrological regime, sediment transport, intermittent rivers, ephemeral streams, hysteresis

Abstract. The general aim of this study is to investigate the relationships and the processes characterizing flow regime and suspended sediment (SS) transport in two intermittent rivers, the Búger (Spain) and the Carapelle (Italy). A set of Hydrological Indicators (HIs) were used to characterize and classify the flow regime. High-resolution data of streamflow and SS Concentration (SSC) were used for analysing flood events.

In the Búger River, the specific SS yield (SSY: 0.5-46 t km⁻² y⁻¹) and maximum SSC were correlated with the runoff, peak discharge, and antecedent rainfall events. In the Carapelle River, SSY and SSC_{max} were correlated to rainfall intensity. The basin size played an important role in the hysteretic behaviour, which is related to the spatial gradient of rainfall and sediment sources distribution. The Búger River showed predominant clockwise loops indicating SS sources close to the outlet. The Carapelle River showed clockwise and counter-clockwise loops since the large agricultural area promoted a huge sediment availability. Lithology and geological characteristics resulted in the most relevant drivers controlling the hydrological regime and river type classification, meanwhile, rainfall was a less relevant factor. Land use and management practices were also relevant drivers of SSY, determining the availability of suspended sediment material. At the event scale, a non-linearity in the rainfall-runoff relationship was found for both basins, where runoff response can be due to different processes and runoff generation was both for saturation and infiltration excess.



Hydraulic roughness estimation induced by floodplain riparian vegetation in some Tuscany rivers: detailed and speed methods comparison

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Keywords. Riparian vegetation, roughness, hydraulic modeling, flood risk, Best Management Practices.

Abstract. Riparian roughness evaluation on vegetated bank by using rapid or detailed surveys for risk evaluation and vegetational management.

Riparian vegetation and its managing can affect on hydraulic and hydrologic characteristics of a vegetated river. Thus different scenarios of vegetation management can reduce or increase hydraulic risk, especially in urban settlements.

Roughness coefficient calculation has been carried out by applying models that take into account relatively simple descriptive parameters, i.e. the diameter and the spatial distribution.

Vegetation structure has been gauged in homogeneous areas by using forest-related and relatively time-consuming field surveys on river banks and floodplains of water bodies in Tuscany region: Arbia stream and Ombrone, Serchio and Tevere rivers.

Alternatively, field survey can be speeded up by using smartphone open source app *MOTI* created by School of Agricultural, Forest and Food Sciences HAFL of Zollikofen. This simple approach can provide basal area and number of plants per hectare by using relascope theory to obtain the parameters necessary for roughness coefficient calculation.

Roughness coefficient along the river banks can be consequently applied on computed simulations to evaluate vegetation effects on hydraulic efficiency, and therefore the most suitable riparian vegetation management.

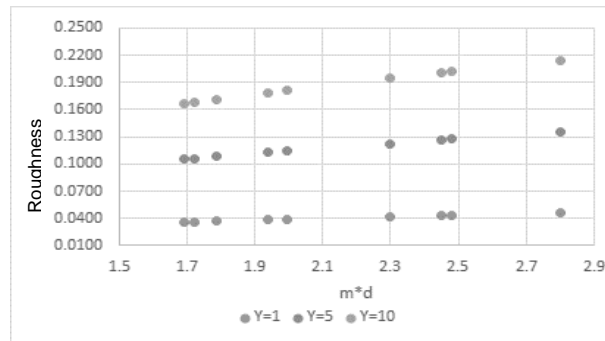


Figure 1. Relation $m*d$ and roughness (m : number of trees per unit area; d : average diameter of average base area)

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Influence of The rainfall Time Step on The Thresholds for Separating Erosive and Non-erosive Events

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Keywords. overall and pattern rainfall characteristics, rainfall acquisition time step, Masse experimental station, rainfall spatial variability, central Italy.

Abstract.

In previous work, Todisco et al. (2019) analyzed 522 rainfall events from 2008 to 2017 at the Masse experimental station (central Italy) to define and evaluate several thresholds of rainfall characteristics able to classify non-erosive and erosive events. Each threshold value was obtained by imposing that the long-term erosivity of the events above the threshold is equal to that of all erosive events observed. The threshold evaluation criteria were based on the percentage of correct selections, CSI (number of erosive events selected to the total number of erosive events) and on the percentage of wrong selection, WSI (number of non-erosive events to the total number of events selected). The analysis was performed on the basis of a 5-min rainfall dataset. In this study, working on the same dataset used by Todisco et al. (2019), we evaluated how the value and performance of the thresholds change when their determination is made based on rainfall records at different time steps. In particular, the original 5-min data were aggregated at 30 minutes, which is one of the typical timesteps of the data provided by the Hydrographic Services.

The results indicate that some rainfall characteristics maintain their effectiveness, passing from a 5-min to a 30-min rainfall dataset. However, the threshold value tends to increase slightly. Among the best thresholds can be mentioned: the total event rainfall, P_e (14.4 and 15.2 mm for the 5-min and 30-min database, respectively), the kinetic energy of the event, E (2.4 and 2.7 MJ ha⁻¹), the rainfall duration above a pre-determined intensity, D_{run} (0.3 and 0.5 h), and the Maximum rainfall amount in a rain shower, P_{max_burst} (7.6 and 10.2 mm). Other thresholds considered effective working on the 5-min dataset obtained very poor performance on the 30-min database. This happened for some rainfall variables related to the number of runs or showers during the event. This poor performance depends on the fact that as the time step increases, the hyetographs become smoother and not suitable to provide pattern rainfall characteristics relevant for the classification of erosive and non-erosive events.

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Event based approach for small and ungauged basins: a web tool version

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Keywords. EBA4SUB, rainfall-runoff modeling, ungauged basins, web tool.

Abstract. EBA4SUB (Event-Based Approach for Small and Ungauged Basins) is a rainfall-runoff model tailored for small basins (i.e. with a contributing area not greater than a few hundreds of km²) and optimized for hydrological studies that need as input the same information necessary for applying the rational formula. It consists of three modules: gross rainfall estimation, excess rainfall estimation, and rainfall-runoff transformation.

Its main advantages in particular regard the excess rainfall estimation (the mixed Curve-Number for Green-Ampt - CN4GA – procedure is implemented) and the rainfall-runoff transformation (the Width Function based Instantaneous Unit Hydrograph is applied, based on Digital Elevation Model and CORINE Land Cover data).

EBA4SUB is a calibration free model, so all the parameters necessary for running the model are automatically quantified using empirical formulas.

In this work, we describe the EBA4SUB implementation either as a simple web tool, freely available online, and in the user-friendly GIS version, that allows its immediate application.



Using the Simplified Falling Head Technique to Determine the Saturated Hydraulic Conductivity of a Sieved Loam Soil Used Repeatedly

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Keywords. Saturated soil hydraulic conductivity, Laboratory experiments, Repacked soil, Soil reuse, Simplified falling head technique.

Abstract. An experiment with a homogeneous soil is expected to yield stable saturated hydraulic conductivity, K_s , data between replicates since the variability typical of real soils is minimized. Little is known on the dependence of the K_s measurements on the reuse of the same soil mass.

The Simplified Falling Head (SFH) technique was applied to verify if reusing the same mass of a loam soil passed through a 2 mm sieve induced changes in the measured K_s values. The same soil was used for eight repeated determinations of K_s . Fifteen soil columns (diameter = 9.3 cm; height = 12.5 cm) were prepared on each date.

Three groups of results were broadly obtained. In particular, the first three datasets (R0, R1 and R2), developed with a nearly fresh soil material, yielded relatively stable and high means of K_s (66.9-75.6 mm/h). Stable means of K_s were also obtained with the last three datasets (R5, R6 and R7) but in this case K_s settled on nearly 2.0-2.5 times lower values (30.4-32.3 mm/h) as compared with the first three datasets. Finally, K_s decreased continuously from the R2 (66.9 mm/h) to the R5 (32.3 mm/h) datasets. Variability of K_s stabilized to small values (coefficient of variation = 8.6-10.4%) for the last five datasets. The soil became progressively finer as the number of reuses increased since the mean weight diameter, MWD, of the soil particles decreased from 0.63 mm before the first use (R0) to 0.36 mm after the seventh reuse (R7). The means of K_s increased with MWD.

Therefore, the soil particle size distribution varied as the same soil mass was reused and the SFH experiment was able to capture the impact of this change on determination of K_s . A limited number of reuses of a soil mass never used before should not be expected to appreciably affect determination of K_s . However, the data obtained with a fresh soil material can be higher and more variable than those obtained with additional reuses of the same soil mass. The highest repeatability of the SFH experiment and the lowest variability of the K_s values is expected when the soil mass has been previously used several times. In conclusion, a fresh soil should not be compared with an intensively used soil. If the objective of an investigation is to ensure homogeneity conditions as much as possible, the recommendation is to use a soil that has already been subjected to many wetting and drying cycles. Reporting the history of the used soil in the investigations dealing with saturated hydraulic conductivity of sieved and repacked soil is recommended.



The paradox of using an old-fashioned TDR portable device to calibrate new-generation capacitance sensors

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Keywords. Upper Alento River Catchment, soil permittivity, soil temperature, soil water content, field calibration.

Abstract. The calibration of low-cost, low-frequency capacitance sensors requires attention and should be designed carefully. The laboratory calibration of electromagnetic sensors in few repacked soil samples can yield unsatisfactory results when establishing soil moisture sensor networks in heterogeneous environments. In this study, two test sites with different soil textures (clay soil in MFC2 and loamy soil in GOR1) in the Upper Alento River Catchment (UARC) in southern Italy were instrumented with SoilNet wireless sensor networks controlling GS3 (Meter devices) capacitance sensors deployed at soil depths of 15 cm and 30 cm over twenty nodes. The GS3 sensors monitor soil permittivity as proxy for soil moisture, temperature, and apparent electrical conductivity. For converting permittivity to soil moisture we used a two-step calibration procedure: in the first step, ad hoc field calibrations were carried out using a domain reflectometry (TDR) portable device connected to a 15-cm-long metallic rod proving reference soil permittivity values that were positively and negatively correlated to soil permittivity and temperature measured by the GS3 sensor. We developed a simple multiple linear regression to estimate TDR-based permittivity from soil permittivity and soil temperature (spanning from 4.5°C and 31.9°C) taken by low-frequency sensors at z=15 cm over 20 measurement campaigns. In the second step, an intensive field calibration was carried out by relating TDR-based soil permittivity with the co-located destructive thermogravimetric measurements of soil water content on ten positions over 13 field campaigns. Our results showed that site-specific calibrations reflect seasonal soil moisture dynamics and outperform the factory calibration. Non European characters should not be used unless absolutely necessary. Please include the font's dot if you must use them.

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Enhancing Water Resources Management By Means of New Non-Invasive Soil Moisture Sensors

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Keywords. soil moisture, cosmic-ray neutron sensing, integrated observation networks, data interoperability

Abstract. Soil moisture is a key variable for understanding water fluxes at the land surface and for supporting water and soil management in many applications, like irrigation scheduling, flood, and landslide prediction. Several methods have been developed to monitor soil moisture ranging from point-scale invasive soil moisture sensors to large scale remote sensing products. The former can provide high accurate measurements at different soil depths. However, their application is limited by the strong variability of the soil-plant systems and by the difficulties to install and maintain these instruments for long-term monitoring. On the contrary, remote sensing products cover large areas but they only detect the surface soil layers. Moreover, the signal is strongly disturbed by vegetation and land cover. For these reasons, so far, hydrological observation systems and networks maintain for instance by environmental agencies or land reclamation consortium do not integrate soil moisture measurements. In this contribution we present and discuss recent advancements of a non-invasive soil moisture method that emerged to fill this gap, called cosmic-ray neutron sensing (CRNS). The contribution covers current sensor developments, accuracy and uncertainty in the detected signal and estimated soil moisture and data integrations in current monitoring systems. A specific application for monitoring the main components of the soil water balance in real time at an agricultural site is presented, as example. An overview of future activities is also discussed.



Stage-cameras to monitor water level in headwaters

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Keywords. headwaters, intermittent/ephemeral drainage network, water level, stage-camera.

Abstract. Understanding runoff formation in ephemeral and intermittent streams is fundamental for the comprehension of natural systems; however, monitoring such watercourses remains a major challenge in hydrology. Direct field observations are best to detect spatial patterns of flow persistence but they are time and labour intensive and may be impractical in difficult-to-access environments. Moreover, instrumentation deployed in the riverbed can provide information about the streamflow state, nevertheless these methods lack in streamflow quantification.

Inspired by latest advancements in digital cameras and computer vision, we propose the development and application of a stage-camera setup to monitor the water level in an ungauged headwater stream. This system encompasses a camera with near infrared (NIR) night vision capabilities and a white pole that serves as reference object in the collected images. To evaluate the efficacy of this system in the detection of river dynamics, a set of 21 stage-camera stations is installed along the entire river network of the 4 km² Montecalvello catchment, near Viterbo (VT, Italy). Time-lapse imagery is processed through a computationally inexpensive algorithm featuring image quantization and binarization and water level time series are filtered through a simple statistical scheme. The feasibility of this approach is demonstrated through a set of benchmark water level estimations obtained from a supervised procedure. Preliminary evaluations are encouraging and support the usability of this approach in monitoring ephemeral and intermittent stream dynamics.



Estimating reference evapotranspiration by ERA5 products under different irrigation districts

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Keywords. Reanalysis dataset; Weather ground-based observation; Water management; Irrigation

Abstract. Nowadays, climate reanalysis products can provide fundamental inputs for agrometeorological and hydrological applications. In this sense, the global reanalysis datasets ERA5 single levels and ERA5-Land (ERA5-L), released by the European Centre for Medium-Range Weather Forecasts (ECMWF), offer consistent time-series of multiple climate variables at about 30 and 9 km horizontal resolution, respectively. The aim of this study was to assess the potential use of these datasets as alternative weather data source for estimating reference evapotranspiration (ET_0). In particular, the daily ET_0 estimates provided by the new generation ECMWF reanalysis datasets were compared with 66 observational sites distributed over 7 irrigation districts throughout the Italian territory during the period 2008-20. In particular, under the Köppen-Geiger classification, a number of 7 study sites, located in Apulia, were characterized by arid, steppe, cold climate (BSk); 19 sites, placed in Campania and Sicily (Eastern and Western part), were featured by dry and hot-summer temperate climate (Csa); 7 sites, placed in Sardinia, were classified as dry and warm summer temperate climate (Csb); and 32 sites, located in Emilia-Romagna and Lombardy, were referred to no dry season, hot summer (Cfa) temperate climate conditions.

At 86% of the total number of the irrigation districts under study, ET_0 performances resulted more consistent using ERA5 than ERA5-L products, when compared to the observational sites. In particular, ET_0 resulted in greater and lower performance under Csa, with average RMSE of 0.65 and 0.59 mm d⁻¹ for ERA5 and ERA5-L, respectively, and Bks, with average RMSE of 0.90 and 0.88 mm d⁻¹ for ERA5 and ERA5-L, respectively, climate conditions. Intermediate performances were obtained under Cfa and Csb climate zones (with average RMSE of 0.69 and 0.67 mm d⁻¹ for ERA5 and ERA5-L, respectively).

The high accuracy obtained in estimating ET_0 by reanalysis products suggests the potential use of this information for calculating the daily crop evapotranspiration rates aiming at supporting the irrigation scheduling especially under Csa conditions.



The Effect of Soil and Vegetation Spatial Variability on Modelling Hydrological Processes for Irrigation Optimization at Large Scales

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Keywords. Spatial variability, soil hydraulic parameters, vegetation indices, optimal irrigation volumes, agrohydrological modelling

Abstract. Spatial variability of soil and vegetation parameters are crucial in agrohydrological models concerned with optimizing irrigation volumes at large scales. Measuring aforementioned parameters can be time consuming and laborious, so it is more efficient to aggregate their spatial variability without significantly affecting the optimal irrigation fluxes at large scales. The main purpose of this paper is to study the effect of spatial variability of soil hydraulic parameters and vegetation indices (i.e. leaf-area index, LAI, and crop coefficient, K_c) and soil profiles’ hydraulic parameters on the optimal irrigation volumes. Here we analyse the effect of aggregating the spatial variability of soil and vegetation parameters on a 140-ha irrigation sector in “Sinistra Ofanto” irrigation system in Apulia Region, Southern Italy. Five soil profiles were excavated and their hydraulic parameters were measured. Remote sensing applications were used to obtain LAI and K_c using European space agency’s Sentinel-2 images 10-meter resolutions. Optimal irrigation volumes were calculated using FLOWS-HAGES agrohydrological at field scale using variable vegetation and soil inputs. Then, a sensitivity analysis was carried out by aggregating soil and vegetation parameters into sector scale. Aggregating vegetation parameters was carried out while preserving soil parameters variability. Aggregating soil parameters variability was carried out five times by applying each of the five measured profiles while preserving vegetation parameters. Aggregating vegetation parameters did not significantly change the optimal irrigation volumes and the resulting deep percolation volumes. However, aggregating soil parameters variability significantly affected the optimal irrigation volumes and the corresponding deep percolation volumes. Aggregating soil vegetation parameters is possible to facilitate irrigation management provided that soil parameters variability is preserved and the cropping pattern is relatively uniform.



A Remote Sensing - hydrological modelling approach to estimate daily actual evapotranspiration.

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Keywords: Remote sensing, SEBAL, Richards model, Actual Evapotranspiration, Eddy covariance.

Abstract

The quantification of the spatio-temporal dynamics of Evapotranspiration (ET) flows in natural vegetation is of fundamental importance for efficient water resource management and environmental modelling, particularly in the semi-arid areas of the Mediterranean. Satellite remote sensing-based surface energy balance (SEB) techniques have emerged as a very useful tool for quantifying actual evapotranspiration at various temporal and spatial scales. The free and long-time series data that Remote sensing (RS) offers, which is characterized by a relatively high spatio-temporal resolution, can be an added value for SEB modelling of ET. However, discontinuous data acquisitions of thermal remote sensing data due to temporal resolution of satellites and/or gaps in image acquisition due to cloud cover can limit RS utility. This study proposes a model-based approach for the construction of daily actual ET between the Landsat 8 acquisition days. The proposed HYDROSAT model integrates actual evapotranspiration (ET_a) obtained by the Surface Energy Balance modelling on Landsat-8 acquisition days, RS vegetative biomass dynamics obtained from diverse platforms, on-field measurements of potential evapotranspiration and a hydrological modeling approaches of soil moisture in the root zone by using the transient flow Richards equation. The proposed approach aims for modelling the dynamics in the soil-plant-atmosphere continuum that occurs between two Landsat acquisitions to estimate the daily time series of ET_a.



Optical remote sensing for supporting irrigation management under different climate conditions

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Keywords. Sentinel-2, OPTRAM, Soil Water Content, Irrigation events, Irrigated areas.

Abstract. Nowadays, irrigation is one of the main sources of consumption of fresh water in the agriculture sector. In this context, remote sensing (RS) techniques can offer their potential for the spatial and temporal assessment of water resources.

The main purpose of this study was to provide a novel stand-alone RS approach based on the use of the Optical Trapezoid Model (OPTRAM) methodology for supporting sustainable irrigation management in different climate conditions, such as humid and semi-arid climates. Specifically, high-spatial-resolution multispectral imagery acquired by Sentinel-2 satellite sensor was coupled with the OPTRAM approach: i) for detecting the irrigation events occurred at the Marchfeld region (Austria) within the irrigation season 2020 and; ii) for mapping the irrigated areas at the irrigation district “Quota 102.50” in Sicily (Italy), within the irrigation seasons 2019-20.

An overall linear parameterization of OPTRAM was tested and applied at Marchfeld region for providing 20 m spatial estimates of soil water content (SWC). The SWC patterns were compared with in-situ observations, showing a good agreement with accuracies of about 70%. Crop-specific linear parametrizations of OPTRAM, based on seasonal Normalized Difference Vegetation Index clusters, were applied at “Quota 102.50”. The outputted irrigated areas were compared with the information provided by the Sicilian Irrigation Consortia at the sub-district level, showing slight overestimations of 2.12% and 0.18%, within the irrigation seasons 2019 and 2020, respectively.

In conclusion, the proposed RS approach provides promising results for supporting the irrigation management in different climate conditions permitting to identify the irrigation events and patterns under humid climate conditions, and mapping the actual irrigated areas in semi-arid climate conditions.



Integrated computer modeling and monitoring for irrigation planning in Italy

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Keywords. Irrigation; agrohydrological models; water resources planning and management; hydrological monitoring

Abstract. As part of the process of implementation of the Water Framework Directive 2000/60 EC (WFD hereafter), withdrawals for irrigation purposes emerge as one of the main pressures on water bodies in Mediterranean countries. This justifies the particular attention that has been paid in recent years to the quantification of irrigation uses at national level, also from a regulatory point of view, especially since the promulgation of the Ministerial Decree of 31 July 2015 of the MiPAAF and of the consequent regional regulations. The WFD actually marks a fairly clear demarcation in the approach to planning water resources, shifting the focus from the needs of water use to that of their protection and the requalification of water bodies. This approach has been consistently maintained in the subsequent Community directives and strategies and is fully reflected in the recent European Green Deal and in the Farm to Fork Strategy. The current context is therefore characterized by partly contrasting pressures: those linked to sustainability, which may lead to a reduction in withdrawals from water bodies; those resulting from climate change, which foreshadow a reduction in water availability. The combined effect of these thrusts can put irrigated agriculture in serious difficulty.

In this context, the INCIPIT- INtegrated Computer modeling and monitoring for Irrigation Planning in Italy Project aims to systematize and deepen the knowledge acquired on the methods of estimating irrigation needs and on the development of mathematical models for simulating irrigation systems within six of the major agricultural departments nationwide. INCIPIT addresses a set of crucial issues: i) the potential of remote sensing for identifying effectively irrigated areas and for estimating their irrigation needs; ii) the effect on the estimation of evapotranspiration and irrigation needs of the use of different sources of agrometeorological data; iii) the application of models for estimating irrigation needs in various agricultural contexts; iv) the potential of simulation models of irrigation uses in collective irrigation systems for the improvement of water management and for the definition of climate change adaptation strategies. A characterizing element of the project is the implementation of these issues through four case studies, involving seven Italian areas with irrigation systems of different extent and complexity. Results emerging from the case studies are presented in a set of other contribution within this AIIA conference.



Monitoring of irrigation water use in Italy by using IRRISAT methodology: The INCIPIT project.

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Keywords. Crop Evapotranspiration, Irrigated Areas, Irrigation Water Requirements, IRRISAT, Sentinel-2.

Abstract. The **INCIPIT** project (**IN**tegrated **C**omputer modeling and monitoring for **I**rrigation **P**lanning in **IT**aly) focuses on the development of a methodological framework to monitor the irrigation water uses at different spatial scales and under different hydro-meteorological conditions in six Italian regions (Apulia, Campania, Emilia Romagna, Lombardia, Sardinia, and Sicily). The objective of the INCIPIT project is to fill the wide gap between research and application in order to meet the requirements of sustainable water-related policies – such as the Water Framework Directive (WFD), and the MIPAAF Ministry Decree of July 31, 2015- where a specific set of obligations of measurement and estimation of the irrigated areas and irrigation water volumes is defined.

For this purpose, the ESA Sentinel-2 (S2) satellites provide a very valuable source of information for mapping irrigated areas and estimating spatially-distributed irrigation water requirements.

This study illustrates the results achieved by using the IRRISAT methodology, the first satellite-based irrigation advisory service developed in Italy and operating in the Campania region. In detail, the quantification of the irrigation water abstraction has been carried out by using one-step approach, based on the Penman-Monteith equation, properly adapted with canopy parameters namely crop height, Leaf Area Index (LAI), and surface albedo derived from S2 data. The assessment of the effective irrigated areas has been performed by using pre-existing maps, unsupervised (clustering), and supervised classification (Machine Learning Algorithms) applied on dense temporal series of vegetation indices.

The results will be presented for the irrigation seasons 2019 and 2020 in seven Irrigation and Land Reclamation Consortium, which differ in size, in the type of the irrigation scheme, in the farm delivery, in the irrigation methods, and in the crop types.



Assessment Of Agro-Hydrological Models Of Different Complexity To Estimate Crop Water Requirements At Irrigation District Scale

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Keywords. crop water requirements, irrigation districts, agro-hydrological models

Abstract. Agriculture is one of the main water users in many areas all around the World. For this reason, a correct agricultural water management is a fundamental factor for reaching a sustainable use of the water resources. Despite that, measurements of water withdrawal for agriculture are sparse and limited to the head of few main irrigation districts. Several agro-hydrological models with different complexity have been developed to overcome this limitation. These models have been applied in several studies with good performance and results to support agricultural water management and planning. However, a comprehensive intercomparisons to understand potentialities and limitations are not commonly performed.

In this contribution we present an intercomparison of three agro-hydrological models that are used for agricultural water assessment: IrriFrame, CRITERIA and IdrAgra. The first model has been developed by ANBI (Associazione Nazionale Consorzi di gestione e tutela del territorio e acque irrigue), with the technical coordination of CER (Consorzio di Bonifica di secondo grado per il Canale Emiliano Romagnolo). This model is available as a decision support tools for farmers and Land Reclamation consortia over Italy. CRITERIA is an agro-hydrological model developed by ARPAe Emilia-Romagna and it is operationally used to estimate crop water requirements and soil moisture over the entire Emilia-Romagna region. Finally, IdrAgra is a distributed agro-hydrological models that has been developed by University of Milano (Italy) and it has been applied in several studies in Lombardia region for the assessment of current practices and future scenarios. The intercomparison is performed at several irrigation districts at Emilia-Romagna region. The results are assessed using measurements of water withdrawals at the head of the districts. Advantages and differences of each model is then presented and discussed.



Macroscopic root water uptake modelling using High-Throughput Screening (HTS) systems: design and validation

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Keywords. Agro-hydrological modelling, high-throughput systems, root water uptake modeling

Abstract. In this work we designed and validated a High-Throughput Screening (HTS) system for the continuous and simultaneous monitoring of plant drought stress response in a semi-controlled environment. Structurally, the HTS-system consists of three hardware segments for high-frequency detection of the agrometeorological forcing variables (i.e., atmometry), the weights (i.e., gravimetry), and the soil water content, SWC, (i.e., time domain reflectometry, TDR) of sixteen pots in which the ornamental crop (*Prunus lusitanica*) was grown. An automated micro-irrigation system was designed to manage water by following a feedback control irrigation scheduling protocol. The three monitoring segments and the irrigation system were controlled in an algorithm written in CRBasic programming language and implemented in a CR1000 datalogger (Campbell Scientific Inc.). The elementary module of the HTS-system consisted of a 5.0 l pot, implemented with a load cell and a TDR probe used, respectively, to detect the weight [g] and the volumetric soil water content [$\text{m}^3 \text{m}^{-3}$].

The weights and/or the volumetric water content measured in each module represented the feedback control variables used to manage the irrigation events. The validation procedure of the HTS-system has embedded two types of soils with different physical properties (coarse-grained and fine-grained soil), and, for each soil treatment, two levels of soil water deficit conditions were settled. In the water deficit treatments (DI) the SWC was maintained below the critical soil water status (i.e., stress incipient condition), whereas in the full-irrigation treatment (FI) the SWC was maintained between the field capacity and the critical soil water status. The system was able to model the crop water stress function following the root water uptake macroscopic approach. The root water uptake model was represented by a nonlinear (logistic) relationship between the crop water stress and soil water status, which allowed to identify the critical threshold of SWC defining the incipient occurrence of water deficit conditions for the analyzed crop.



ADAPTING P-k-C* MODEL IN MEDITERRANEAN CLIMATE FOR ORGANIC REMOVAL PERFORMANCE IN HORIZONTAL CONSTRUCTED WETLANDS

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Keywords: horizontal constructed wetland, P-k-C* model, semi-arid climate

Abstract. The P-k-C* is considered as the most suitable in modeling constructed wetland (CW) performance (IWA, 2017), providing a good compromise between accuracy and computational simplicity to assess the degradation processes for selected pollutants (Dotro et al., 2017). The k_A indicates the treatment process rate and is related to water temperature through the Arrhenius theta factor (θ) (Kadlec and Wallace, 2009). There is a need to test the model in different climate conditions due to its high sensitivity to temperature. This, in fact, could deepen the knowledge on model application. This study aims at demonstrating the applicability of P-k-C* model to describe the response of horizontal CWs (H-CWs) for domestic and agro-industrial wastewater treatment, and evaluating key design parameters for the model optimization in Mediterranean semi-arid conditions. In particular, k_{A20} (m year^{-1}) and θ values were assessed in two H-CWs in Eastern Sicily, characterized by different organic loads and hydraulic and design features. The model was evaluated for simulating BOD₅ and COD effluent concentrations at the outlet of the H-CW units. Calibration parameters, k_{A20} and θ , were found by summing and minimizing the squared differences between measured and modeled data, obtained by simultaneous adjustment of k_{A20} and θ for all samples ($15 < n < 30$). The coefficient of determination, R^2 , the Nash–Sutcliffe efficiency, NSE, and the root mean square error, RMSE, were used as statistical performance measures for the model. Results showed a good reliability of the model to describe water quality response in terms of BOD₅ and COD effluent concentrations. In particular, the performance got worse when the influent and effluent concentrations did not differ a lot and when the flow was lower than the designed one. Moreover, generally the model overestimated the smallest effluent concentrations and underestimated those highest. Most important finding was that a $\theta < 1$ should be used from practitioners to optimize H-CW design in Mediterranean conditions.



Productive response of a pear orchard (*Pyrus communis*, L.) to the precision irrigation conducted through a Decision Support System (DSS)

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Keywords. Normalized difference vegetation index (NDVI), soil moisture-based wireless sensor network (SM-WSN), unmanned aerial vehicle (UAV), water distribution uniformity (DU)

Abstract. In this study, a soil moisture-based wireless sensor network (SM-WSN) was adopted in a commercial pear orchard to support the reduction of irrigation water consumption. The sensor network was designed and validated during three growing seasons (2019-2021). First, the micro-irrigation system performance was assessed in terms of water distribution uniformity (DU), which was evaluated with field measurements of emitter flow rates. Then, a zoning analysis was carried out to divide the orchard into homogeneous areas according to the normalized difference vegetation index (NDVI) detected with unmanned aerial vehicle (UAV) and GIS tools. In this way, the effect of DU on the vigour of the trees has been identified assuming that the zoning outcome was only associated with the soil spatial variability. Moreover, unlike the ordinary irrigation scheduling applied in the farm, the smart system allowed maintaining the soil water content within a pre-defined optimal range, in which the upper and lower limits corresponded respectively to the soil field capacity and the threshold below which water stress occurs. Based on the smart irrigation management, water-saving up to 50% of the total water supplied with the ordinary schedule was achieved during both investigated growing seasons. In addition, the quality parameters of the production (i.e °Brix, fruit size and firmness) were in line with the standard required by the farmer. The adoption of the new technology, which aims at identifying the most appropriate irrigation management, has therefore the potential to generate positive economic returns and reduce the environmental impacts.



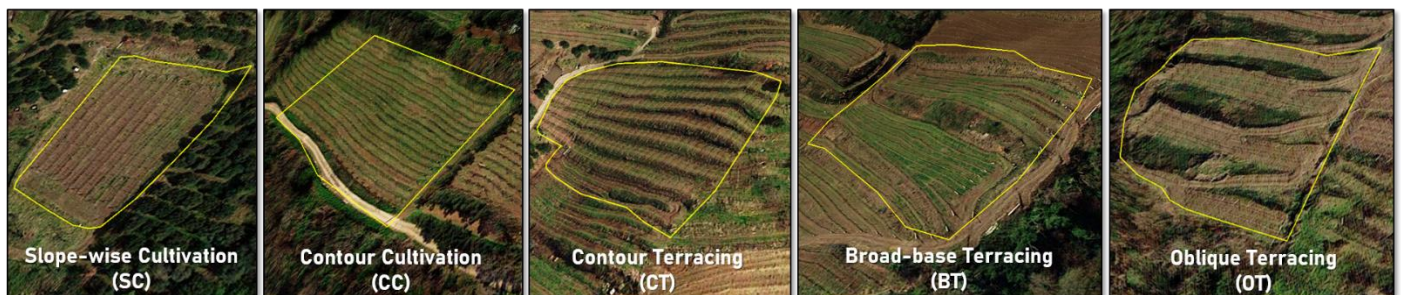
Evaluating steep-slope cultivation practices through a grand comparison of 50 vineyards

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Keywords. Soil and water conservation; agricultural landscapes; terracing; remote sensing; modelling.

Abstract. Agricultural hillslopes typically show diverse terraced and non-terraced cultivation systems. Effective Soil and Water Conservation (SWC) performance is increasingly important to cope with climate impacts such as extreme rainfall or drought, both common threats in Italian agriculture. Whereas past research has illustrated the SWC impact of several cultivation techniques (<https://doi.org/10.1016/j.catena.2020.104604>), we provide a first-time extensive analysis of 50 vineyards cultivated by 5 different terracing and non-terracing techniques in the cultural landscape of Soave, northern Italy: Slope-wise Cultivation (SC), Contour Cultivation (CC), Contour Terracing (CT), Broad-base Terracing (BT) and Oblique Terracing (OT). Through a systematic workflow of high-resolution topographic analysis, physical erosion modelling, and statistical analysis, a set of SWC indicators are computed for the 50 vineyards. The processes and patterns of surface water flow and erosion occurring in the different systems are visualised and quantified. In this analysis, a distinction is made between uphill and downhill zones inside each vineyard, in order to distinguish between detachment and deposition hotspots. Our findings provide novel and relevant insights about the SWC effectiveness of common Italian terraced and non-terraced cultivation practices, providing practical guidelines for sustainable landscape planning based on extensive and systematic analysis.





The Vaia event: primary impacts of the storm and subsequent evolution of the Malgonera Stream (Dolomites)

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Keywords. Vaia storm, Alpine stream, Morphological changes, LW load, LW recruitment

Abstract.

Large Infrequent Disturbances (LIDs), defined as major events that overturn both the morphological setting of the river networks and hillslopes, increasingly affect mountain basins. The subsequent secondary impacts (i.e., wood recruitment after windstorms; mass movements after wildfires; alteration of sediment fluxes after volcanic eruptions) are often disregarded although their understanding would provide important advice to river managers. The following work aims at investigating the primary impacts of the Vaia windstorm event (27th-31st October 2018) and the subsequent evolution of the channel morphology and large wood (LW) load of a small Alpine stream (Malgonera, study area 6,025 m²). To achieve the objectives, remote sensing (LiDAR; UAV) and field data were exploited. Remote sensing products were used to compute two Dem Of Difference (DoD): the first investigated the Vaia impact (pre vs post Vaia; 2010-2019) and the second monitored the evolution of the channel (post vs post-post Vaia, 2020-2021). Field data of LW, combined with the LiDAR and UAVs surveys, were collected to compute both the LW load entailed by Vaia and the subsequent LW fluctuations (2020-2021). The net sediment volume after the event was estimated around -2,025 m³. The area of total erosion was 2,659 m², while the deposition covered 1,222 m². Notably, the average depth of surface lowering was deeper than 1 m. On the contrary, the most recent DoD (2020-2021) featured almost irrelevant geomorphic changes and balanced net volume. Concerning the in-channel wood, not present before Vaia, the results showed an input of 58 m³ (96.3 m³/ha) for a total amount of 279 (463 N°/ha) wood elements. Around 50 logs were classified as single elements while the remaining as elements composing wood jams. Between 2020 and 2021 the LW load increased up to a volume of 61.50 m³ (102 m³/ha), increasing the number of elements to 292 (485 N°/ha). This new LW input was caused by cantilever failures of small portions of the unstable forested banks. Therefore, this work underlines the capability of LIDs to affect and rearrange the morphology of mountain streams. Nonetheless, it provides some first evidence on the secondary processes of LW recruitment along an unstable mountain stream affected by a windstorm. Additionally, it interestingly highlights how changes in the LW are detached from limited changes in the channel morphologies. Such information, as well as covering gaps in the literature, provides some useful advice for future river management strategies.



Vegetation-induced occlusions in agricultural ditches: rapid, low-cost and flexible mapping by UAV-SfM

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Keywords. agricultural ditches, high-resolution topography, roughness, UAV, vegetation obstruction

Abstract.

Drainage networks represent a crucial aspect for controlling the floods generation, reducing waterlogging and water erosion, improving groundwater recharge and supporting water supply in cultivated areas. Therefore, the assessment of the network storage capacity plays a key aspect to consider in water resource and flood management risk. Drainage network efficiency can be reduced by the uncontrolled growth of vegetation that can modify the ditch cross-section altering the hydrological response and network functionality. Consequently, the continuous monitoring of the potentially critical areas, where vegetation could obstruct the section, become a fundamental point that can be solved by the advanced in the high-resolution topographic technologies. In the last few years, the Structure from Motion (SfM) photogrammetry technique in parallel with Uncrewed Aerial Vehicles (UAVs) have increased the possibilities for the realization of rapid, low-cost and very detailed Digital Elevation Models (DEM). UAV-SfM surveys are fundamental to generate accurate and high-resolution DEM used to derive geomorphometric features of the agrarian landscape. This research aims to present a flexible and low-cost workflow to realize an accurate and high-resolution UAV-SfM DEM, in a large agrarian area of Taiwan, that can be used to automatically detect the drainage network and to map the vegetation into the ditches through the roughness index. To validate and assess the methodology, the high roughness index values due to the presence of vegetation in the ditches were identified and compared with corresponding measurements in the field. The results confirm the effectiveness of the approach used and underline how the developed workflow could provide, on a farm scale and with an unusually high level of detail, useful, rapid and low-cost information to map vegetation obstruction in channel network. This information could be help to precisely intervene on obstruction points, planning the ditches maintenance, and identify some numerical benchmarks to be included in flood risk models and in the computations of the storage size of the drainage network, essential for stakeholders.



Understanding hydrological processes to mitigate surface water stagnation in agriculture: new opportunities from remote sensing

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Keywords. Water ponding, Agriculture, Remote sensing, UAV-SfM

Abstract. Surface water ponding is a surplus of water that remain on agricultural terrain surface, mainly after extreme/prolonged rainfall events or due to not optimal irrigation. It could be a major issue in lowland agriculture. Firstly, it can damage crops at the biological level due to lack of oxygen supply, leading to the mortality of entire field areas and reducing production; secondly, it can compromise the normal management schedule with problems related to in-field trafficability. Stagnant water is mainly concentrated in concave areas of the surface. Indeed, it is more evident in areas highly frequented by heavy agricultural machinery, which compact the soil reducing the water infiltration capacity and creating concave surface profiles. Mapping high potential water ponding areas can help stakeholders in planning mitigation strategies. The advance in topographic technology and remote sensing provides great potential in surface processes investigation. In this study, we present a novel approach aimed at mapping potential water ponding in lowland agriculture, using a low-cost remote sensing approach. For the investigation, we selected an 8 ha lowland agricultural field in northern Italy (Rovigo province) historically subjected to water stagnation. The methodology is based on the application of the geomorphic indicator Relative Elevation Attribute (REA), which can map the more pronounced concavities and convexities of the terrain, thus providing a pioneering map of potential water ponding in agriculture (**Straffelini et al., 2021**). REA was calculated on a high-resolution Digital Terrain Model (DTM) created using an Uncrewed Aerial Veichel (UAV) combined with the Structure-from-Motion (SfM). Results are promising, and assessment was performed using a high-resolution orthophoto for stagnant water extension (Cohen's $k(X)$ accuracy of 0.683) and in-field measurement of water depth (Pearson's r_{xy} coefficient of 0.971). The methodology aims to provide an easy-to-read map of potential ponding in lowland agricultural areas and at farm scale. With it, farmers and stakeholders can understand where the problem is more likely to occur and design target solutions efficiently.

Straffelini, E, Cucchiaro, S, Tarolli, P. Mapping potential surface ponding in agriculture using UAV-SfM. Earth Surf. Process. Landforms. 2021; 46: 1926– 1940. <https://doi.org/10.1002/esp.5135>



Assessing daily ERA5-Land reanalysis data to estimate olive orchards actual evapotranspiration in Sicily

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Keywords. Climate variables, Eddy Covariance, FAO-56 model.

Abstract. Accurate estimations of actual crop evapotranspiration obtained with agro-hydrologic models are of utmost importance to evaluate crop water requirements and optimize water use efficiency.

The objective of this work was to assess the suitability of ERA-5 Land reanalysis data to estimate actual evapotranspiration (ET_a) of an olive orchard (cv. "Nocellara del Belice") located in the southwest of Sicily, Italy. After examining the errors associated with each climate variable deduced from the ERA5-Land product and verifying the reliability of the FAO-56 model, the comparison between the ET_a values predicted by introducing the reanalysis data in model simulation and the corresponding measured on the ground was carried out.

Experiments were implemented during three irrigation seasons (2009-2011) in an orchard extended about 13 ha and characterized by trees having a height of about 3.5 m and spaced 5 m × 8 m. An Eddy Covariance tower (EC) was installed in the orchard to measure, at a sub-hourly time step, air temperature and relative air humidity, wind speed and direction, net solar radiation and, finally, sensible and latent heat fluxes. A meteorological station of the Sicilian Agrometeorological Information Service (SIAS) to monitor the climatic variables used to estimate crop reference evapotranspiration was also installed about 500 m apart from the study area. The hourly values of reanalysis climatic variables, including rainfall, were finally deduced from the ERA5-Land product, characterized by a spatial resolution of about 9 km.

For the three examined seasons application of the FAO-56 model with climate data measured on the ground produced fairly good estimations of ET_a , with values of root mean square error (RMSE) ranging between 0.40 and 0.69 mm/d and mean bias error (MBE) from -0.24 to 0.10 mm/d. Similar results were obtained when model simulations included the ERA-5 Land data, whose results indicated values of RMSE and MBE respectively in the range $0.46 \div 0.65$ and $-0.13 \div 0.07$ mm/d.



Hydrological and isotopic response of a small forested catchment to short-term climatic variation

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Keywords. stable isotopes; forested catchment; young water fraction; stream water; soil moisture.

Abstract. Long-term monitoring of the main hydro-meteorological variables, as well as of the isotopic composition of the various water sources in a catchment can help to gain new insights on how the hydrological response will be affected by climate change. In this study, we used hydrometric and stable isotope data from the 2-ha Ressi forested catchment in the Italian pre-Alps to i) investigate trends in the meteorological forcings and in the hydrological response, ii) determine whether a significant temporal trend in air temperature affected the isotopic composition of the various water sources, and iii) estimate the young water fraction (i.e., the fraction of water in a stream younger than about 2-3 months) and assess how it will be affected by significant trends in the isotopic composition of the water sources.

Precipitation, air temperature, streamflow, soil moisture and groundwater levels have been monitored in the catchment since August 2012. Soil moisture has been measured at 0-30 cm depth at four locations along a riparian-hillslope transect. Depth to water table has been measured in a piezometer installed in the riparian zone. Water samples for isotopic analysis were taken monthly from bulk precipitation and approximately biweekly from stream water, shallow groundwater, and soil water. Isotopic analyses were carried out by laser spectroscopy. Young water fraction was computed as the ratio between the amplitudes of the sine curves fitted to the isotopic composition of stream water and precipitation. The fitting of the sine curves was performed on the complete time series and on 2-year time windows.

Preliminary results show that monthly air temperature had a significant positive temporal trend, whereas monthly precipitation, soil moisture and streamflow had a decrease. The isotopic composition of the water sources (particularly in precipitation and stream water) showed a significant positive trend, which was correlated to the increase in air temperature. The estimated young water fraction varied between 52% and 68% depending on the methodological approach. Our results suggest that the combined trend in temperature and precipitation has a considerable effect on soil moisture and streamflow, and the climatic variation should be considered for the estimation of the young water fraction.

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Conceptual interpretation of infiltration under sealing process by membrane fouling models

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Keywords. Mathematical models, Darcy's equation, pore blocking, resistance to flow.

Abstract. Membrane fouling models (Hermia, 1982) describe filtration membrane fouling which can occur by pore blocking, pore constriction, caking or a combination of the mechanisms (Bolton et al., 2006). In the paper, we are interested in the application of these models to the infiltration of overland flow into the soil porous media under sealing formation. The soil porous media is assumed to be the filter and the turbid runoff, flowing over an erodible slope, infiltrating into the soil porous media, is assimilated to the filtrating fluid. The mathematical models relate by explicit equations the pressure to time during constant flow process, and volume to time during constant pressure process. In particular the Complete Pore Blocking (CPB) assumes that each single particle participates to the blocking of the pores and that these do not settle on the previously deposited particles. Furthermore, each filtration deposit particle obstructs and blocks a single pore. The intermediate pore blocking IPB assumes a pore blocking and particles accumulation at the surface. Standard pore blocking SPB model assumes that particles accumulate inside membranes on the walls of straight cylindrical pores thus the pore volume decreases in proportion to the filtered volume. The pores are assumed to have a constant diameter and length. The cake filtration model (CF model) occurs when particles accumulate on the surface of a membrane in a permeable cake of increasing thickness that adds resistance to flow. The total resistance R is the sum of the membrane resistance and the cake resistance. In the paper, we study exchange fluxes between the pore water in the vadose zone and the free water body in the soil surface. The focus is on a post ponding phase, when the surface runoff occurs and a water layer flow on the soil surface slope, while the soil is saturated. The question is: assuming a rigid media, how much does the infiltration is impeded by the sealing layer and/or by the pore blocking? This is especially important for soil erosion processes and flooding formation. To this purpose, the individual Hermia models and the combined Bolton models were assessed through testing under constant pressure. We validated the models with experimental trials of runoff flow infiltration, measuring the infiltration rate by rainfall experiments in a silty-clay loam soil.

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Monitoring and predicting irrigation requirements of tree crops in Eastern Sicily as a tool for sustainability

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Keywords. Random Forest, Water needs, FAO-56, QGIS, Sustainable irrigation management.

Abstract. In arid and semi-arid climates, improving the management of water resources through the use of innovative technologies is of primary importance to increase the productivity of the agricultural sector. Appropriate measures have been applied in Europe to limit water use to sustainable levels. In particular, the 6th Environmental Action Program (PAA, 1600/2002/EC) and the Water Framework Directive (WFD, 2000/60/EC) established the main political objectives about the use of water, to ensure a more sustainable environment and integrated approaches to water management. In Italy, the Ministry of Agricultural, Food, and Forestry Policies approved the Ministerial Decree of 31 July 2015 which obliges the Regions to monitor irrigated areas and volumes. The irrigated agriculture of southern Italy, often managed by the reclamation consortia, generally lacks the necessary information and tools which would allow to improve the water management and achieve the necessary sustainability of the system. In this context, the general objective of the study is to monitor the water needs of tree crops at the irrigation district level and to evaluate the reliability of the use of IdrAgra model for management purposes. IdrAgra is based on the FAO-56 double-crop coefficient approach, and it is easily accessible through the IdrAgraTools plugin in the QGIS framework.

The study concerned the “Quota 102.50” irrigation district (Eastern Sicily, Italy), for the reference period 2019-2020. First, a Random Forest (RF) classification was applied to map the main irrigated tree crops in the study area. The RF model was constructed using a monthly time stack of green (B2), red (B3), and near-infrared (B8) bands of 24 Sentinel-2 images and 503 ground truth sampling points.

Subsequently, the IdrAgra model was applied and the obtained irrigation requirements were compared with the volumes distributed by the reclamation consortium at each sub-district. The results showed the effectiveness of IdrAgra for monitoring water management in the context of tree crops and its use by reclamation consortia could allow improving the sustainable use of water resources.



Monitoring and numerical modeling of border irrigation: lesson learned in northern Italy

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Keywords. border irrigation, shallow water equation, uniformity distribution, application efficiency

Abstract. Achieving a good irrigation performance is not straightforward in border irrigation practices. This is almost always due to a lack of balance between natural factors (i.e. soil texture, infiltration characteristics), geometrical features (field length, slope and border strip width) and management elements (flow rate and cut-off time). Such lack of balance makes it difficult to reach an optimal water depth across the field and a uniform intake opportunity time to satisfy crop water requirements at every point. In light of these concerns, studies

exploring sagacious practical approaches to field design and irrigation management are needed to understand how we can keep this ancient but still crucial irrigation practice alive. In this work, the results of an intensive monitoring campaign carried out in 2021 over three maize fields located in the Padana Plain (North Italy) and aimed to detect



actual flow rate, cut-off time and distance, advance and recession trajectories were used to calibrate an hydrodynamic model based on the combination of 2D Shallow Water Equations and Green-Ampt approach for describing infiltration process. The model was tested on real-world case studies by evaluating its reliability in reproducing the actual dynamics of the watering within the examined fields. The results of the numerical experiments will be presented for different initial soil conditions and infiltration proprieties, and the effects on application efficiency and water distribution uniformity of different field geometries (i.e. field length, slope and border strip width), flowrates and cut off-times will also be discussed.



Comparing Theory and Practice of a Beerkan Infiltration Experiment in a Layered Soil

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Keywords. beerkan infiltration experiment, theoretical infiltration model, ring insertion, ponded depth of water, layered soils.

Abstract. The use of the Haverkamp infiltration model to deduce hydrodynamic parameters of a saturated soil presupposes fully unconfined infiltration experiments (ring insertion depth, $d=0$) with a null ponded depth of water on the soil surface ($H=0$). In practice, a ring is inserted a short depth into the soil and a small positive head of water is established on the infiltration surface for at least a part of the run.

In this numerical investigation, the combined ring insertion and ponded depth of water effects on infiltration were tested for both a homogeneous and a layered soil. In particular, a 2 h infiltration process was simulated for homogeneous loamy-sand (LS) and silt-loam (SIL) soils and for layered soil profiles consisting of a 0.5, 1 and 3 cm thick SIL soil overlying a LS soil. A source with a radius of 5 cm and both the theoretical ($d=H=0$, $d0H0$) and a practical ($d=H=1$ cm, $d1H1$) setups were considered.

In comparison with the data obtained in accordance with theory, the $d1H1$ setup yielded i) a very similar cumulative infiltration at the end of the process, I_{2h} , for the homogeneous LS soil (+1.2%) and a smaller I_{2h} value for the homogeneous SIL soil (-10.2%); ii) a larger I_{2h} value for a thin SIL soil layer overlying the LS soil (+15.6% and +4.1% for the 0.5 and 1 cm thick upper layer, respectively); and iii) a smaller I_{2h} value in the case of a thicker SIL soil layer (3 cm: -9.1%). Similar results were obtained by considering the final infiltration rates. Therefore, in the case of a thin low-permeability upper soil layer, the practical experiment enhanced infiltration as compared with the theoretical experiment. As the thickness of the upper soil layer increased, the practical experiment induced a slower infiltration process than the theoretical one and the difference between the two setups approached the detected difference for the homogeneous SIL soil.

In conclusion, the thickness of the upper soil layer influences the difference between the theoretical and the practical experiment. For the investigated layered soil, the best correspondence between theory and practice should be expected to occur when the upper soil layer has a thickness falling in the 1 to 3 cm range. A wider investigation, including other soils, layered soil profiles, ring radii and antecedent soil water conditions is necessary to reach general conclusions.



Interception/Evaporation Measurements for Lemon Tree

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Keywords. Interception, evaporation, lemon tree, experimental tests, thermal imaging.

Abstract. It is known that at the event scale, evaporation losses of rainfall intercepted by canopy are a few millimetres, which is often not much in comparison to other stocks in the water balance. Nevertheless, at yearly scale, the number of times that the canopy is filled by rainfall and then depleted can be so large that the interception loss may become an important fraction of rainfall. Recently, a simplified interception/evaporation model has been proposed (Baiamonte, 2021), which considers a modified Merriam model to compute interception during wet spells, and a simple power-law equation to model evaporation by wet canopy during dry spells. Thus, the model can be applied for continuous simulation, according to the sub-hourly rainfall data that is appropriate to study both processes. Modelling evaporation process required the two-parameters of the power-law, describing the initial condition and the evaporation rate. In this paper, for lemon tree and for different temperature, T , and relative humidity, RH , conditions (Fig. 1), numerous experimental testes were carried out to derive the aforementioned two parameters. The results obtained in this work help understanding the studied process and could be implemented in the recently introduced interception/evaporation model to quantify this important component of the hydrologic cycle.

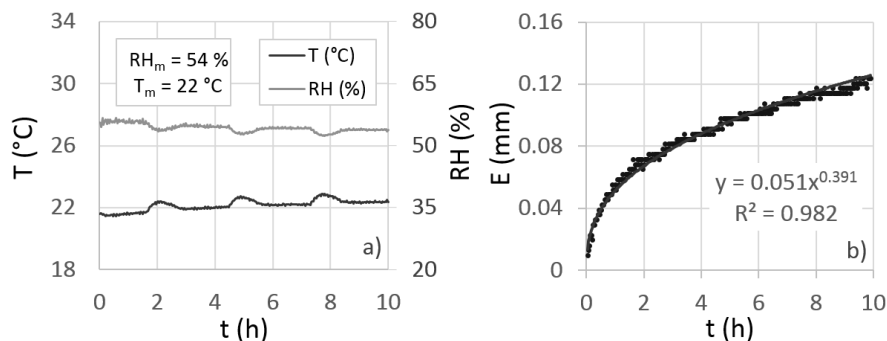


Fig. 1 – For lemon tree, and a) for a temperature and relative humidity scenario, b) time-varying evaporation loss by the wet canopy and the corresponding power-law.

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Effects of solids accumulation on treatment performance and hydraulics in horizontal treatment wetlands

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Keywords: Treatment wetland, clogging, porous medium, accumulated solids

Abstract. Although clogging is one of the crucial issues that attracted increasing attention in the scientific community, there are still several gaps in its genesis process and assessment. Void pores clogging in horizontal flow (HF) treatment wetlands (TWs) may severely impact water permeability, making the substrate prone to be clogged by solids accumulation, biofilm growth, and root filling causing hydraulic malfunction and expansive management costs. This study aims to evaluate the behaviour of three full-scale HF-TWs regarding treatment performances and accumulated solids nature and build-up process in relationship to the hydraulic conductivity variation of the filter medium. The first HF unit (HF₁) planted with *Phragmites australis*, has been operating for eight years working as a tertiary system for conventional wastewater (WW). The other two (HF_{2A}, HF_{2B}) planted with *Canna indica*, are one year old and treat dairy WW. In the HF₁, the total solid (TS) concentration varied between 920 and 7381 g · m⁻³ with an average value of 3154 (CV= 74.1%). The volatile solids (VS) concentration ranged from 173 to 1157 g · m⁻³ with an average value of 456 g · m⁻³ (CV= 61.1%). The VS fraction accounted for 20% of the TS concentration. The minimum and the maximum value ratio was 8.0 and 6.7 for TS and VS, respectively. The HF₁ showed more spatial variability of hydraulic conductivity and solid accumulation in the porous media rather than HF_{2A} and HF_{2B}. The average concentration values of TS, PRB and VS in HF₁ were higher than those observed in HF_{2A} and in HF_{2B}, and dead plants played an important role in determining the solid organic accumulation. Independently of the operational time and plant species, spatial variability of PRB concentration was high, highlighting a significant heterogeneity in the root distribution along the porous medium. As expected, in HF₁, the inlet zone was mainly hit by the interception and sedimentation of solids and it was characterized by a severe hydraulic conductivity reduction. At the same time, HF_{2A} and HF_{2B} did not show significant differences in the spatial distribution of solid accumulated which recalcitrant material are predominant. Despite the different development of solid accumulation processes, all the systems efficiently removed the principal chemical and physical pollutants.

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Evaluating Flow Regime Alterations Of Intermittent Rivers Due To Point Sources: A Modeling Approach

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Keywords. Flow regime, flow regime alterations, intermittent rivers, hydrological indicators, SWAT Model

Abstract. Anthropogenic activities and climate change may severely alter the natural flow regime of rivers. In intermittent streams, hydrological regime alterations influence river morphology, water quality, river ecosystem. The divergence between “impacted” and “un-impacted” hydrological condition is needed to support ecological status assessment as required by the Water Framework Directive.

The aim of the present paper was to define an integrated modeling framework for analyzing the hydrological regime alterations induced by point sources (PSs) discharges in regions with limited data availability through two case studies: the Canale d’Aiedda (Italy) and Nil wadi (Algeria). At this aim, long time series of daily streamflow in natural and impacted (current) conditions were generated by applying the Soil and Water Assessment Tool (SWAT) model and the hydrological regime was characterized by using several hydrological indicators (HIs) computed by using daily streamflow data.

Flow regime alterations due to PSs were assessed with the range of variability approach. Results showed that the PSs induced alterations of some components of the flow regime (i.e. magnitude, duration, and timing). Hydrological regime classification of the river reaches receiving wastewaters from PSs shifted from intermittent to perennial. All the components of the low flow (1-, 3-, 7-, 30-, and 90-day minimum flow, zero-days) and the monthly flow recorded in summer were severely altered. Minor hydrological alterations were assessed for high flow components (1-, 3-, 7-, 30-, and 90-day maximum flow) and mean monthly flow in the wet period. The timing of minimum flow was found to shift later in the year. This study may support river ecologists in the ecological status evaluation.



Monitoring runoff and sediment production in forests affected by the Vaia Storm

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Keywords. Vaia Storm, runoff, sediment production, forest recovery.

Abstract. The Vaia Storm hit the northeast of Italy on October 28th, 2018, causing severe damage to mountain forest ecosystems, mainly in subalpine Norway spruce forests. As a result, about 42 million trees on an area of 41,000 hectares between Friuli Venezia Giulia, Lombardy, Trentino-Alto Adige and Veneto were blown down by wind with gust velocity above 200 km/h.

The current study was carried out in a damaged area and it aims to estimate the effects of management strategies after storm events on runoff and sediment production. The considered forest treatments were (1) salvage logging and natural regeneration, (2) no intervention, and (3) salvage logging and artificial regeneration.

The four experimental plots have an area of 27 m² (4.5 m x 6 m) and are located on a 40% slope facing East, previously covered with subalpine spruce forest. The area of interest was affected by two windthrows in 2003 and 2018 (Vaia). The plots are located at about 1650 m asl. In these plots, we measured runoff and sediments from September 2020 to the present. Data collection season ranges from May to October depending on the course of the winter season, where snow cover and ice do not permit measurements. Water and sediments mobilized in the experimental plots are conveyed in a 1 m³ tank where the content is weighted by a load cell, and a pressure transducer records the water level. An *in-situ* radar rain gauge measures cumulative precipitation and intensity.

Sediments samples were collected twice a year, dried and sieved to obtain the percentage of organic material and the texture of the eroded soil.

The first results showed a contrasting behaviour in terms of runoff/sediment production between the four plots upon the occurrence of an intense precipitation event. The differences could be explained by the time passed after the windthrow, and the different forest treatments applied. However, we noticed that under certain conditions, such as high intensity and short precipitation duration or vice versa, runoff and sediment production tend to be equivalent in the four plots. We will keep monitoring the succession dynamics in the experimental plots and the effects on runoff and sediment production for the years to come to gain further insights into the involved processes.



How do existing torrent control structures perform effectively? From first-level inspections to maintenance strategies

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Keywords. Check dams; Flood risk; Vulnerability; Mountain Catchment; Hydraulic Structures.

Abstract. Torrent control structures are countermeasures build in torrent catchment areas for mitigating losses due to flood and debris flow events. The durability of these measures depends on structure type, material, quality of design, construction, and maintenance as well as on the physical pressures they are under. During last half-century the decrease of investments in ordinary maintenance activities and the natural degradation of the structures have exacerbated the reduction of protection level, reason why they were built. In this context, monitoring and getting maintenance of existing structures should be the focus of the future investments to improve or maintain their functionality and to increase safety from natural hazards. The present study describes a proposal of a first-level inspection that was applied on the torrent control structures of Pioverna torrent, in Valsassina (North Italy). The results of the first-level inspection have filled a dataset with a wide spectrum of information, such as absent structure details (width, length, height, age of construction, materials, etc.), structure’s status, residual functionality, torrent and hillslope instability level of the neighboring area. Then, a homogeneous Markov chain model was adopted to assess the vulnerability of the existing surveyed torrent control structures. Such proposed approach was integrated with a statistical analysis of the dataset in function of structure type, construction materials and neighboring torrent-hillslope conditions. These additional results provide a comprehensive knowledge of how actually control structures perform, crucial for planning risk management, and a reliable model for forecasting the decline of functionality over the time. Moreover, this framework allows to evaluate the time-dependent impacts of different levels of ordinary maintenance on torrent control structures. Finally, the study could be extremely useful for enhancing the role of the first-level inspection and monitoring, essential for estimating the actual and future vulnerability of existing torrent control structures, and for improving a decision support method that can manage the future investments in ordinary maintenance of torrent control structures.



Testing The Effect Of The Rill Channel Slope On The Correction Factor Of Surface Velocity

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Keywords. soil erosion; rill flows; flow velocity; dye method; correction factor.

Abstract. Flow velocity is one of the most important hydrodynamic variables for both channelized (rill and gully) and interrill erosive phenomena. The dye tracer technique to measure surface flow velocity V_s is based on the measurement of the travel time of a tracer needed to cover a known distance. The measured V_s must be corrected to obtain the mean flow velocity V using a correction factor $\alpha_v = V/V_s$ which is generally empirically deduced and can vary in different flow conditions. Experiments were performed by a fixed bed flume simulating a rill channel located at the experimental area of the Department of Agriculture, Food and Forest Sciences of the University of Palermo. The sloping flume was 5 m long, 0.078 m wide, and 0.04 m high. Two different bed roughness conditions (smooth flume, and flume covered by sieved soil characterized by a median diameter of 0.014 mm) were tested.

The measurements were carried out for four slope values ($s = 9, 11, 13,$ and 15%) and different discharges. For each slope-discharge combination, 20 measurements of V_s were carried out using a Methylene blue solution as a dye-tracer. The tracer injection section was placed 4.3 m upstream from the end of the flume. The travel time of the leading edge of the dye cloud was measured by a chronometer.



Figure 1. View of the flume during the experimental runs.

The results of the present investigation were compared with those previously obtained using the same experimental setup, bed roughness conditions, and channel slope values ranging from 0.1% to 8.7%. The investigation aimed to test the effect of the channel slope on the correction factor α_v for a wide s experimental range.



Indigenous knowledge integration for large-scale siting of sand dams in Angolan drylands

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Keywords. Water harvesting, best siting, sand dams, participatory approach, Angola

Abstract. Sand dams are simple and effective structures built across ephemeral riverbeds in arid/semi-arid regions to harvest water within sand pores and increase water availability and quality for rural communities. The complex morphological, hydrological, social and economic conditions that make sand dams a beneficial tool for climate change adaptation are largely influenced by the siting phase. Proper location of a sand dam can reduce community’s travel time to water points, reduce water conflicts and increase food security through expansion of irrigated agriculture. On the other hand, a misplacement of sand dams can, at worst, increase disparities in water access and increase local conflicts. To approach a viable siting of sand dams, most projects are developed and delivered with the community through a bottom-up approach. However, in case of large-scale project, remote sensing and biophysical analysis are the dominant approach, leaving out the precious indigenous knowledge and eventually affecting both the actual location selection and the benefits to local communities. In this paper, we propose a large-scale participatory methodology to sand dams siting, which draws on mixed-methods connecting the conventional top-down biophysical analysis with bottom-up participatory research. The generic approach developed for sand dams siting in Namibe can be adapted to other dryland regions to foster the integration of scientific and local knowledge for water harvesting expansion and success.



Environmental and economic advantages of Giant Reed harvesting in semi-arid climate conditions

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Keywords. riparian vegetation management, hydraulic risk, invasive species, remote sensing, energy crop.

Abstract. The vegetation development in riverbeds creates obstructions to the regular water flow with the consequent flooding hydraulic risk increase. *Arundo donax* L. or giant reed (GR) is one of the most successful invasive species of riparian ecosystem in Mediterranean areas, causing a strong economic impact for its removal and disposal. Meanwhile, due to its high biomass yield and adaption capacity to several conditions, GR is a very promising no-food crop to produce biogas by anaerobic digestion.

The research activity provides for the involvement of territories belonging to the inner areas of Sicily, especially the Calatino area, characterized by heightened phenomena of climate change with water scarcity and drought and flooding risk increase, typical of the Mediterranean environment mostly in the last decades. The aim of the study was to map and quantify the actual spatial distribution of GR in watercourses embankments in Geographic Information System (GIS) environment using Remote Sensing (RS)-based classification algorithm. In this regard, a method based on the automatic supervised classification, was applied on three different combinations of spectral bands (True Color Image – TCI; Near-Infrared, Green and Blue – NGB; Vegetation Red Edge – VRE) of Sentinel-2 satellite related to summer season (11th August 2019), with the aim of identifying the most suitable classification to map the GR. The results showed that the VRE composition is the most accurate for the determination of GR, followed by the NGB image. The worst performance was obtained by using the TCI combinations. A further elaboration was carried out combining the three classified image, in order to obtain a more accurate localization and quantification of GR. The final thematic map allowed to correctly classify GR for the 46% of the cases, with an overall accuracy of 85.02% and a high Kappa Coefficient of Agreement value equal to 0.81. Finally, the surface covered by GR in the study area (computed in GIS environment) was about 2 km².

The study could contribute to the development of a maintenance plan with the aim to reduce the risk of streams flooding in valley areas and at intersections with infrastructure works. The plan could be used by stakeholders to manage watercourses and get economic benefits in inner areas.

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Treatment of steep and clayey soils with olive pruning residues for conservation purposes: hydrological monitoring and modelling approaches

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Keywords. Surface runoff, soil loss, soil cover, soil conservation practices, SCS model, USLE-family models.

Abstract. When olive groves are cultivated on clayey soils with steep slopes, as in many Mediterranean areas, reducing runoff and soil erosion by adopting effective soil management practices (SMPs) is imperative. A soil cover by pruning residues may result in a viable alternative to the commonly-adopted mechanical tillage. However, while the literature about the soil protection with a crop cover is abundant, the studies about the SMPs using pruning residues are much less. To fill this gap, this study evaluates and simulates the hydrological response of a steep and clayey olive grove of Southern Italy under three SMPs (mechanical tillage, MT, mulching with 3500 kg ha⁻¹ of pruning residues, M, and standard protection of soil, assumed as a control, C). Under these scenarios, the infiltration rates under simulated rainfall, and the surface runoff and soil loss after natural rainfalls have been evaluated at the plot scale throughout two years. Moreover, the accuracy of the SCS-CN and two USLE-family models (MUSLE and USLE-M) in predicting runoff volume and soil loss has been evaluated using those hydrological observations. The MT led to the lowest water infiltration rates (on average +63%, compared to the control), and the highest runoff (+8%) and soil loss (+57%). The M practice increased the soil infiltration rates by over 20%. For this practice, noticeable reductions in runoff (on average -22%) and soil loss (-48%) were detected. The SCS-CN model was accurate in predicting runoff volumes (mean difference of 7% compared to the corresponding observations) for all SMPs. The MUSLE model showed better performances in soils subjected to MT and SP (differences between predictions and observations lower than 10%), while the USLE-M was more reliable in simulating the soil loss in M plots (differences of 8%). Overall, the results of this study are promising in view of a broader diffusion of SMPs in croplands with adverse conditions under Mediterranean semi-arid conditions. Moreover, the Curve Numbers and C-factors coming from calibration are useful for future models applications in orchards with steep and clayey soils.



Drivers of adoption of sustainable practices and technologies for soil protection among winegrowers in North-west Italy

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Keywords. Soil management, mixed methods research, sustainability, winegrowers perception

Abstract. The study aimed at investigating drivers of adoption of good practices and technological innovations for soil protection in a group of winegrowers in Piedmont region, North west of Italy. Many previous studies addressed soil conservation and degradation, but the points of view of land operators have not been frequently addressed. Understanding farmers' perceptions, intentions and needs could help in a better suited implementation of measures for soil protection in vineyards. Four focus groups has been conducted with winegrowers (N=17) in Piedmont region, North-west Italy. Topics addressed in the focus groups were related to: perception of soil erosion and the role of the human factor in preventing/causing it, adoption and intention to adopt good practices and technological innovations for soil protection and, finally, barriers and drivers for their adoption. A questionnaire assessing participants' socio demographic characteristics and operation, vineyard management practices and perceived causes of soil erosion was administered to the respondents and the responses were used to encourage the discussion. Preliminary results showed that soil erosion was perceived as a relevant issue by the majority of the participants. Wide use of machinery during vineyard plantation and management was acknowledged as affecting soil and water conservation. Cost-benefit ratio did not sufficiently capture the complexity of farmers' decision making and behaviours, since the adoption of sustainable practices and technological innovations was more often related to place attachment and landscape protection. Social norms and peer pressures were not perceived as critical drivers for good practices adoption, whereas tradition and habits appeared to play a role in hindering the adoption of soil protection practices and technologies. Some recommendations arise from the present study: to encourage the adoption of soil protection practices and technologies, access to economic support should be spread but it does not seem to be enough. Personal values and habitual processes emerged as critical variables which could be targeted with awareness raising and education interventions. To maximize the fit between farmers' needs and sustainable innovation, these interventions should be based on a participatory approach and the co-creation of tailor-made solutions to better support the transition toward a more sustainable farming paradigm.



Analysis of Bedload Mobility in an Andean Stream

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Keywords. Glaciers, Mountain streams, Andes, Bedload, Tracers

Abstract. High gradient streams form the majority of the mountain drainage network and the sediment dynamics that occur here influence the features of sediment delivered to downstream channels, particularly by controlling the timing of sediment fluxes and the amounts and size of material released to the lowland rivers. In this sense, the bedload is the transport process that regards the coarser particles, which are mobilized by rolling, sliding and saltation on the channel bed. In mountain streams, bedload can be the main sediment transport process, particularly, during flood events. Therefore, its analysis and quantification is crucial for several aspects, including hazard assessment, understanding the morphodynamics of higher order channels and managing reservoir sedimentation. However, the importance of bedload contrasts with the fact that it is difficult and impractical to monitor, especially in steep mountain streams, due to its impulsive nature. To cover this gap, different direct and indirect methods were used to investigate the bedload. One of these is the bedload tracing, which starting from the assumption that bedload transport may be understood as the result of random individual particle displacements, permitted to obtain precious data concerning sediment dynamic in mountain streams during the last decades. In this work, bedload was analyzed in an Andean stream by the use of tracing method. The site is the Estero Morales, a high-gradient stream located in the Metropolitan Region (central Chile). The streambed exhibits boulder-cascade, step-pool and plane bed morphologies with an average slope of about 9.5% and a $D_{50} = 59$ mm. The basin (27 km²) extends between 3815 and 1850 m a.s.l., hosting the San Francisco glacier (1.8 km²) that strongly affects the hydrological regime. In particular, during the melt period (December-March) the glacier ensures daily discharge fluctuations with highly variable associated bedload transport rates. In January 2016, 197 clasts equipped with Passive Integrated Transponders were seeded along the Estero Morales and their mobility monitored along a reach 745 m long. Specifically, 11 surveys were realized between January and March 2016 using a mobile antenna in conjunction with a laser rangefinder, obtaining a mean recovery rate of 25.9 %. During the study period, the tracers experienced a maximum and mean water discharge equal to 4.28 and 2.59 m³ s⁻¹, respectively. This hydraulic forcing conditions induced the transport up to a maximum diameter of 280.0 mm, while the average diameter mobilized and average transport distance were equal to 95.0 mm and 12.0 m. The mobility observed resulted not clearly related to the hydraulic forcing, stressing the complex transport dynamics of mountain stream.



Assessing Path Tortuosity On Rill Flow Resistance

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Keywords. Rill erosion; tortuosity; flow velocity profile; rill flow resistance.

Abstract. The structure of the flow of meandering channels is surprisingly more complex compared to that of straight ones. The channel tortuosity is defined as the ratio between the actual channel length and the straight length measured between the upstream and downstream boundary sections. Currently, the effect of tortuosity has been little investigated for rill flows. In this study, a theoretical flow resistance law, initially developed for open channel flows, has been applied to investigate the effect of rill tortuosity on flow resistance using experimental measurements. This flow resistance law is obtained by integrating the power velocity profile and depends on its scale parameter Γ .

The experiments were carried out on a plot, 2 m wide, 7 m long, located at the experimental area of the Department of Agriculture, Food and Forest Sciences of the University of Palermo. The plot was filled with soil having a clay percentage of 32.7%, silt of 30.9%, and sand of 36.4%, and slope equal to 18%. Mobile bed rills were manually incised to obtain four different values of tortuosity, approximately equal to 1 (straight rill), 1.08, 1.16, and 1.30. The rills were initially shaped by a low clear flow discharge. Then, the experimental runs were carried out using a constant inflow clear discharge equal to 0.32 L s⁻¹. Each rill channel was divided into nine longitudinal segments. Each segment was bounded by two cross-sections having a linear distance of 0.624 m. A rill reach is defined as the distance from a given cross-section to the rill end. For establishing the rill channel geometry, the three-dimensional Digital Terrain Model (3D-DTM) was created by the Structure from Motion technique using a set of about 70 photographs taken from the plot area by a digital camera.

In each experimental run, the mean hydraulic radius R in the reach was determined using a method, recently developed, which couples the ground survey of the rill channel from the SfM technique with the survey of the water tracks inside the channel marked by a dye solution. The slope steepness s of each rill reach was obtained by the rill thalweg extracted by 3D-DTM. The mean rill flow velocity V was measured by the dye-tracing technique using a Methylene blue solution as a tracer. The abovementioned measurements allowed to calculate the Darcy-Weisbach friction factor

$$f = \frac{8gRs}{V^2}$$

in which g is the acceleration due to gravity. The measurements were used to calibrate the relationship between Γ and the rill slope, the Froude number, and the rill tortuosity. Finally, the reliability of the theoretical flow resistance law was tested by comparing the measured and estimated f values.



Agricultural use of biosolids in the Mediterranean karst environment

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Keywords. Integrated land and water management; coastal marine environment; industrial and domestic sewage; karst stony terraces; soil health and quality

Abstract. Rural areas in Croatia have great potential in the shape of natural assets and landscapes, which is an excellent basis for the economic development, considering two main economic branches: agriculture and tourism. In the context of integrated land and water management, production of wastewater effluent and large quantities of sewage sludge from the local sewage treatment plants may be an issue of high significance. Submerged wastewater effluent discharge in the vicinity of cities along the Adriatic Sea coast may lead to coastal marine sediment contamination by inorganic and organic pollutants, depending of sewage treatment system performance. The city of Šibenik area (Middle Eastern Adriatic coast) had faced in the past the serious problem of the eutrophication of the Krka River Estuary and coastal marine environment that had been receiving untreated industrial and domestic sewage for years. As a region is very attractive because of natural beauties, the problem was becoming more pronounced during the touristic summer period. Sewage treatment system and pipeline to outside of Krka River Estuary was constructed in 2008, and treated effluent is being released into the near shore marine environment SE of the Island of Zlarin by 5000 m long sub-marine pipe system. The investigation undertaken to examine the metal concentrations in marine sediments influenced by the wastewater disposal system showed no distinct anthropogenic loads of trace elements in sediment that may be related to the wastewater effluent discharge. Anyway, quantities of the sewage sludge that remain after the treatments may pose great risk for environment if not treated, stored or disposed properly. It was estimated that 1.846 tones (dry mater) are being produced monthly from sewage treatment plants in 5 agglomeration of the Sibensko-kninska County (SKC). Application of treated sludge to agricultural land was considered to be the best practical environmental option for most sewage sludge, but this option has to be carefully examined. In the last two decades more than 5000 ha of karst stony terraces and steep slopes in the study region have been remediate by stone crushing to make the land suitable for agricultural production, mostly for grapevine and olive production. After the deforestation, new grapevine and olive trees plantations are made particularly on the slopes exposed to sun and sheltered from strong winds. So, the capacity of the arable land of the to take on sewage sludge from the local treatment plants in SKC has been defined by this study.



Testing An Automatic Approach For Rill Network Extraction To Measure Rill Erosion By Terrestrial Photogrammetry

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Keywords. Plot measurements, rill erosion, Structure from Motion, terrestrial photogrammetry.

Abstract. In a recent investigation, the applicability of close-range photogrammetry to measure rill erosion was positively tested on two plots with a length of 22 m and steepness of 22% and 26% at the Sparacia experimental area (Sicily, Southern Italy). An objective method, based on the *convergence index*, was applied to delineate the rill network from the Digital Elevation Models (DEMs) and measure the eroded channel volume, accordingly.

For the erosion event of September 2017, rills also formed on the 14.9% slope of the experimental area and were surveyed on two 44 m-long plots with a series of photographs taken from the ground to cover each plot. Rills were characterized by apparent differences in the cross-section geometry as compared to those previously detected on the more sloped plots, inasmuch they were wider and shallower.

The present investigation aimed to test the applicability of the method based on the convergence index for this different morphologic condition. In other words, the aim was to check the effects of the rill cross-section morphology on the proposed procedure to measure rill erosion.

The three-dimensional (3D) Digital Terrain Models and DEMs were obtained by an image-processing software using the Structure from Motion technique. The rill channels detected by the convergence index were separated into contributing and non-contributing to the total soil loss measured in the tanks downstream of the plots. The rill density and frequency, and the soil loss due to contributing rills were obtained. Finally, the sediment weight measured by the contributing rills was compared with the weight of the sediment stored in the tanks that was assumed as reference value.



The ground pressure exerted by the tractors in the last five decades

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Keywords. contact area, soil compaction, soil degradation, soil protection, tractor tyres.

Abstract. Currently, the potential serious consequences of the impact of agricultural machines on the soil are increasingly known. As the soil is and will be the main commodity for food production, the issues of prevention, conservation and restoration of the "health" of agricultural soils are extremely paramount. Soil compaction is one of the eight factors causing soil degradation, according to the EU "Strategy for soil protection". During the last five decades, soil compaction was caused by the traffic of agricultural machines having increasingly higher power and weight. In order to reduce the soil compaction caused by the traffic of agricultural machines, the type of tyres and their inflation pressure should be carefully selected. The mean ground pressure can be quickly and accurately estimated for several combinations of tractor weight/tyres, in order to evaluate the possibility of soil compaction. The aim of this study is to evaluate the anthropogenic and technogenic impact of agricultural tractors on the soil during the last five decades (i.e. from 1971 to 2021). In fact, the negative impact of both wheeled and tracked agricultural machines on the soil and its causes, taking into account the design features of tractor propulsion organs (i.e. tyres and tracks), is described in this work. Data such as the construction year, manufacturer, model, power, total weight, weight (load) on the front and rear axle, wheelbase, types of front and rear tyres, as well as tyre specifications, were collected. The main indicators of the negative impact of the tractors manufactured during the last 50 years on the soil, i.e. the average and maximum pressure of their propulsion organs on the soil itself, were computed and the mean pressure applied by each tractor onto the soil was calculated. The results show that during the specified periods: 1) the average power increased and the production of 2WD tractors highly decreased; 2) the weight/power ratio decreased from 70 to 60 dN/kW; 3) most tractors were fitted with cross-ply tyres during the 1970s, while almost all tractors are nowadays fitted with radial tyres having aspect ratio lower than 85% and even reaching 65%; 4) the average ground pressure increased, especially for tractors having power higher than 100 kW. Therefore, these results show that tractor manufacturers did not take care of reducing soil compaction during the above period. Therefore, manufacturers must pay more attention to designing machines not exceeding the limit of 0.1 MPa (low soil compaction), by decreasing the loads and/or increasing the soil contact area.



Monitoring rainfall erosivity in the Sparacia experimental Area by an optical disdrometer

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Keywords. Soil loss, Rainfall erosivity, Rainfall kinetic energy, Erosion models, Drop size distribution.

Abstract

The rainfall kinetic energy has an important role in water soil erosion processes and it can be determined by the knowledge of both drop size distribution (DSD) and falling velocity of the drops. The paper shows the results obtained by the DSDs measured by an optical disdrometer installed at the Sparacia experimental station in the period May 2015 - January 2020. At first, the measured DSDs, that are recorded with a 1 min sampling time, are used to test the applicability of Gamma and Weibull theoretical distributions. Then, the dataset of DSDs and the falling velocity estimated by the relationship suggested by Ferro (2001) are used to obtain the rainfall kinetic power. To better highlight the relation between kinetic power and intensity, the DSDs are also aggregated into rainfall intensity classes, having different amplitudes.

The kinetic power values are initially used for testing the applicability of the kinetic power-rainfall intensity relationships proposed by Wischmeier and Smith (1978), applied in the Universal Soil Loss Equation (USLE), Brown and Foster (1987) (RUSLE), and McGregor et al. (1995) (RUSLE2). Then, the reliability of theoretical relationships for estimating the kinetic power by rainfall intensity and a characteristic diameter (median volume diameter or mean diameter) are verified. The above tests are carried out for both single and aggregated DSDs. Finally, for each rainfall event, the kinetic energy obtained by DSDs measured during the event is compared with those obtained by the above literature relationships to establish the most reliable equation at event scale.

All the results obtained by DSD measurements carried out at Sparacia are compared with those obtained in Palermo (Italy) and El Teularet (Spain) using the same optical disdrometer in previous investigations. In particular, the differences on DSDs characteristics and on the relation kinetic power – intensity are analyzed in detail.



Different strategies to alleviate soil compaction risk during tillage operations

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Keywords. Soil compaction, Controlled traffic farming, Tillage

Abstract. Compaction causes soil degradation, but different strategies can help to mitigate this phenomenon, such as increasing soil strength during traffic events and decreasing soil stress due to equipment features. The first one can be achieved by raising soil organic carbon and limiting the traffic when the soil water content is too high. Decision support systems help this choice and can improve the machine settings to reduce soil stress. Controlled traffic farming can enhance soil compaction mitigation by confining all the equipment transit on the traffic lane. Crop seedbeds remain undisturbed, improving crop performance and increasing yield. Controlled traffic needs equipment standardisation for all the operations, from tillage to harvest, that can overcomplicate equipment travel on public roads and resort to contractors.

This work aims to investigate three different strategies to alleviate soil compaction risk during soil tillage. The first is “Random traffic with wheeled tractors” (RW), the Second is “Random traffic with tracked tractors” (RT), and the third is “Controlled traffic” (CT). The three scenarios were compared by using the following traffic indexes: Rut Length, Traffic Intensity, Mechanization Degree, and Field Load Index. Soil stresses on specific scenarios were calculated with the Terranimo® model. Collection of soil bulk density, penetrometer resistance, working time analysis, field traffic analysis and fuel consumption with telemetry was carried out to complete the analysis on a real scale thanks to a 19 ha field test on a farm in northeast Italy.

The soil stress is higher in the Controlled traffic than in the other two random traffic scenarios, due to the narrow width of the wheels used to decrease the trafficked area. The field index Ruth Length shows a higher value on CT caused by a lower working width. On Mechanization Degree the RT scenario has a 47% increase in comparison to CT and 21% more than RW due to the high power tractor used. Lower bulk density values were found in CT and penetrometer resistance showed statistically significant differences among scenarios and correlation with stresses modelled with Terranimo®.



Experimental validation of IRRILAB software for a sloped microirrigation sector

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Keywords. IRRILAB software application, microirrigation, sloping fields, non-pressure compensating emitters.

Abstract. Recently, the IRRILAB software application to design microirrigation units for sloping fields and for non-pressure compensating (NPC) emitters was developed (Baiamonte, 2018). This software does not require iterations since it based on analytical solutions, however, it can be applied to rectangular shapes of the microirrigation units. The objective of this paper is to test the output parameters for a sloped irrigation sector (15%) by using NPC emitters (Fig. 1), which usually are not suggested for sloping fields. However, NPC is cheaper, simpler, providing higher durability, than pressure compensating emitters. Applications were performed by neglecting and by considering minor losses due to the emitter connections. Results showed that IRRILAB provides good performance of the design parameters, with uniformity coefficients close to 90%. A slight improvement was obtained by considering the effect of local losses according to a method recently introduced, which links the kinetic head coefficient to the equivalent drip lateral length to be considered.

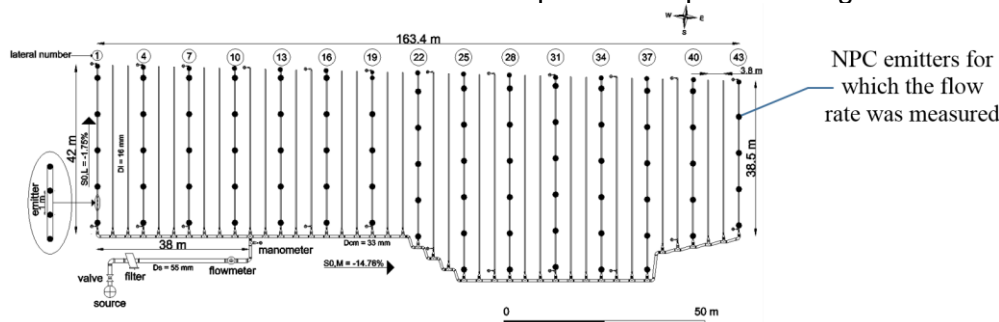


Fig. 1 – Sloped microirrigation unit designed by IRRILAB.

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TREATMENT OF DOMESTIC WASTEWATER THROUGH NATURE-BASED SOLUTIONS FOR IRRIGATIONAL REUSE

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Keywords. Nature-Based Solutions; Constructed wetlands; Wastewater treatment; Wastewater reuse

Abstract. The depletion of water resources induced by climate change, anthropic activities and pollution has rendered the implementation of technologies for the treatment and the recovery of wastewater an essential focus. Due to the high energy inputs and the expert maintenance required by the traditional centralised wastewater treatment plants, more sustainable alternatives have greatly gained interest of the research community. Nature-based solutions (NBS), particularly constructed wetlands (CWs), are simple solutions based on natural processes and suitable for the agricultural context. These systems demand lower economic and environmental resources than their traditional counterparts. Price-competitive and decentralised, this kind of technology promotes the closure of the water and nutrients cycles, through their recycle and re-evaluation. Within the framework of the FIT4REUSE project, the present work deals with the use of CWs to treat municipal wastewater and to reach an output quality sufficient for its reuse in agricultural irrigation. To study the system treatment capacity and to reach the effluent quality required by wastewater reuse regulations, a pilot plant (Figure 1) consisting in three vertical and three subsurface horizontal CWs was established in Granarolo dell' Emilia (Northern Italy). Two plant species, namely *Phragmites australis* and *Iris pseudacorus* have been cultivated on six different substrates, i.e. pumice, agriperlite, gravel, vermiculite, sand and cork, to study their influence on the overall performance of each system. The treatment efficiency of each CW has been evaluated on the reduction of different pollutants typical of domestic wastewater. The preliminary results indicated average removals of 80.7 % for COD, 35.3 % for TN, 65.3 % for $\text{NH}_4^+\text{-N}$, 36.1 % for $\text{NO}_3^-\text{-N}$, 34.9 % for PO_4^{3-} , 98.4 % for Total coliforms and 99.1 % for *E. coli*. Although further studies are necessary, this technology can be considered as capable to reach the project aims in terms of wastewater treatment.



Figure 1: Granarolo dell'Emilia pilot plant



Impact of compost addition on physical quality of a loam soil estimated from hysteretic water retention curve

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Keywords. soil water retention, compost, hysteresis, soil physical quality

Abstract. Application of compost to agricultural soils is a viable option for disposal of organic wastes but the effects on different soil physical attributes need to be evaluated. Capacitive soil physical quality (SPQ) indicators derived from the soil water retention curve allow assessment of potential effects of compost addition on the soil's ability to store air and water. However, estimation of SPQ indicators has been generally conducted from water retention data obtained from desorption experiments and assuming simplified assumptions, and little information is available on the hysteresis effects on soil physical quality estimation.

This study evaluates how hysteresis of the water retention curve affects the soil pore volume distribution functions and the capacitive SPQ indicators of a loam soil amended with compost. The van Genuchten model was fitted to experimental sorption (WWRC) and desorption (DWRC) water retention data determined for different compost to soil ratios. The pore volume distribution functions highlighted that sorption process involves larger and more heterogeneous pores than the desorption one. Consequently, different information is provided from the two processes with air capacity SPQ indicators higher in WWRC than DWRC and the opposite for the water storage SPQ indicators. Compost amendment was effective in modifying the soil pore distribution system as the water entry potential increased and the air entry potential decreased at increasing the percentage of compost. Whereas the SPQ indicators estimated from DWRC were sensitive to compost amendment, the same result was not obtained for SPQ indicators estimated from WWRC. It was concluded that compost addition could trigger positive effects on soil hydrological processes and agronomic service as both water infiltration during wetting and water storage during drying are favoured.



Field study on multifunctional irrigation of vineyards

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Keywords. multifunctional irrigation; vineyard; heat stress; spring frost; hydric nutrition

Abstract. Due to climate change, grapevine is increasingly exposed to both thermic stress and water stress, that affect the physiological activity and the phenological stages of vine. In particular, high temperature can accelerate ripening, involving in excessive sugar accumulation and high alcohol in the wine, reducing the total acidity due to a faster degradation of organic acids. Beside the technological ripening, the temperature increase also affects the synthesis and the accumulation of polyphenols, vitamins, and aromatic compounds in berries. The effect of the warming conditions is aggravated by the increasing exposure of vines to water stress, due to decreasing trend of rainfall during spring and summer. Depending on the level and the phenological stage, water stress reduces the yield and affects the quality of grapes. The warming trend not only affects grape ripening, determining an impact on grape and wine quality, but also induces an anticipation in the sprouting phases of the vine, increasing the risks caused by late spring frosts. Low temperature during sprouting can involve to the loss of buds and shoots (Poling, 2008), reducing the production of grape.

Different adaptation strategies could be adopted in viticulture to counter the emerging problems related to climate change, including both long-term measures (e.g., changes in vineyard locations) and short-term ones (e.g., use of tolerant varieties, of shading systems, of wind machines, of delayed pruning). Smart irrigation strategies are also an option and in this study we explored a multifunctional approach to vineyard irrigation, capable to counter the negative effects of excessively high summer temperatures and of late spring frosts, as well to provide hydric nutrition when needed. The capacity of evaporating water to achieve the canopy and berry cooling has been well studied from 1970s. The first studies considered overhead cooling sprinkler systems, that mainly water the outer canopy layer and only partially the bunch zone. More recently micro-sprinkler cooling system inside the canopy at the bunch level were also applied. Overvine sprinklers have been widely applied also for protection from frosts, allowing to form a layer of ice over vines that keeps the temperature slightly above the critical values and preventing damages of buds and shoots.

Our study was conducted during the 2020 and 2021 agricultural seasons, in a commercial vineyard located in Cavriana, Italy, at 135 m a.s.l. in the viticultural area of Garda Colli Mantovani DOC. The grapevine variety is Chardonnay, grafted on rootstock 420A; the vines are trained using Guyot system. Soil between rows is grass-covered with periodic mowing. Eight plots were designed within the experimental vineyard to compare four different irrigation strategies. The following strategies were considered: i) automated drip irrigation; ii) automated drip and sprinkler irrigation; iii) traditional drip irrigation, iv) no irrigation. Results obtained during the two seasons highlight the potential of automated, multifunctional irrigation for protecting from thermal stress and increasing water use efficiency in vineyards.



Quantifying Irrigation Volumes Using Sentinel-1 Soil Moisture Data in Central Italy

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Keywords. Soil moisture, remote sensing, irrigation volumes, water balance model

Abstract. The efficient use of water resources in agriculture represents a strategic objective, particularly in areas like Central and Southern Italy, where crops are strictly dependent on irrigation and where deficit phenomena are more likely. This objective must be pursued through technical and infrastructural improvements of irrigation systems and management optimization. A reliable and effective management strategy requires the availability of updated and detailed data of the actual extension of irrigated areas and water consumption, as required by the EU directive on water (2000/60 EC). The most interesting perspective for obtaining this information is represented by satellite data, particularly those that provide information on soil moisture.

However, the use of satellite soil moisture data for this purpose is still an open challenge, especially in agricultural contexts where a mismatch exists between the spatial resolution of satellite retrieved information and the extent of the irrigated fields.

In this work, soil moisture datasets at different spatial resolutions (1 km and plot-scale), derived from Sentinel-1 observations, as well as rainfall and evapotranspiration products are used to input the SM-based inversion approach (Brocca et al., 2018; Dari et al., 2020) with the aim of retrieving information on irrigation volumes. The method is applied over a complex-topography agricultural area of about 3000 ha, corresponding to the Upper Tiber River valley (central Italy). For this area, information about irrigation water consumption in the period 2017-2021 is used as a benchmark. The analyses are carried out both at the district and the plot scale, thus allowing to evaluate the performances of Sentinel-1-derived soil moisture data in estimating irrigation quantities at different spatial scales and highlight potential benefits associated with the progress towards hyper-high-resolution data.

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Drought risk assessment of five coastal agricultural watersheds in the Tuscany region

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Keywords. Drought risk assessment; climate change; drought hazard; cluster analysis; archetypes.

Abstract. Due to climate change, drought events are expected to increase in frequency and severity in the Mediterranean area. Some regions, such as the coastal agricultural watersheds of central and southern Tuscany, are particularly prone to drought impacts due to the concurrent high water demands for irrigation and tourism during the summer months. To properly tackle this natural hazard, it is essential to shift from a reactive approach towards a proactive one and, for this scope, detailed drought risk assessment is fundamental. In this study, the drought risk was calculated for 58 municipalities belonging to the Cecina, Cornia, Bruna, Ombrone, and Albegna watersheds. Multiple drought hazard indicators were selected to consider both past and future conditions; exposure indicators represented the infrastructural, social, and economic characteristics of the agricultural systems, while vulnerability indicators the social and ecological susceptibilities and the coping and adaptive capacities. As a result, 42 indicators were finally included to estimate drought risk. The highest risk and hazard were found in the southernmost part of Tuscany; exposure was significant in the coastal and high-value wine producers' municipalities of the Chianti area, while vulnerability patterns were less clear. To validate the results of our assessment, we conducted a robustness evaluation by applying alternative methodologies in the calculation of the composite drought risk index. Finally, to link the results of the assessment with possible adaptation strategies, we used archetype analysis, which is an emerging approach for identifying recurrent patterns within cases and supporting a context-specific generalization of insights. The maps, rankings, and clusters of municipalities were analysed, and specific adaptation strategies were proposed considering each drought risk profile. The results of the assessment are meant to be used to fuel the discussion about effective drought management in these watersheds.



Characterizing water stress (Ponding and Droughts) in irrigated agricultural systems: integrating remote sense data, field surveys, and local knowledge.

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Keywords. water conservation; agricultural landscapes; water scarcity; remote sensing; crops.

Abstract. Quantifying surface water stress [Drought and surface water ponding (DSP)] in lowland agricultural regions is challenging because limited water supplies are distributed over long distances based on complex water management systems constrained by legal, economic, and social framework. Facing shortages of freshwater resources, irrigated agriculture often requires more effort and more careful practices than typical agriculture for production to continue for a long time. This work focus on an irrigated area in north-eastern Italy, a territory of about 400k ha, part of the central Veneto, where water demands is met through a mechanical and well-regulated widespread distribution of water resources. For this complex landscape, reliance on weather data alone is not sufficient to monitor areas of DSP, particularly when these data can be i) untimely, sparse, and incomplete, and ii) water inflows are mechanically controlled, with varying flow exchanges, not necessarily reflecting climatic fluctuations. Augmenting climatic data with satellite images to identify the location and severity of DSP phenomena, therefore, is a must for complete, up-to-date, and comprehensive coverage of current crop conditions.

The objective of this research is to apply and standardize open-source data to augment DSP-monitoring techniques in conjunction with local knowledge. For this, we selected four pilot study areas, characterized by different agricultural production, and farm management.

The study was conducted with 20 years (2000-2021) satellite images, together with weather data from local meteorological stations covering the timeframe 1994-2021.

From the harmonization of Landsat7 and 8, and Sentinel2 data, we retrieved a baseline information for each parcel. The Z-scores of the NDVI distribution were used to estimate the probability of occurrence of the present vegetation condition at a given location relative to the possible range of vegetative vigor, historically.

At the end of each irrigation season [March-October], DSP_{crop} events were identified as periods of low vigor from the NDVI Zscore. Similarly, from the climate data, DSP_{climate} events and characteristics were identified using the SPI [Standardized Precipitation Index]. We identified DSP events by using run theory. Specifically, a DSP event has been defined as



the period in which the NDVI Zscore or SPI is continuously below (for both SPI and NDVI) or above (For the SPI) a critical threshold. For each season, we identified and analyzed the following four main DSP characteristics: duration, frequency, and severity.

Over multiple years, we compared the results of the DSP identification with local knowledge of the farmers, highlighting specific management conditions that were applied over the fields, to identify and target locations more susceptible to DSP.

Findings indicate that the framework, along with other monitoring tools, is useful for assessing the extent and severity of DSP at a spatial resolution of 10m. The framework can provide a near-real-time indicator of vegetation condition within irrigated regions, and more specifically areas of varying water management conditions.

Acknowledgements: The present study is founded by the Consorzio di Bonifica di II grado Lessinio- Euganeo- Berico (LEB) Cologna Veneta, Italy.



Grasslands in the historic rural landscape of Lessinia Regional Park (Veneto, Italy): threats and sustainable management

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Keywords. Grassland, Pond, Ecosystem service, NDVI, climate change

Abstract. Grasslands are distributed worldwide and provide important ecosystem services including animal husbandry, cultural and recreational needs, and potentially work as a carbon sink to alleviate greenhouse gas emissions.

However, under unsustainable management and climate change, grassland systems have become one of the most degradation-prone landscapes around the world. For example, 23% of China's grassland is facing the threat of degradation. In addition, grassland ecosystems of Italy, Mexico, Germany etc., are suffering from severe degradation as well. Thus, understanding and managing grassland degradation has become a worldwide concern. A valuable example of grassland landscape is the Lessinia highland, a geographical area of the Venetian Pre-Alps in northern Italy. This area plays an important role in cultural and historical value, as it was recognized by the Italian Ministry of Agricultural, Food and Forestry Policies as one of the important rural historical sites in September 2020. Ponds are an iconic land surface feature in Lessinia, providing water for livestock and helping vegetation to resist droughts. The key their importance is water, or—more specifically—the length of time a pond holds water (hydroperiod). Pond hydroperiods naturally vary with differing amounts of precipitation, ground water, and the type of substrate the pond sits on. Climate variability can cause pond hydroperiods to become more temporary, which is problematic for vegetation and livestock supply. Here, we explored the variability of hydroperiods and vegetation growth, focusing specifically on drought seasons. Specifically, this work leverages the Normalized Difference Vegetation Index from various remote sources (e.g., Sentinel-2, Landsat 8). This study can provide insights for water resource management in a typical grassland system. Such information is critical for policy maker, for a sustainable development of these valuable landscapes particularly considering climate change.



Runoff analysis and solution in high steep slope agricultural landscapes

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Keywords. Water storage, Steep Slope Agriculture, SIMWE

Abstract. Steep slope agricultural systems play an important role in food production and economic development such as terrace landscapes. In Italy, terrace system in steep slope make a great contribution in wine production. However, the increase of the frequency of intense rainfall is considered one of major challenges to water conservation in terrace cultivation. The water and soil loss caused by these intense events induced runoff, largely decrease the value and sustainability of a terrace system. Thus, it is urgent to find the solution for mitigating the impact of extremely rainfall events in these precious landscapes. This study simulates the overflow situation before and after setting some water conservation practice in different climate scenarios to evaluate the resilience of designed water storages in the background of climate change. In detail, the study aims at: (1) to simulate overflow process in steep slope agricultural landscapes by GIS-based model SIMulated Water Erosion model (SIMWE); (2) to design realistic water conservation practices for study area based both field observation and model simulation; (3) to compare the influence of designed water storages in three plot-scale watersheds in reducing runoff and water saving in different climatic scenario; (4) to find the best water conservation practice in steep slope agriculture areas. Our study provides more realistic and intuitive guideline in designing water conservation practice in steep slope agriculture landscapes for local farmer and political makers. Furthermore, this study provides an example of improving resilience of steep slope agriculture landscapes under the adverse climate conditions, which is important for the design and management as well as sustainable development for terrace agricultural systems.



Application of spectral indices for the evaluation of conservative techniques in crops management.

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Keywords. Sod-seeding, NDVI, NMDI, NDWI, satellites, precision agriculture.

Abstract. The common agricultural policies set out in the Green Deal and expressed into the Farm to Fork recommendation document, call all the players in the food supply chain to pay attention to sustainability. The use of not renewable resources and goods for food production must be rationally managed with the aim of their conservation for future generations.

Soil conservative practices, including no-tillage and sod-seeding, reduce energy inputs and prevent the organic matter from exposure to oxidation and loss of moisture; for these reasons, they could represent a solution for crop cultivation not only in water stress conditions.

The satellite image acquisition technology allows to access databases of satellite maps with different spectral indices. Some of these, based on spectrum bands with wavelengths in the near and far infrared zone, are dedicated to the surface water content of crops or soils.

The purpose of this study was to evaluate the trend of two spectral indices: the NMDI (Normalized Multi-band Drought Index), which is dedicated to the evaluation of bare soil and the NDWI (Normalized Difference Water Index) which is used both on crops and soil. Both of them decode the surface moisture.

The NDVI spectral index dedicated to the evaluation of vegetative vigor and to the estimation of the variability in the vegetation cover was observed throughout the cultivation season of the winter cereal.

The analysis were carried out in a land cultivated with durum wheat in Sicily (Italy) and the test conditions included two test-field with different slopes, sown in no-tillage system compared with a test-field sown after conventional tillage.

The results indicated the possibility of the spectral indices to understand the effect of the seeding technique on soil moisture. The use of these indices - available free of charge from ESA (European Space Agency) dataset - allows to have a high-frequency information tool for evaluating the effect of agricultural practices, uniformity of crops and characteristics of the soil; moreover it could provide a greater awareness on the application of management choices dedicated to sustainability.



Environmental and economic impact assessment of different water and nitrogen management systems in vineyard

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Keywords. Precision viticulture, Irrigation, Fertilisation, LCA, Gross margin.

Abstract.

Viticulture is slowly shifting to more sustainable production systems, and several studies are now using the Life Cycle Assessment (LCA) approach to examine the environmental impact of different technologies and practices used in wine production. Water, soil, and energy consumption, management of organic and inorganic solid waste streams, greenhouse gas emissions, and chemicals use are the key environmental challenges mentioned in current literature. Due to the site-specific application of water and fertilizers, precision viticulture techniques can play an essential role in the sustainable use of these inputs in grape production processes, enhancing yield and quality of grapes while reducing negative environmental effects. Precision viticulture, on the other hand, frequently involves investments and additional management costs.

The purpose of this research is to evaluate multiple water and fertilizer management systems in vineyards, ranging from those conventionally used in the Colli Morenici region (South of Garda lake, Lombardy region, Northern Italy), to the most innovative ones to date adopted in a pilot farm of this geographical region. Six scenarios have been explored, considering different irrigation water supply (private groundwater well *versus* water provided by an Irrigation Consortium), different irrigation management (sprinkler through a hose reel, uniform-rate drip irrigation, variable-rate drip irrigation) and, finally, different nitrogen management (fertilizer spreader *versus* fertigation). LCA, gross margin analysis and multivariate analysis have been used as a multidisciplinary approach to assess the sustainability of the different scenarios from both an economic and an environmental point of view.

Results obtained demonstrated that variable rate drip irrigation (VDI) and fertigation scenarios achieved the higher environmental and economical sustainability. In terms of the environment, variable rate drip irrigation and fertigation can dramatically cut CO₂ equivalent emissions generated during grape production by more than 50% while increasing water use efficiency by more than 30% compared to the most widespread methods in the area. In terms of economic outcomes, scenarios based on precision viticulture have the highest investment costs for introducing advanced technologies. However, these costs are offset by a higher revenue (+23%) resulting from increased and more stable grape yield and quality. However, VDI requires that irrigation water could be available on-demand rather than following a rigid irrigation delivery. Without finding a solution in term of collective irrigation service, farmers would rely on private groundwater wells to implement advanced irrigation and fertigation solutions.



Smart Irrigation Systems For Treated Wastewater Reuse

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Keywords. wastewater reuse, "smart" irrigation, drip irrigation, fertigation, circular economy.

Abstract. Climate change is causing an irreversible modification of the hydrological cycle, leading to unpredictable water availability, exacerbating water scarcity and contaminating water resources. Water scarcity is having a huge impact on agricultural irrigation, and therefore on food production. The treated wastewater (WW) reuse is a sustainable and resilient solution to face water scarcity and thus to preserve freshwater quantity and quality. WW is continuously produced by WW facilities and it contains nutrients, mainly *N* and *P*, which are essential elements for crop growth. With this in mind, one of the main activities performed within the VALUE CE-IN research project was the analysis of the effects of treated WW reuse on the efficiency of precision irrigation (drip irrigation) and fertigation systems at an experimental field site. In particular, the effects of secondary- and tertiary-treated domestic WW on crops (horticultural and orchards), soil, and soil-plant interaction were investigated. The experimental activity focused on the implementation of a "smart" pilot system (Figure 1), located within a full-scale WW treatment plant. The system was equipped with an automated control unit, which allowed the continuous treated WW quality control as well as the management of fertigation activities, based either on previously set or monitored parameters (e.g., crop nutritional and water needs, treated WW nutrient content, etc.).



Figure 1. "Smart" pilot system.

The research proved that WW reuse can be a sustainable and safe practice using both secondary- and tertiary-treated WW, highlighting the importance of carrying out regular monitoring of WW quality and automatic irrigation systems, having positive effects on the operational costs and the environment, in accordance with the circular economy approach.



Farm Constructed Wetlands for Nutrient Removal and Recovery from Agricultural Drainage Water

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Keywords. Constructed wetland, Agricultural drainage water, Nutrient recovery

Abstract. Agricultural areas are one of the most important non-point sources of pollution, which can cause negative effects in different types of ecosystems. Drainage water from these areas often contains considerable concentrations of nutrients and pesticides, pollutants that are important to be intercepted. Moreover, nutrients present in agricultural drainage water, if reused, could be an important resource in the agricultural production.

Constructed wetlands (CWs) are a nature-based technology that can be used for treatment of different types of polluted waters. Their advantage lies in the fact that they can manage variable water flows and pollutant loads, common of agricultural drainage water.

To assess these aspects, a full-scale surface flow CW (SFCW), located in Metropolitan City of Bologna, was monitored taking into account its inflows and outflows. The field site is a 12.5 ha experimental farm operated by Land Reclamation Consortium Canale Emiliano Romagnolo. At the same site, a pilot plant was built in order to test effect of different CW types and substrates such as biochar on the nutrient recovery (Figure 1).



Figure 1 - The full-scale SFCW and the pilot plant at the experimental farm

The experimental part, done within the H2020 project WATERAGRI, aimed to evaluate a possibility for nutrient recovery through uptake of plants and adsorption on the substrate. The first results have shown that plants can accumulate important part of the influent nutrient load and therefore a further processing of these materials could yield soil amendments, contributing to the overall circularity of agricultural production.



Using high resolution climate models to represent sub-daily precipitation upper tail in complex orography

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Keywords. Climate change; Precipitation extremes; Regional Climate models; Convection-permitting models.

Abstract. Recent literature agrees on the significant increase of short and intense precipitation in the next future, driven by the global warming. Subdaily extremes have specific impact on fast hydro-geomorphic hazards (flash floods, debris flows, shallow landslides). Estimating their changes in climate models is of fundamental importance for improving risk management and adaptation to changing climate. Compared to coarser resolution models, convection-permitting models (CPMs) provide higher confidence in the future estimates of sub-daily precipitation and allow to study the spatiotemporal patterns of heavy rainfall over complex terrain. However, given the high computational cost of CPM runs, the existing simulations cover relatively short time periods (10–20 years), which prevent the use of conventional extreme value methods. Alternative approaches based on the concept of ordinary event have shown the capability of deriving frequency analyses from shorter data records (e.g., Marra et al. 2020), promising improved applications based on CPMs.

In the present work, we investigate the CPM ability to represent sub-daily precipitation extremes in a complex-orography area in North-eastern Italy. This is a challenging test case for CPM simulations because the region lies in a transition zone between Mediterranean Europe and Continental Europe, with opposite projected changes in precipitation and different responses to climate oscillations. Recent works have shown that the region exhibit i) significant temporal trends in the intensity of the extremes during the last few decades and ii) different orographic impacts on sub-daily precipitation extremes at different durations (Formetta et al., 2022). We use precipitation records from ~150 5min-resolution rain gauges to benchmark the CPM simulations from the COSMO model, run at 2.2-km 1-hour resolution and driven with ERA Interim for the period 2000-2009. Hourly time series are created from



both stations and CPMs, for the latter by extracting the data at the grid points corresponding to the rain gauges. By applying a storm-based statistical method to each time series, ordinary events upper tails are modelled using a Weibull distribution, which was previously reported to well reproduce the statistics of extremes in the area. We investigate 9 event durations between 1 and 24 hours. The outputs of the model are the distribution parameters and extreme quantiles up to 100-year return period. We evaluate: their dependence on elevation, the bias between the observation and the CPM results, the dependence of the biases with elevation. We find CPM generally overestimates the annual maxima (10-40%), and the modelled quantiles (10-60%), especially for short durations, and the biases have different spatial patterns. The bias significantly depends on elevation, with increasing overestimation of the 1-hour quantiles with elevation. It seems that CPMs can't well represent the “reversed orographic effect” at the short durations (that is, decreasing extreme intensity with increasing elevation) reported by previous studies and which was linked to the interaction of convective cells with orography.

These findings help improve our understanding on the changes in the meteorological processes underlying the changes in the precipitation extremes and to develop CPMs bias-correction approaches that account for the role of orography and the precipitation durations.

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Automatic irrigation in paddy fields: a farm-scale application in Northern Italy

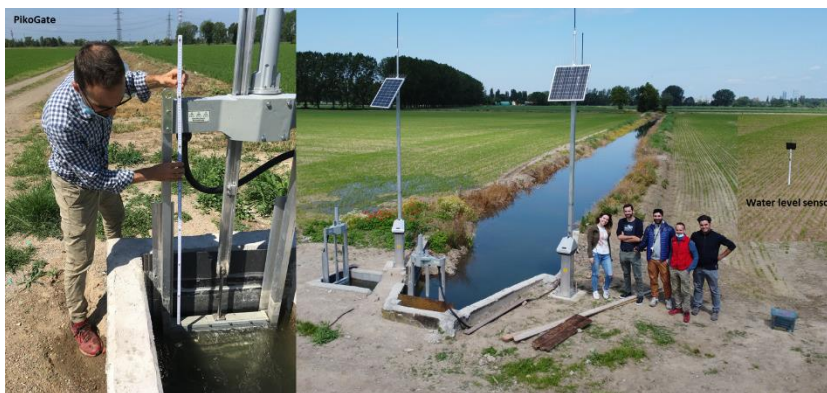
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Keywords. Rice, automation, monitoring system, sustainability.

Abstract. Rice is one of the major staple food crops in the world. In Europe, Italy is the main producer, with almost all of the production concentrated in the north of the country. Traditionally rice is grown in fields flooded from before seeding to close to harvest. This water management technique requires a huge labor for farmers who have to manually adjust inlet and outlet gates in order to maintain a constant ponding water level in the fields. A new water soft-path strategy based on the introduction of automatic water flow rate regulation systems is under investigation in a rice farm of about 40 ha located south of Milan, in northern Italy. The purpose of the experimental activity is to assess the environmental and economic sustainability of the introduction of innovative water flow monitoring and automation systems at the farm level. The installed instrumentation is constituted by four



PikoGate® automatic gates positioned in strategic points of the farm irrigation network and Ferit® water level sensors installed in five groups of fields. In the first year of the experimentation (2021) automatic gates and water level sensors were installed and tested; agro-meteorological, soil, crop and groundwater level data for the computation of a farm water balance were moreover collected. In the 2022 agricultural season, a newly developed irrigation algorithm will allow the automatic management of the farm gates to maintain a predetermined ponding water level in the fields, which may change in time based on site-specific conditions. Results achieved so far in the experimentation will be discussed in terms of economic and environmental sustainability, whereas the technical scalability of these automatic systems will be analyzed in cooperation with local irrigation agencies and farmers.



Assessing the Performance of Different Systems to Prevent Root Intrusion in Subsurface Drip Irrigation

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Keywords. Emitters, Root growth inhibitors, Clogging, Citrus orchard.

Abstract. The combination of subsurface drip irrigation (SDI) with management strategies such as the Regulated Deficit Irrigation represents a promising solution to increase water use efficiency. However, one of the main concerns of SDI is related to the root intrusion into the emitters' labyrinths, which can affect the water distribution uniformity. The solutions adopted by the emitters' manufacturers involve the addition of physical devices or introducing chemical substances into the emitters during the manufacturing process.

The objective of the research was to assess the performance of different methods to prevent root intrusion in commercial emitters recommended for subsurface drip irrigation systems, based on a four-year experiment (2018-2021) in a citrus orchard.

The field was split into two plots managed according to different irrigation strategies, i.e. Full (FI) and Deficit Irrigation (DI). Each plot was then divided into four irrigation sectors, three of which irrigated with co-extruded laterals buried at 30 cm depth and containing the same self-compensating emitter model impregnated with different chemicals (two different herbicides, He1, He2 and Copper, Cu); the fourth sector was irrigated with a different self-compensating emitter and used as control (C). Emitters were characterized by nominal flow rates of 2.3 and 2.1 l/h at a pressure of 150 kPa. Each plot was also equipped with a pressure regulator, water meter and manometer installed at the sector inlet.

After a total of about 425 and 340 working hours in FI and DI plots, the sector with Cu emitters was characterized, on average, by the strongest reduction of the discharged flow rate, with a decrease of about 13% of the initial value and the consequent increase of the operating pressure from 150 to 200 kPa. On the other hand, the reductions of average flow rate in the sectors with emitters containing He1 and He2 resulted lower than 0.5% with an increase of inlet pressure from 150 to 175 kPa. An intermediate behaviour characterized the C emitter, for which the reduction of flow rate resulted slightly higher than 6% with a rising operating pressure from 150 to 200 kPa. The study, still ongoing, provided useful information on the efficacy of the tested systems to protect the emitters from root intrusion.



Experimental tests to validate a simple procedure to design dual-diameter drip laterals on flat fields

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Keywords. Dual-diameter drip laterals, tapered lateral, flow rate experimental measurements, analytical solutions.

Abstract. Multiple-diameter laterals reduce the total cost in microirrigation systems, however, the length of each sublateral should be determined carefully to assure appropriate performance of emitter flow rates. The most accurate method is the numerical trial and error, which is time-consuming. A series of research efforts have been made to propose simple analytical design procedures. By using the power-law form of the Darcy-Weisbach formula, and equal emitters spacing for the sublaterals, Sadeghi et al. (2016) extended a previously introduced design solution for one-diameter laterals to tapered laterals. Recently, a simplified procedure to design dual-diameter drip laterals (Fig. 1) has been introduced, providing relative errors in pressure heads less than 0.5%, and allowing to set different Hazen-Williams coefficients, flow rates and emitter interspaces for each sublaterals. Moreover, this analytical procedure easily detects the required commercial emitter characteristics. According to drip laterals ($\phi = 16$ mm and $\phi = 20$ mm) made by IRRITEC, where the emitter characteristics are imposed, the objective of this paper is to experimentally test this solution for drip sublaterals with different lengths, flow rates and emitter interspaces.

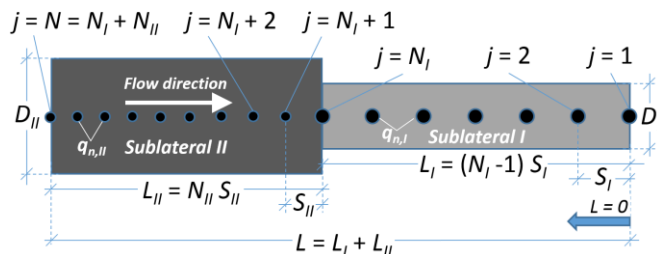


Fig. 1 – Sketch of the considered dual-diameter drip lateral.

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A comparative life cycle analysis of living walls

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Keywords. Life Cycle Assessment, Vertical Green system, Sustainability, Environmental Impact Assessment, Green wall.

Abstract. Urban population growth and changing people's lifestyles have led to the expansion of the construction sector, with environmental consequences such as increasing heat island effects, air pollution, storm runoff, and reduction of green spaces and biodiversity. A key strategy consists in the use sustainable solutions to improve the grey urban environment. Green infrastructures have a high potential of reduction of these environmental impacts: integrating green systems in the design of new buildings can turn the above-mentioned challenges into great opportunities, greening the building envelopes and providing more resilient urban spaces. The increasing interest on green wall systems and the advances made in recent years have led to the availability of various models with different designs and technical solutions. However, in their environmental assessment poor attention is usually paid to production and construction phases. By using the life cycle assessment (LCA) as a systematic and comprehensive approach, the sustainability of a product can be examined. LCA provides a quantification of product's potential burdens and environmental benefits. In this study, different components and materials used in the construction of vertical green systems are evaluated using LCA, with a cradle to gate approach. Both modular systems using soil as growing medium for plants and soilless living walls solutions are analysed, since the structural characteristics and related differences of the two systems can consistently affect their environmental performance. Both systems have been modeled in the OpenLCA software and analyzed using the CML-IA baseline impact assessment method. The results obtained from 11 different categories show that the processes involved in the production of plastic panels play a major role in terms of environmental burdens. The results emphasize the importance of the materials used in vertical green systems and confirm the need to design and create more sustainable products.

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Green Façade to Improve Building Energy Performance in Summer and Winter

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Keywords. Green infrastructure, heat transfer, shading, thermal barrier, energy saving.

Abstract. The need for a more sustainable and responsible approach to the territorial planning and managing is a date of fact. Systematic and widespread adoption of green systems can be a proper answer to that. With reference to the building sector, the application of green systems to the building envelope is the specific solution. These green technologies are passive systems which allow to increase buildings thermal control making these less energy-intensive. Among green systems for buildings, green façades seem to be a particular feasible solution. A long experimental test was carried out at the University of Bari, under Mediterranean climate conditions. An evergreen double skin green façade was tested together with an unvegetated wall to grasp their different energy behavior. The experiment was conducted throughout the year, allowing to study both the summer and winter functioning. Experimental data were used to compare microclimatic conditions characterizing the covered and the bare wall and to analyze the thermal energy transfer at the two walls. The presence of the green façade provided benefits both during summer and winter, at daytime and night-time, respectively. In summer days, the main positive effects concern the cooling of the wall surface and of the air near the wall. Sensible reduction of the energy input, thanks to solar shading and plant evapotranspiration was recorded too. In winter nights, the warming of the wall surface and of the nearby air and the lower air velocity near the wall were the most relevant effects. The reduced radiative and convective losses, thanks to the thermal and wind barrier role played by the vegetation, provided further advantages. The improvement of the building thermal performance due to the presence of green façade inevitably and positively affects the building energy requirements for cooling and heating. The findings of this research aid to increase the knowledge on the performance of green façades both in warm and cold periods and the specific benefits provided.



Blue-green roofs: one-year monitoring in Viterbo, central Italy

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Keywords. Blue-green roof, green roof, nature-based solution, runoff mitigation, urban areas.

Abstract. Green roofs are nature-based solutions designed for providing multiple ecosystem services in urban or periurban areas, like for instance the reduction of runoff and consequent load for drainage systems, or the mitigation of urban heat island effect with the consequent related energy saving. The green roof effectiveness depends on several factors linked to climatic and structural conditions. It is well known, indeed, that the runoff reduction of green roof increases with increasing substrate depth, soil moisture and plant coverage. Regarding soil moisture, literature analysis shows that one of the main limiting factors of green roofs is the water availability. Indeed water sustains vegetation, and vegetated roofs during hot and dry periods can have a cooling effect better than other roof solutions. Recently, an innovative solution of (blue-) green roof (named Polder Roof) has been developed, aiming to maximize the system efficiency. Polder Roof couples a water storage below the green roof that is able to gather infiltrated rainfall. A portion of such infiltrated rainfall is then reused by green roof vegetation thanks to capillary effect allowing best plants survival in dry periods, in doing so increasing the evapotranspiration and the cooling effect. Moreover, the system is expected to reduce the urban runoff and consequently to mitigate the flood peak. A pilot and small Polder Roof having an extension of 16 m² has been installed in Viterbo, at the experimental farm of Tuscia University, and several hydrological and climatic data has been collected and monitored in the last year. In this work, we focus on the hydrological behaviour of the system, analyzing the runoff reduction and its dependency on the antecedent rainfall. Results show that the antecedent rainfall is indeed a key variable, strongly affecting the system efficiency.



"Green" Investments in sustainable farming systems: a survey among Italian enterprises

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Keywords. Green Deal, water resources, emissions, renewable energies, sustainable practices.

Abstract. The promotion and diffusion of sustainable agricultural practices, together with technological innovations, play a pivotal role in climate change mitigation and/or adaptation. The present study reports the results of a national-scale survey investigating the diffusion of sustainable agricultural practices and technologies among Italian farming enterprises, also in the light of EU's goals of reaching climate neutrality by 2050. An online questionnaire was administered to a sample of 456 farm managers and contractors. Participants were asked to evaluate their rate of adoption, intention to adopt and willingness to invest in sustainable practices and technologies aimed at limiting the impact of their agricultural activity on the environment and on climate (e.g. a wide range of practices aimed at saving water, reducing agrochemical inputs, reducing emissions and producing renewable energies from biomass). Results showed that the majority of the participants have already adopted practices and technologies aimed at reducing agro-chemical inputs (54.8%), whereas practices and technologies aimed at reducing emissions and generating renewable energies from agricultural biomass have a more limited and recent diffusion (16.0% and 12.2%, respectively). However, 59% and 47% of participants respectively expressed the intention to adopt them in the short/medium term. The increasing interest in these practices may be due to the positive pressure exerted by the ambitious targets of the European Green New Deal. Only 7.4% of the respondents are prone to invest more than 100 k€ in "green" practices, whereas more than half of the enterprises (54%) would be willing to invest a maximum of 10 k€ in the next future. This willingness to invest may vary according to agricultural sector and farm size, whereas it does not seem to be influenced by the personal characteristics of the respondents (e.g. age, education). The present study allowed to glimpse future lines of investments and identifying intervention measures aimed at fostering the "green" transition within the Italian agricultural sector.



Agriculture ecosystem services in highly urbanized metropolitan areas

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Keywords. Agricultural areas, Ecosystem services, Land-use planning.

Abstract. Agricultural areas in highly urbanized metropolitan regions represent a very important territorial resource capable of providing human communities with a wide range of ecosystem services (ES).

The study was inspired by the need of the Municipality of Rho (in the metropolitan city of Milan) to revise the municipal land-use plan. Rho, located north-west of Milan, despite having a high population density (about 50,000 inhabit. on 22 sq km), still has about a quarter of its territory occupied by agriculture (545 ha), mainly arable land and about 15 ha of orchards, vegetable gardens, meadows and nurseries. These agricultural areas are scattered in the external part of the municipal territory and are highly fragmented due to the presence of urbanization and infrastructures. The municipal green area is completed by the presence of some wooded areas, riparian vegetation and urban green areas (included those attached to the road infrastructures), for a total of about 442 ha.

In this context, the study aimed to assess the existing agricultural areas, identifying (1) the areas that still have a strong agricultural production vocation and (2) those that, on the other hand, it is preferable to focus on the supply of regulation and cultural ES.

As regards the first objective, the study performed a series of assessment phases in order to calculate a composite score (0-1 scale) used to identify the agricultural areas with a productive vocation (293 ha, 54% of the municipal agricultural area), where the new municipal land-use plan established to encourage as much as possible the productive activities of the farmers.

Then, as regards the second objective, the study identified the agricultural areas that can provide natural and cultural ES, among those with a lower productive vocation: 694 ha (252 ha of agricultural areas and 442 ha of woods, uncultivated areas and urban green areas) equal to 30% of the municipal area, within which it is possible to create a soft mobility network scheme about 40 km long. In these areas, the new municipal land-use plan established to start a shared path with farmers for the definition of activities related to the supply of natural and cultural ES.



Assessing different land cover datasets in Ecological Network implementation at medium scale

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Keywords. Landscape Connectivity, Graph Theory, Urban Atlas, Corine Land Cover, Ecological Network implementation.

Abstract. Today, the environmental issues of land use modifications and landscape connectivity denote an increasing interest in the global scientific debate. Among these, those concerning ecological connectivity and the possibility of building ecological networks would prove capable of providing a means and solutions to counter phenomena such as land fragmentation, loss of biodiversity and land management.

The proposed method focused on a multi-species approach for implementing an ecological network in the Reggio Calabria metropolitan area, comparing two land cover datasets and their combined use. To have a coherent representation of the EN, a crucial step is to collect accurate data on the artificial and natural elements of the landscape. This is the reason why Urban Atlas (UA) 2018 and Corine Land Cover (CLC) 2018 data have been used both individually and jointly. UA is shown to be more accurate in the representation of man-made elements, also retaining roads, which are absent in CLC, which is shown to be more accurate in the differentiation of agricultural and forest land. Graph theory was used to test the robustness of the network calculated in three scenarios: UA dataset, CLC dataset, and a UA+CLC dataset. Landscape connectivity was modelled based on ten focal faunal species' requirements. Parameters such as dispersal distance, home range, environmental resistance to species movement were used to identify links, corridors, nodes and patches. Numerous metrics and connectivity indices were calculated and compared in the three different scenarios.

Free open-source software such as QGIS and Graphab constituted the software environment to implement the proposed methodology.



Mainstreaming of adaptation to climate change into six Italian cities: an analysis of planning tools

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Keywords. Cultural heritage preservation, planning tools, resilience, landscape protection.

Abstract. Climate change is an increasingly concerning phenomenon. Over the last decades, mitigation strategies have been promoted to reduce greenhouse gases emissions. However, mitigation is likely to have effect in the long-term, while short-term measures are called for. Thus, the interest of scholars in adaptation to climate change solutions has increased and European member states are introducing adaptation principles in national strategies and plans. Italy adopted the National Strategy for Adaptation to Climate Change in 2015 and the National Adaptation Plan to Climate Change is currently under strategic environmental assessment. Some Italian regions have adopted regional strategies for climate change adaptation (CCA), which should be a reference framework for introducing adaptation considerations in the planning systems and processes at regional and sub-regional (for example, cities) scale.

This study addresses the integration of CCA into strategies, plans, programs, and projects (SPPPs) adopted by six cities (Bologna, Milan, Naples, Rome, Turin, and Venice), by using a set of four criteria rooted in scientific literature and European and national adaptation strategies. We assessed if SPPPs: (i) refer to international, European and/or national strategies for adaptation to climate change; (ii) include -even in implicit form- CCA objectives and (iii) measures; (iv) are based on a climatic analysis on historical series and/or future projections.

We found out that CCA is being considered in different ways over the six cities, most of which have introduced CCA principles and scopes in a promising way. However, the mainstreaming of CCA is still in its infancy and it needs more time to be deeply integrated into the planning system.



Contribute of digital information modelling to Territorial Governance and Airport Safety interaction management

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Keywords. GIS, BIM, obstacles and hazards, assessment procedures, land-use planning.

Abstract

As part of the relationship between the airport infrastructure and the surrounding area, at both urban and rural level, the orography of the land and the vegetation as well as the artifacts inside or outside the aerodrome's boundary can constitute important limiting and risk factors to aviation.

The method used to assess the impact of any existing or potential obstacle or hazard to navigation on airport airside or in the surroundings, involves definition of Obstacle Limitation Surfaces, in relation to the type of runway and use.

In Italy, with the aim to ensure aviation safety, areas in the airport surroundings are identified and the related restrictions are specifically established in each of them. These areas and the relative limitations are then graphically represented and published in specific constraints maps (Obstacle Free Zones) produced by Enac (Italian authority for civil aviation), which constitute an essential tool for the governance of the territory in relation to aviation safety.

Local authorities, in the exercise of their competences with regard to the planning and governance of the territory, adapt their planning tools to the requirements of the constraint maps.

This study proposes an investigation on the relationships between territorial governance and airport safety, in the light of sector regulations, highlighting the contribution deriving from the use of digital information modelling. The management of obstacles and hazards through their representation in GIS systems using specific models considerably increases the understanding of their impact on the territory itself. Furthermore, models acquire even more applicative value by integrating the data using BIM tools. In fact, the definition of a management information model of obstacles and hazards to aviation based on the integration of GIS and BIM modelling represents an effective decision-making tool for an aware, efficient, resilient and sustainable territorial management in the airport surroundings. The results of this study are enriched with flow charts and diagrams describing the assessment procedures of obstacles and hazards to aviation in relation to the governance of the territory.



An Innovative Bioengineering Work by Waste Materials: the RiVite Project

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Keywords. Bioengineering Work, vine shoots, vine pruning, *Posidonia oceanica* residues.

Abstract. This paper describes the RiVite project granted by the Italian Ministry of Economic Development according to the JUMP (Joint Universities Program for PoC) program for patents enhancement, proposed by Sant’Anna School, Scuola Normale and the University of Palermo. The patent (MISE, n. 102017000141369 on 27/02/2020, inventors F. D’Asaro, R. Calvo, G. Baiamonte) consists of an advanced bioengineering work providing anti-erosion function, consolidating and stabilizing of slopes, thus for land protection. The technique is based on modular elements construction (Roll Modular Fascine, RFM, 40 cm x 60 cm) made with the residues of vine pruning collected with specialized agricultural machines (Fig. 1a). The RFMs are filled with a pre-seeded cultivation substrate, consisting of a mixture of beached *Posidonia oceanica*, seeds of autochthonous species and coolant fluids. The wooden part of the work resists only for the time to rooting and development of the native species, after which the resistant action will be exerted by the root systems. The final work (Fig. 1b) was realized connecting longitudinally the RFMs with cables or wire meshes (Fig. 1c). Differently from the common works, thanks to the assembling system, the proposed patented work is less time consuming, and reduces CO₂ emissions because of reusing waste materials. The project was based on different prototypes, and the JUMP program made it possible to realize all prototypes in two areas near Etna volcano (Nicolosi, Giarre).

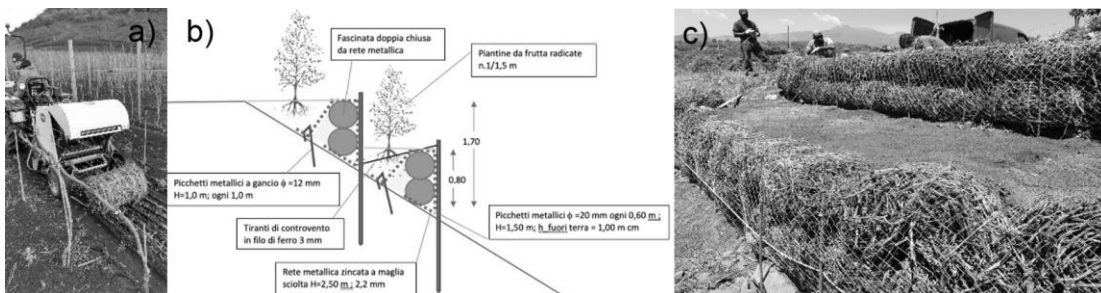


Fig. 1 – a) RFM collecting, b) example of a designed prototype and c) the realized work.



The MAGIC Project: a Tool for Promoting Safety in Agriculture during Covid-19 Pandemic

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Keywords. Decision Support System, infection, monitoring, real time, social distancing.

Abstract. Covid-19 pandemic poses a threat to global health highlighting the importance of prevention and measures of social distancing. In agriculture, cultivation operations carried out in open field by farm workers represent a serious danger in this sense. Social distancing of the workers during the labor day is not always easy to be maintained, especially for the very close rows among the plants (both in open field and greenhouses). In 2020, the researchers of the Mechanics Section of the Department of Agricultural, Food and Forest Sciences in collaboration with the Department of Engineering of the University of Palermo, presented a project entitled "Design of a real time Monitoring and control system for Agricultural workers to limit the SARS-Cov-2 virus" (acronym MAGIC) to the Italian Ministry of University and Research, which was supported by the Fondo Integrativo Speciale per la Ricerca (FISR). The aim of the project was the design of a real time monitoring and control system for workers in agriculture in order to monitor record and control any violations of the distance between all the workers. The system includes georeferencing and remote real-time display of all contacts between employees. Respect for privacy was guaranteed through the application of a black box accessible only by the authorities responsible for control. The system provides for the use of a device wearable by the single operator and equipped with an autonomous battery for data recording. The system is based on the use of a token, i.e. a small device (wrist strap) equipped with a uniquely stored serial number that securely emits an alarm signal to both the worker and the manager when the distance between two employees is below the permitted threshold. A central manager perform a historical "track" that lists all the subjects with whom a person has come into close contact (and for how long). In the first phase of the project, the functionality of the system was verified in the laboratory, and then it was tested at a farm in Sicily during winter pruning in vineyard.



Green Infrastructures and wine landscapes: a case study in Bordeaux.

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Keywords. "green infrastructures", "wine landscape protection", "ecosystem services".

Abstract.

In the last fifty years, an excessive land use based on uncontrolled urbanization affected landscapes leading to fragmentation and loss of biodiversity. Useful countermeasures consist of green infrastructures (GIs), a network of natural and seminatural areas, connected by environmental elements of various shape, which provide many ecosystem services (ESs) or benefits to people's wellbeing. GIs could be a strategic tool for enhancement and protection of important rural landscapes. In the case of wine landscapes, GIs could provide many ESs including: i) stopping biodiversity decline, ii) improving soil physical and chemical characteristics, and iii) offering recreational and cultural services.

In this study, we focus on the wine-growing areas of Bordeaux, Nouvelle Aquitaine, France, as they are a vivid symbol of the cultural heritage of the city. In many cases, these agricultural areas have been incapsulated in the metropolitan area of Bordeaux and are very vulnerable, with respect to recent urbanization processes. In this situation, landscapes need protection from the continuous development of the city. In addition, the vineyards are characterized by intensive, conventional, and mechanized viticulture, thus are questioned by many residents, who are worried for health issues related to the intensive use of pesticides.

We propose a Green Infrastructure (GI) able to protect and relaunch the ecological patches through their inclusion in a complex network providing the community with relevant direct and indirect Ecosystem Services (ESs), including ecological connectivity and tourist facilities. from those ecologic to touristic services. This GI is designed for the protection of urban vineyards located in Pessac, in the metropolitan area of Bordeaux.

We start from the identification of already existing GIs and proceed by detecting natural and seminatural candidate green areas to be included, according to the set of ESs selected. We obtain interesting results and present some preliminary discussions.



Landscape Valorization and Rural Tourism Development: An Application for the Promotion of the Lauretana Way in Tuscany Region

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Keywords. Rural tourism, agricultural landscape, APP application, sustainable tourism.

Abstract. Europe has in its walkable landscape a pillar of its cultural identity (Steiner et al., 2006) and Italy, where the Way of Saint James and the Way of Jerusalem are superimposed on the itinerary of the Via Francigena, holds a prime position. Italy has a network of 44 routes (*Cammini*) recognized by the Ministry of Cultural Heritage and Activities and Tourism (MiBACT, 2016) for their historical-cultural interest. Whilst following, in most cases, ancient pilgrimage routes, these itineraries are not strictly related only to religious tourism that has its main motivation in visiting religious sites such as shrines, convents, churches, abbeys, hermitages and sacred places. They are doubtless an attraction for their religious essence, but they have often great artistic and historic value. It could be the main driver of sustainable socio-economic and cultural development of many rural areas (Makuc, 2015). The tourism generated along the cultural itineraries can be considered rural tourism, in its widest acceptance. The rural tourism, fostering the discovery of wine and food, agriculture, and typical handicraft, becomes a great potential for a wide range economic development and represents that form of tourism that today takes the name of “experiential tourism”.

The objective of this work is to provide tools for reading landscape and developing experiential knowledge, with particular reference to historical and traditional rural landscapes of slow-travelling cultural itineraries to encourage their landscape and economic enhancement. The case study presented is the Tuscan segment of the ancient Via Lauretana that mainly goes through the Siena countryside. The main output is an application for smartphones and tablets designed to narrate the landscape as well as to provide the practical and experiential exploration of the territory. The app intends to connect insiders and outsiders, architects/actors and users/spectators of the landscape, inhabitants and pilgrims. In this way the experience of the cultural roads could be transformed, for travellers, in an opportunity for a cultural growth and for residents in an economic chance.



Trend analysis and abrupt changes detection using MODIS and Landsat data to support Natura 2000 habitats planning and management in Umbria, Italy

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Keywords. Natura 2000, NDVI, EVI, Mann-Kendall test, BFAST, google earth engine.

Abstract. Habitats' mapping and monitoring are essential to implement the European Directive 92/43/EEC and protect and manage the Natura 2000 network. Understanding habitat dynamics in space and time is crucial to assess the protection measures' effectiveness and support the definition of sustainable management strategies and practices. Field surveys are needed for habitat detection and identification; however, analyzing trends and processes requires gathering adequate spatial and temporal information, time-consuming and expensive activities, especially when dealing with large areas. Despite the known limitations compared to on-field surveys, Earth observation by satellite remote sensing offers many possibilities for cost-effective, timely, and reproducible vegetation analysis. In this context, this study aims to perform a long-term analysis of vegetation within the Natura 2000 network's areas in Umbria (Central Italy), focusing on grasslands habitats (Annex I types 6210 and 6230*). The objective is to assess the protection's effectiveness in the last 21 years and gather helpful information to address more sustainable planning and management strategies. We used the NDVI and the EVI indices obtained from the MODIS and Landsat datasets from 2000 to 2021. Satellite data were preprocessed, modeled, and analyzed within the Google Earth Engine cloud platform. We applied the Mann-Kendall test to identify and quantify significative long-term trends and Breaks for Additive Season and Trend (BFAST) algorithm to characterize the trend components further and identify possible abrupt land cover changes. The analysis was performed on all the Natura 2000 areas in Umbria. Results show that combining the two approaches is effective for characterizing long-term trends and identifying rapid and possibly uncontrolled changes. Moreover, this information helps detect the areas where the conservation measures related to the Natura 2000 network have been more (or less) successful and address more appropriate management strategies for grasslands of European concern.

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Multi-temporal satellite imagery for monitoring productivity trend in Mediterranean coastal forest ecosystems: the state natural reserve "Duna Feniglia" (Italy) study case

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Keywords. Vegetation Dynamic Assessment, Multi-Temporal Remote Sensing, Forest Management sustainability, Multispectral Vegetation Indices.

Abstract. Forests play an important economic and social role in the development of many parts of the world, representing an important resource for countering the effects of climate change, allowing to achieve the future goals of sustainable development. Those within protected areas also represent a historical and cultural landscape asset that characterizes the landscape in many areas of the Mediterranean basin, especially in the coastal zones. Other than the transformations made by humans in the past, many factors influence the ecological stability of these forest ecosystems, such as an increase in the pressure of wild animals or the increase in global warming. In this scenario, the forests show high vulnerability and a subsequent decline in their natural renewal rate.

This study aims to detect the changes in the forest vegetation growth rate that took place over 20 years, from 2000 to 2020, by a remote sensing multi-temporal satellite imagery monitoring approach, analyzing their effect on structural properties. The proposed framework was tested and validated in the state natural reserve "Duna Feniglia" forest in the province of Grosseto (central Italy), dominated by umbrella pine (*Pinus pinea* L.), characteristic of the Italian coastal landscape. Multispectral vegetation indices were evaluated as a proxy of forest productivity by means of trend curves analysis, indicating potential improvement and significant negative trends. Forest vigor was also evaluated by developing a productivity state indicator, allowing for the detection of recent changes in primary productivity as compared to a baseline period. Monitoring results and data from this research could represent an important decision-making tool for sustainable forest management of the study area, as well as identify potential areas of high forest vulnerability, in which to decode and apply suitable silvicultural models to promote natural forest renewal.



Pattern analysis of olive grove distribution in the time series. A case study if Cartoceto (Italy)

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Keywords. Landscape ecology, olive orchard, tradition/innovation, landscape pattern

Abstract. For centuries, olive orchards have played a key role inside the municipality of Cartoceto, a small village in the north part of Marche Region, Italy. In this portion of land, *the vast* presence of olive trees steadily merged with the spirit of life of the small community and the history of *the place* was rooted *for a long time*. This cultural tradition of olive growing includes the surrounding municipalities also. In particular: Mombaroccio, Saltara, Serrungarina and Fano. Since 2004 the production area was awarded as "Geographical indication" (IG), linking clearly the product and its original place of production. This event was assigned the Protected Designation of Origin Brand' according to strict technical production policie [1]. Actually the consortium includes the land and the producing farms is called Areale PDO of Cartceto. This study aims to provide shreds of evidence of how different olive groves, in the past, the olive trees mixed with crops (extensive type) and now the specialised olive orchards (intensive type), have shaped structural and functional features of the olive trees landscape. The main goal of the research is to assess landscape transformations in the Cartoceto's territory: from the year 1820, as reported in the historical "Gregorian Cadaster" map, up today. Changes within the set of selected orthoimages (1955, 1978, 1988, 2000 and 2019) by applying photo-interpretative skills allowed to draw-up thematic maps for each period in QGIS software by considering the most significant land use/land cover types. The work focused on the most considerable olive growing typologies, detecting six (6) different classes: isolated olive trees mixed with crops, olive rows mixed with crops, specialised olive orchards, intensive olive orchards, high-intensity olive orchards and garden olive trees. Changes and transitions among those different olive growing typologies were calculated for the temporal period taken into account. Besides, the evolution of the landscape in the study area, by processing a set of landscape metrics from Landscape Ecology, has been done concerning: number of classes, Landscape proportion, mean patch size, Hill's diversity number, edge density, patch density, land use diversity [2] were calculated.

Despite the natural reforestation of abandoned crop fields and the urban sprawl dynamic that have affected the study area in most recent decades, Cartoceto's territory still preserves different landscape typologies with high level of complexity. In short, two phenomena seem



emerging: the flat areas have favoured the urban/industrial extension by leaving the cultivation of the olive tree relegated within the so-called "hobby farms for self-consumption"[3]. On the other hand, the hilly areas remained excluded from this intensive neo-urbanisation process. At the same time, a few olive farmers have led a kind of renovation of the olive sector implanting new olive orchards with a higher density of trees in some suitable arable lands.

The methodology applied in this study provided a large amount of information about land use/land cover distribution and changes within the study area over a considerable temporal interval. Furthermore, the analysis of landscape complexity through the metrics has proven effective for assessing the landscape structure. This comprehensive collection of data/information might open to building a geo-database for Cartoceto's territory, explicitly dedicated to managing the olive growing of this area and particular attention for identifying new arable land suitable for the extra-oil production.

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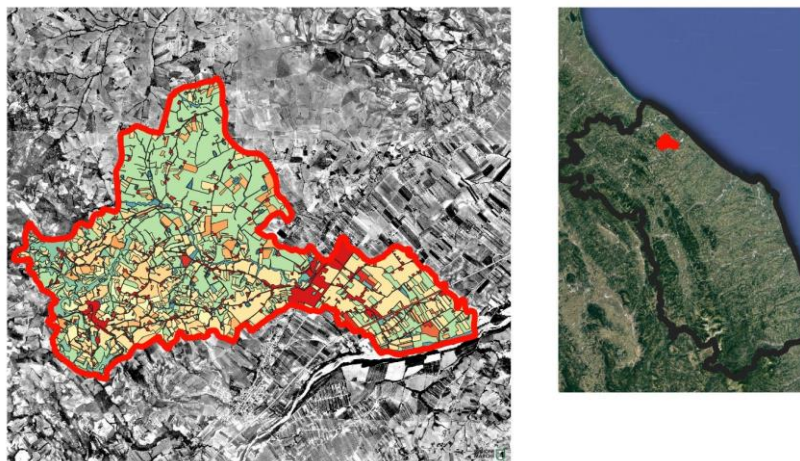


Figure 1 On the left an example of vectorizing different land use since 1978. On the right the location of the Cartoceto in the Region Marche, Italy



A model of Sicilian environmentally friendly multifunctional farm for soil protection

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Keywords. *Asparagus albus*, *Asparagus acutifolius*, walnut, intercropping, environmental protection, agricultural mechanisation.

Abstract. Roccaforte farm is an example of environmental friendly best practices in inland Sicily. The *Asparagus* association with walnut represents an added value, in terms of yield, production diversification and high economic value linked with the territory. This work aims at offering a virtuous example of how crop yield can be combined with environmental protection, by enhancing the marginal areas of Sicilian Region. A model of environmentally friendly cultivation of *Asparagus acutifolius* and *Asparagus albus* in association with walnut in a multifunctional farm is described in this work. The methods for the propagation, cultivation and transformation of wild asparagus, as well as the best practices of conservation soil tillage, aimed at reducing soil degradation, i.e. compaction and erosion, are described in this work. These best practices will reduce fuel consumption, keep the active topsoil layer and soil organic matter, increase the water retention capacity and carbon sequestration in the soil and, therefore, reduce the emission of Greenhouse Gases (GHGs), i.e. CO₂, into the atmosphere.



Marginal areas identification to support bio-energy supply chains in Southern Italy contexts

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Keywords. Marginal lands, landscape, bio-energy crops, land-use planning.

Abstract. Amongst European landscape there are wide areas without simple or easily definable characters and structure, in spatial, functional, and perceptive terms. These areas generally characterized by close interactions urban/rural, or fragmentation, abandonment, pollution or low level of productivity, etc., were in first studies identified as "marginal lands" with a negative meaning. Nevertheless, they are increasingly recognized as important areas providing solutions and opportunities in landscape maintenance and management, thanks to landscape care of traditional social structures, as well as a multifunctional basis for other economic sectors. As a consequence, their environmental, social and economic sustainability assessment is needed. Many studies deal with the definition of marginality and the possible recovery of marginal territories without achieving a common framework for their identification. The present work intends to contribute to the definition of the criteria for identifying marginality condition in support of the bio-energy supply chains. The study area extends on three regions of southern Italy. A specific action framework was developed, which, based on typical land-use planning approaches -the Spatial-MultiCriteria Decision Analysis- integrates various factors and clusters of criteria. The results show that almost 15% of the study area can be classified as marginal, allowing identifying macro-areas suitable for the establishment of dedicated supply chains. The approach aims to support: i. decision-makers in identifying possible critical areas and their conversion into strategic resources; ii. landowners in new opportunities assessment. The present work proved to be useful in the meta-analysis study-phase for identifying marginal land with a significant reduction in costs and times. Further developments will concern the validation of the proposed framework and the definition of specific intervention lots, through site-specific surveys. Although the study is focused on a specific Mediterranean context, the methodology used can also be extended to other contexts, thanks to scientific approach which integrates the different landscape aspects (environmental and socio- economic ones).



Assessing differences in land productivity trends to climatic data in arid and semi-arid zones: a study case in northern Mozambique

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Keywords. Land degradation, NDVI time series, Trend analysis, Multi-Temporal Remote Sensing, SDG.

Abstract. In recent years many efforts have been made to locate and measure land degradation worldwide to reach the target to reduce its progress, reduce poverty and increase food security and nutrition, following the United Nation Convention to combat desertification (UNCCD) and the Land degradation neutrality (LDN) initiative of the Sustainable Development Goals (SDG) of Agenda 2030. Several international reports provide different guidance on the most suitable land degradation indicators, and methodological approach in measuring and monitoring them. Among all, land productivity indicator raised interest because it can be easily quantified and spatialized using remote sensing data and techniques, and influence that the various limiting factors have on its performance can be verified.

Focusing on the land productivity trajectories, the objective of this study is to analyze how different climatic datasets and trend calculation methods may affect productivity analysis. Analysis was tested and validated in the northern part of Mozambique, as it is a climatically vulnerable zone whose natural resources are rapidly depleting in recent years due to deforestation actions and reduction of soil fertility.

Long-term normalized difference vegetation index (NDVI) time series were used as a proxy of land potential productivity from 2000 to 2015. Results were tested for trend significance using different calculation methods and climatic dataset to analyze the effect of data to trend responses. Rainfall dataset was used for climatic signal as the rain is the main limiting factor in arid and semi-arid zones.



Historic agricultural landscape characterisation: first attempt of historic landscape characterisation (HLC) to Costa Viola terraced landscape (Calabria, Italy).

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Keywords. Change detection, Historic Land-Use Assessment (HLA), Agricultural Terraces, Multi-Temporal Remote Sensing, GIS.

Abstract. By its own definition, the landscape is a constantly changing entity because of the continuous interactions between nature and human factors. These interactions are synthetically represented by land use land cover (LU/LC) changes.

The main object of this study is to analyse LU/LC changes that occurred for almost 60 years, from 1955 to 2014. The resulting landscape configuration was analysed, highlighting how yesterday’s landscape influenced the current landscape. Seven different years have been analysed: 1955, 1976, 1989, 1998, 2008, 2012 and 2014. A LU/LC map has been digitalised for each year based on a photo-interpretation process, using different base data.

In order to highlight the steps that led to the development of today’s landscape, the obtained polygons have been overlapped, obtaining a vector layer with all changes that occurred to the analysed landscape during the considered time interval. The last LU/LC stored have been taken into account. The proposed approach wants to identify the time when this LU/LC appears for the first period, the so-called *first occurrence*, highlighting how the past influences landscape composition. This is the common approach of the historic landscape characterisation (HLC) and historic land-use assessment (HLA), two very similar methods whose aim is to study today’s landscape and how it has originated.

The study object is the historic agricultural terraced landscape of the Costa Viola, in the province of Reggio Calabria (Southern Italy). This landscape is important because of its status as a protected landscape, listed by UNESCO in the convention for safeguarding the intangible heritage in 2018.



The local community perception of agrobiodiversity as cultural heritage. The case of *Ceratonia siliqua* L. as an identity resource of the rural landscape of Modica and Rosolini (Sicily-Italy).

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Keywords: agrobiodiversity, carob trees, cultural ecosystem services, multi-stakeholders network, collaborative GIS-maps

Abstract

The improvement of agrobiodiversity is a pivotal ecosystem service provided to human beings. Thanks to the complexity of the relationships it hosts, it can influence agricultural production and enhance resilience, well-being, quality of life, and rural landscape. This paper develops a proposal to valorize the *Ceratonia siliqua* L. (carob) in two Sicilian municipalities (Rosolini and Modica, Italy). The carob tree in this area is a crucial resource to understand the identity of the rural local landscape since the first descriptions of the island's flora (Tornabene, 1887). Furthermore, it has a significative productive value, representing the municipalities with the highest carobs plants of the Free Municipal Consortiums of Ragusa and Syracuse that cover the 98% of Italian production (ISTAT, 2020). Italy's carobs production follows only the production of Portugal at the international level, covering 14.36% of world production (FAOSTAT, 2020). At the same time, the carob trees often are located in marginal agricultural areas, and the local communities do not recognize their value. To protect the carob tree from extremely selective agriculture, from the overbuilding and neglect that local populations reserve for it, a system of enhancing the relationships that the carob develops is needed. For this reason, the method uses a multi-stakeholder approach to involve the elderly living in the municipalities, the farmers producing the carobs, and the local product storage and processing companies. The method develops a network to activate cooperation between stakeholders producing a collaborative GIS map dedicated to the carob, as the main result. This map highlighted the rural dimension of Modica and Rosolini and allowed sharing of memories, practices, recipes, and moments between local communities and companies. Furthermore, the map can be used for touristic promotion of carob plants by sharing it online using common devices (smartphones, tablets). The paper also develops two tourist paths dedicated to *Ceratonia siliqua* L., its products, its traditional and actual uses, and the rural landscape.

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Precision Livestock Farming as mitigating technique for the environmental sustainability of dairy cattle farms

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Keywords. Life Cycle Assessment, dairy cows, monitoring tools, smart farming

Abstract. The livestock sector has both positive and negative impacts on the environment, similarly to other production sectors. The positive aspects include food production and preservation of the territory and biodiversity, while the negative ones are mostly related to emissions to the environment. The adoption of the Life Cycle Assessment (LCA) method is very important because it is a method globally used and standardized that permits to quantify the potential environmental impact of different products, such as milk. The main environmental hotspots of milk production are emissions from rumen activity, storage and field application of manure/slurry, and feed and energy production and use. In this context, the adoption of Precision Livestock Farming (PLF) techniques can be a valid way to monitor the health and welfare of farmed animals, finally supporting the farmer with the decision-making process. Enabling livestock to be more efficient, PLF can lead also to sustainability improvements related to environmental, economic, and social aspects. The aim of this study was to quantify the environmental impact through LCA of the milk production on farms that adopted PLF techniques within the Project “Smart Dairy Farming: Innovative Solutions to Improve Herd Productivity”. Data were collected from 2 dairy cattle farms before and after the introduction of PLF tools. In the first farm were adopted pedometers to improve the oestrus detection capabilities, while in the second were adopted cameras to monitor the daily access to pasture and recording systems for milk production. Both techniques allowed to achieve, directly or indirectly, some improvements on the environmental sustainability. In fact, even small enhancements that permit to use target inputs result in increased efficient production, improved animals’ health and welfare, and finally lead to improved environmental sustainability. The use of pedometers allowed to reduce the environmental impact of milk production in the category of Climate Change by 5.4%, simply by properly identifying the oestrus and inseminating cows when needed. Instead, making cows access to pasture allowed to achieve an increase of 4.1% in milk production and a reduction in health problems, which involves a direct reduction of the environmental impact on Climate Change.



Development of an integrated automatic system to monitor cow welfare

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Keywords. Barn climate, cow behaviour, accelerometers, precision livestock farming

Abstract. In the last decades, many sensors and tools have been developed to monitor welfare in dairy cows. However, since there many different types of instruments, there is still a need to integrate data from single sources, such as those monitoring cow behaviour and microenvironmental conditions in the barn, to obtain a complete picture of cow welfare. To test the feasibility of collecting and integrating parameters from the barns, we developed a prototype of an integrated system, based on existing technologies to monitor cow behaviour and barn climate. In this system, a series of sensors were installed on 3 dairy farms in Northern Italy, characterized by a loose housing system. The system was installed in barn sections hosting 90-145 cows. To monitor the barn climate, microenvironmental sensors were installed at different positions in the barn to measure internal air temperature, humidity, light intensity, wind speed, black globe temperature, gas concentrations (NH₃, H₂S, CO₂), sound level, drinking water temperature and intake, litter temperature and humidity. In addition, a weather station was installed close to the barn to measure external air temperature, humidity, wind speed and rainfall. To monitor cow behaviour, 3D accelerometer devices were developed and mounted on neck collars. Each device included a system on board, antenna and a host-board, all fitted in a hard plastic case. With these sensors, 32 cows were observed for a total of 108 hours to train and validate an algorithm that could detect the time cows spend lying, standing, feeding and ruminating. A Decision Tree algorithm was selected as the best method to classify behaviours, with an average accuracy of 85%. All the sensors of this integrated system can be accessed on the farm through Bluetooth, using a custom-made app. At the same time, they are connected via a dedicated 2.4 GHz radio channel to a gateway on farm. This data is then stored on the cloud and can be monitored and processed remotely on an online dashboard. On this dashboard, graphs and tables visualize the data of single sensors as well as computed data, such as mean values from multiple sensors and the Temperature-Humidity-Index. The architecture, implementation and first data collected by this system will be presented. The integration of information on the farm is a key point of current issues that need to be solved by Precision Livestock Farming technology. This prototype provides a good starting point towards integrated automatic welfare monitoring that could assist farmers in detecting reduced cow welfare on their farms.



IoT-based technologies for herd management

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Keywords. grazing cows, IoT, cow behavior, GIS, spatial analysis.

Abstract.

Recently the scientific community has shown increasing interest in the adoption of wearable sensors in intensive livestock systems for monitoring animals health, carrying out the early detection of diseases, and more generally improving the quality of production. In extensive livestock farming the use of wearable sensors can be significantly useful, since in this type of breeding there is an infrequent farmer-to-animal contact. Furthermore, extensive livestock systems generate various environmental impacts, among which the most significant ones concern greenhouse gas emissions and soil degradation. However, it is not easy to quantify and model the environmental impact of the extensive breeding, unlike intensive ones, as it is not possible continuously long-distance monitor the herd. A valid solution to all the above reported issues could be provided by IoT technologies, which recently are becoming increasingly efficient and reliable. The main objective of this study was to investigate the feasibility of a locating and tracking system in extensive livestock farming based on space-time data provided by a IoT-based low power global positioning system (LP-GPS). It is well known that by knowing the movements of the herd it is possible to provide not only crucial information in terms of locating and tracking cows and monitoring animal behaviour, but also, by combining the recorded data and the large dataset of Geographical Information System (GIS), it is possible to have very useful information such as the activities of animals around the landscape, the spatial heterogeneity of field occupancy by animals, the pasture utilization, and soil degradation. Promising results have been obtained by this study, such as the detection of lameness in a cow from the herd, which strongly motivate the necessity of adopting IoT systems for correctly managing herd in the extensive livestock farming. Therefore, the LPGPS system could be further integrated with other sensors for monitoring a wider range of animal behavior such as that feeding, lying, rumination and oestrus.



Automatic feeding systems for cattle in Italy: state of the art and perspectives

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Keywords. AFS, total mixed ration, farm management, online survey, (animal welfare).

Abstract. The AUTOFEED project (<https://autofeed.crea.gov.it>) is a farm management project that aims at pointing out the advantages and the disadvantages of the adoption of automatic feeding systems (AFS) in cattle breeding. In this context two surveys were carried out to investigate the market offer and collect the final user impressions.

A survey on the offer that agricultural machinery market provides about AFS in cooperation with manufacturers to point out the driving variables of the purchase and installation. In parallel, the research group set up an interview for farmers already using AFS in their barns or willing or thinking of adopting them.

The market research identified 38 AFS models by 20 manufacturers with high variability of making and installation potentials ascribable to self-propelled (37%), rail-suspended (34%), these equipped with both delivering and mixing wagons, wheel-driven (11%) and belt-conveyor (16%) models. The missing 2% refers to fully automatic models currently under development and that the market doesn't offer yet. Such an articulated offer aims at meeting the needs and the requirements of most of the livestock breeding sites. The manufacturers interview confirmed this: in 2021, in Italy, there were 101 AFS installations (self-propelled - 63%, suspended-rail -26%, wheel-driven -9% and belt conveyor -2%) mainly located in Northern Italy (Trentino-Alto Adige, Lombardy and Veneto) whose driving technology depends on the orography of the sites (in mountain regions prevail the rail-suspended model while plan and hilly sites mainly foresee the adoption of self-propelled and wheel-driven robots). The dimension of the barns tends to discourage the adoption of wheel-driven and belt conveyor AFS because of the required high length of rail/belt lines.

The interview (both online and direct) provided fact-finding insights on the user feedback about this technology. Despite the still limited diffusion of AFS on the national territory, the perceived resulting advantages, compared to a traditional mixer wagon, involve various aspects of cattle breeding. Above all, farmers underlined the increase of animal welfare and performance (high dry matter intake, low animal competition and reduced waiting for feed), followed by the advantages related to workload transformation towards managerial and decisional tasks and the possible remodulation of the barn design in favor of the resting area resulting from the reduced space AFS require to move within the production site. A further positive impact is represented by a saving in terms of energy and operating costs, in line with a sustainable development of the farm and with a decarbonization of the energy system toward clean and renewable forms.



Assessment of milk yield loss induced by heat stress in dairy cows

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Keywords. Precision livestock farming, data analysis, agricultural engineering, animal welfare, numerical model,

Abstract. This study was developed within the EIT Food European project DAIRYSUST “Big data and advanced analytics for sustainable management of the dairy cattle sector”, running in 2021-2022. The aim of the project is to improve sustainability, animal welfare and productivity in dairy farming through the use of advanced data analytics. Livestock farms routinely produce and monitor data relating to environmental conditions, animal behaviour, and production parameters. The development of data-driven platforms and solutions which bring together all the separate data could be used to enhance decision-making and improve the sustainability of the agri-food system. This project is developing a system which integrates and harmonises the different data types. The outcomes are planned to be used by stakeholders in the dairy farming sector to improve their decision-making processes relating to sustainability, animal welfare and productivity.

In this context, the study aims to define, train, and test a model developed through machine learning techniques, adopting a Random Forest algorithm, with the main goal to assess the trend in daily milk yield of individual cows in relation to environmental conditions. The model has been calibrated and tested on the data collected on dairy farms which expressed their availability in collaborating in the project. The results show that the model can detect the drop in the cow’s milk yield due to extreme hot conditions inducing heat stress effects and milk yield loss. In fact, the average relative error provided by the model in the predictions, is 2% of the total milk production in the test days. The results confirm that the obtained Random Forest Model represents a reliable and viable tool for the evaluation of future production scenarios of dairy cows in presence of heat stress environmental conditions.

The model proposed may thus help to develop and improve decision support systems for farmers to increase both milk yield and animal welfare and, on the other hand, to reduce the resources needed, hence increasing sustainability of the dairy sector.



Spatial Variability of Microclimatic Parameters in a Closed Compost-bedded Pack Barn for Dairy Cows with Tunnel Ventilation

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Keywords. animal welfare, compost barn, dairy cattle, geostatistics, heat stress

Abstract. The development of breeding systems contributing to improve animal welfare and to increase productivity and milk quality, with a sustainable use of resources, is one of the main challenges of modern dairy farming. The aim of this study was to evaluate the spatial distribution of microclimatic conditions inside a closed Compost-Bedded Pack Barn (CBP), equipped with a negative ventilation system in tunnel mode, associated with an evaporative cooling system (EC), through geostatistical analysis. The research was conducted during the summer season in a compost barn placed in the area of Zona da Mata, in the state of Minas Gerais, the largest milk producing state in Brazil. In different periods of the day, microclimatic parameters were measured inside the building, such as air temperature, relative humidity, air velocity. Temperature and Humidity Index and enthalpy were subsequently calculated. The results showed the predominance of strong and moderate spatial dependence, as well as variability of attributes within the CBP installation, with heat stress zones occurring. It was verified, by kriging maps, that the most critical housing conditions were mainly found from the central part of the CBP installation towards the northwest face, close to the exhaust fans. On summer afternoons, the entire area of the CBP was in a situation of discomfort. The distribution of air velocity throughout the total internal area of the facility always remained below 2 m s^{-1} . As a result, it is possible to affirm that an increase in the ventilation flow inside the building could allow to reach more favourable conditions for the thermal comfort of the animals. It was observed that the EC can help to improve the internal thermal conditions of the barn. However, probably due to the lack of thermal insulation of the enclosures, it does not allow to reach a spatial thermal uniformity and to create comfortable conditions for dairy cows during the critical summer period.



Remote sensing imagery for mapping and monitoring High Nature Value Farmland areas (HNVF)

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Keywords. biodiversity conservation, natural value, MODIS, GIS, bioeconomic, Big-Data.

Abstract. The definition of High Nature Value Farmland Areas (HNVF) was provided by Andersen in 2003: "HNVF comprises those areas in Europe where agriculture is the major (usually the dominant) land use and where that agriculture supports or is associated with either a high species and habitats diversity, or the presence of species of European conservation concern or both".

In agriculture, generally, a higher level of biodiversity is found in those areas where agricultural production systems make use of fewer inputs of fertilizers, pesticides and machinery, or in semi-natural areas with extensive agriculture or, again, in agricultural areas which have preserved particular structural elements such as hedges, grassy strips, rows of trees, patches of spontaneous vegetation (Morelli et al., 2014, De Lucia S., 2013). Crop diversity alone, if not associated with low input intensity management, is not an indication of agricultural areas with high naturalistic value (European Evaluation Network for Rural Development, 2008). The objective is to develop a GIS prototype service for the identification and characterization of HNVF adaptable to different scales (local, regional, national). The proposed methodology is based on the statistical and farm systems approach. The developed procedure uses MODIS satellite images to improve the number and the accuracy of the land cover classes of the Corine Land Cover map and to calculate indicators aimed at monitoring soil and vegetation properties. A good agreement was found between our HNVF map and the results of literature works, although the analysis approaches were different. The study area was located in the Basilicata region, in southern Italy. The map of HNVF areas were elaborated at municipal level (spatial resolution) in 2012. The developed algorithm provides the possibility to vary the spatial resolution of the HNVF map from the national to farm level. The main advantage of the proposed methodology is that the inputs are free data, accessible from the public authority data-base.



Impact of agricultural plastics on rural landscape: visual impact assessment on the “Metapontino” agri-food district (Southern Italy)

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Keywords. Protected cultivations, plastic covers, landscape impact, visual quality, GIS.

Abstract. The use of plastics in agriculture represents one of the main topics for planners and policy-makers, dealing with the issues of environmental sustainability in the agricultural sector. The effectiveness, economy and versatility in the use of different plastic polymers made these products widespread in highly profitable agricultural activities (orchards and horticulture). The intensification in the use of agricultural plastics is often localized in some specific areas, where there is a concentration of different covering materials to reduce production costs. These clusters of agricultural plastics pose a problem of their end-of-life disposal, since an incorrect management can determine serious environmental impacts.

Moreover, another problem concerns the visual impact that these large clusters can have on the surrounding rural landscape. In fact, the aesthetic quality of these territories - often located in areas characterised by a fragile environment and a marked tourist vocation - may be deteriorated. Indeed, new structures for protected cultivation covered with wide surface of plastic material are increasingly spreading all over Europe, mostly in the Mediterranean Countries. If this phenomenon should continue with the same trend, an increase of these plastic-covered areas could be predictable in the next years. In some cases, it has been assessed how they alter in a significant way the local agricultural landscape, that constitute one of the most important heritage of these fragile territories. Therefore, their visual impact should be properly evaluated and potentially mitigated, so contributing to the preservation of the formal aesthetic characteristics of the rural landscape. However, its perception is difficult to quantify and measure it.

In this paper, a GIS-based methodology, aimed to perform a visual impact assessment, has been proposed, by applying it to the case study of the “Metapontino” agri-food district (Basilicata Region - Southern Italy), where there is an increase in the use of agricultural plastics, accompanied by an increase in tourist flows. From the obtained results, GIS tools, besides allowing complex spatial analysis, have hence revealed as a powerful planning tool for public authorities, able to enable mitigation strategies for the visual impact of plastics on the rural landscape as well.



Preparatory activities for the care and maintenance of historic parks and gardens: a case study

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Keywords. Urban greening, Zoning, Work planning.

Abstract. Historic parks and gardens are certainly an important part of the Italian cultural heritage and a fascinating resource for tourism. Since they are green spaces, they can also provide many other benefits, among which urban heat island (UHI) mitigation, carbon sequestration and oxygen production, habitat and biodiversity enhancement, and when accessible to citizens, they offer opportunities for their recreation and physical activity. However, the benefits and the ecosystem services of historic parks and gardens are closely related to their quality standards. In fact, these green infrastructures require a lot of efforts in terms of care and maintenance and their management usually involves qualified personnel, a large number of working hours and different types of equipment and machinery.

Historic parks and gardens are often composed by areas and areoles with different geometries and uses (e.g., luxury lawns, utility lawns, parterres, groves, etc.) and the complexity and artistic and naturalistic value of these cultural assets require the highest level of professionalism and expertise, with maintenance work that must scrupulously respect the garden's original layout. In addition, in areas with similar uses, differences in fruition as well as in visibility by visitors could lead to large differences in the intensity of maintenance required.

It is precisely the number and complexity of the tasks and the high-quality standards required that lead to high working hours and rising costs. Thus, the organisation of areas according to similarities in terms of operations and equipment could improve productivity in the required tasks with a reduction of costs and an improvement of the use of these assets.

The Miramare Park, which has a total area of 220,000 m² and was designed in the mid-19th century, is an example of an artificial mixed planting of forest species, trees and shrubs, with large areas of lawn, combining a more typically romantic English style with areas of Italian garden near the castle. At present, it is a public park much frequented by tourists and locals, especially in the areas close to the castle, while other parts are almost unused or hardly accessible.

In this work the different areas of the park were firstly identified. Then, the maintenance requirements of each area were assessed and, finally, a zoning process was carried out by grouping areas according to similarities in management needs, considering both softscape and hardscape requirements. This preparatory work will make it possible to verify and quantify the presumed benefits of the proposed organisational approach and provide a good basis for future management improvements.



Geomorphometric approach to estimate soil volumes stored in agricultural terrace systems for cultural landscape management

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Keywords. Volume computation, high-resolution topography, agricultural terrace systems, geomorphological features, landscape management

Abstract.

Agricultural terraces are highly productive and culturally distinctive socioecological systems. They are iconic landscapes recognised by UNESCO through the FAO Globally Important Agricultural Heritage Systems (GIAHS) program. Geomorphometric information can be exploited to study and manage such landforms in a world increasingly affected by anthropogenic activities and climate changes. High-resolution topographic (HRT) techniques allow the mapping and characterisation of geomorphological features with wide-ranging perspectives at multiple scales through high-resolution Digital Terrain Models (DTMs). By using riser bases as well as terrace edges (riser tops) and through the computation of geomorphometric parameters as the minimum curvature, it is possible to obtain environmentally useful information on these agricultural systems such as terrace soil thickness and volumes. This work aims to realize and test an innovative and rapid methodological workflow to estimate the minimum anthropogenic reworked and moved soil of terrace systems in three different terrace sites in central Europe. HRT techniques (i.e., Airborne Laser Scanning) were used to map terrace systems at large scale, while more detailed HRT surveys (i.e., Structure from Motion and Terrestrial Laser Scanning) to extract geomorphological features, from which the original theoretical slope-surface of terrace systems were derived. The exploitation of ground-truthing through field excavation and sampling confirmed the reliability of the methodology used across a range of sites, and in



each case confirmed the nature of the reconstructed, theoretical original slope. Differences between actual and theoretical terraces from DTMs and excavation evidences were exploited to estimate the minimum soil volumes and masses used to remould slopes. Moreover, geomorphometric analysis through indices such as sediment connectivity permitted also to quantify the volume of sediment transported downstream. The quantification of terrace volumes can provide extremely useful standards for further multi-disciplinary analysis on the terrace sediments themselves, new benchmarks for soil erosion models, and new perspectives for land and stakeholders in terms of terrace management, preservation and natural hazard risk link to these important cultural landscapes.



Sustainability performance of mountain food value chains

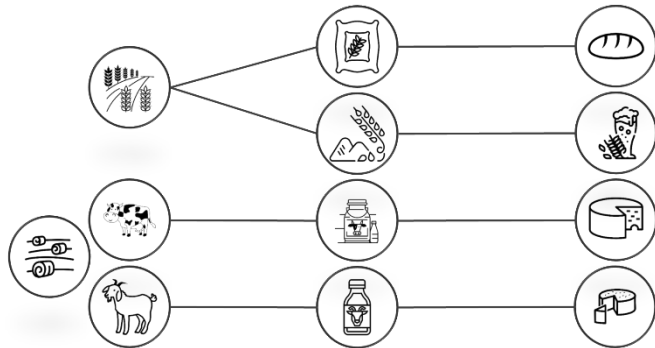
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Keywords. Mountain agriculture, cereal value chain, LCA, multicriteria analysis

Abstract. In the framework of the Brotweg project ("The bread route for mountain areas"), the performance of some alternative supply chains was evaluated. Geomorphological considerations on the territory, namely the high slopes and highly uneven terrain, meant that the chosen sites are suitable for the cultivation and processing of different types of cereals and for animal husbandry. For this reason, four alternative supply chains were considered: 1) rye-bread, 2) barley-beer, 3) cow's milk-cheese, 4) goat's milk-cheese. Regarding the cereal cases, the innovative cultivation and post-harvest methods developed during the Brotweg project were considered. For the dairy farming ones, the haymaking phase was also included. Two methodologies were used to assess the performance of the supply chains: Lifecycle Analysis (LCA) and Multi-Criteria Analysis (MCA). Both approaches present pros and cons, hence affecting their applicability depending on the context and decision-making processes that they must support.



The paper introduces the preliminary results of the supply chain analysis with a related critical discussion. In particular:

- For both approaches there is a need for consistent knowledge of the performance of different alternative supply chains.
- For territories as the one here studied, a further assessment of short supply chains (all on-farm) and cooperative models (e.g. sharing of plants and machinery) is necessary; in addition, logistics considerations must be even integrated.
- The short cereal-bread chain is an interesting and valuable alternative from operational, environmental and economic standpoints; unfortunately, its main cons is related to meteorological risks – e.g. loss of primary production. Alternative systems linked to animal husbandry are less risky, although more critical in relation to the major standpoints (in particular, environmental and operational).

Sustainable livestock waste treatment technologies: survey on a group of Italian farm enterprises

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Keywords. Animal waste-treatment technologies, Mitigation measures, Survey, Technology adoption.

Abstract.

The present study focuses on the perceived benefits and on drivers that may influence the adoption of sustainable waste treatment technologies in the livestock sector, as well as enterprises' provision for future investments pursuing sustainability. Forty-six livestock enterprises were administered a questionnaire investigating: i) the strategies and technologies adopted to reduce the environmental impact of livestock waste and the intention to adopt, ii) the expenses they incurred and iii) the perceived drivers and benefits. The results showed that 65.2% of respondents adopted sustainable technology solutions to manage livestock waste aimed at recovering nutrients or reducing GHG emissions. The perceived benefits in adopting sustainable technologies are firstly "the improved soil fertility and soil organic matter content". For those enterprises that do not adopt any of the proposed technologies, the rising prices of mineral fertilizers and the possibility of producing on-farm bioenergy would be the main drivers to adoption. The average expense for initial investment is 20-50 k€, primarily funded by enterprises own capital and secondarily by rural development programmes. 43% of respondents expressed their intention to continue investing in the future, primarily on "high-precision distribution system for slurry in-field application" and "automated systems for the management of waste within the livestock house". Results from the present survey are a valuable baseline to develop and disseminate targeted information on implications and opportunities for sustainable livestock treatment systems, addressing policy makers, farmers trade associations and technology providers.



Potential bioenergy and biofertiliser production from livestock waste in Mediterranean islands within Circular Bioeconomy

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Keywords. Anaerobic Digestion, animal manure, biogas, digestate, nitrogen balance, Renewable Energy Sources.

Abstract. It is crucial that the EU plays an important role in developing a policy framework offering equality of development opportunities to all its territories, also including the Mediterranean islands, aimed at taking into account adequate measures for reducing their dependency on fossil fuels. This study evaluates the potential biogas and digestate production through the Anaerobic Digestion (AD) process of livestock manure on a selection of European Mediterranean islands: Balearic Islands, Corse, Sardinia, Sicily, Malta, Crete and Cyprus. The potential manure generation from cattle and pigs was estimated using available livestock statistical data. An estimated yearly generation of 10.90 million tons of livestock manure with a corresponding potential biogas production of 269.28 million m³ was observed. The yearly digestate yield is calculated at 4.69 million tons. It is a by-product that is better described as a liquid biofertiliser that can replace conventional chemical fertilisers, in adherence to Circular Bioeconomy (CBE) principles, while the separated solid fraction could partially replace peat as an alternative growing substrate for the soilless cultivation of Mediterranean crops.



Heating from Biogas Plants: an areal approach for enhanced environmental sustainability

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Keywords. biogas, rural environment, excess heat, environmental analysis.

Abstract. The availability of renewable energy sources and highly efficient technologies are two critical issues when evaluating a sustainable low-carbon energy supply. At present, the efficiency of power generation in biogas plants is around 40%. The remaining energy percentage is mainly ascribable to heat produced in biogas combustion. Such heat is commonly implemented to supply the plant and the production facilities serving and surrounding the plant itself. However, this supply is only a fraction of the produced heat, which is mainly lost as waste. One possibility would be to recover the excess heat produced in biogas plants for the thermal needs of the buildings around the plants. This work analyses such a possibility, taking into consideration one province of the Veneto Region (Italy) as case study.

In the first phase of the research, data on biogas plants in the province of Padova have been collected. For each plant, the coordinates, the installed electric power, the produced thermal power and the days of effective work during the year have been defined. These data have been fed into the analysis software QGIS. Thus, it was possible to determine the location and potential of heat sources from anaerobic digestion. A total of 34 facilities were included in the analysis. Data on buildings located in the study area were collected in the second phase. Each structure was classified based on its size, location, height and intended use. A heat consumption per cubic meter of building per day was defined for each use category (based on bibliography). By combining the technical and geometric parameters of the structures, it was possible to calculate the daily heat demand for each building in the study area. Using the proximity criterion, it was possible to relate the heat production in the facilities to the heat demands of the buildings.

The analysis quantified a heat availability of 544 MWh/day. Preliminary results show that 41% of the plants can fully supply the heat demand of almost 100% of the buildings within 500 m. About 15% of them could offer full supply up to 800 m. Assuming that building heating is commonly done with natural gas, a complete conversion would save 89 t of CO₂eq/ day.

The analysis demonstrated the feasibility of using the waste heat produced in biogas plants in the power generation process. The distances between the potential heat users and the production plants are compatible with those imposed by the technical constraints of a district heating grid. Further studies can optimize the network routes to maximize the number of buildings supplied.



Evaluation of the Efficacy of a Radial Flow Settler for Aquaculture Wastewater Treatment

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Keywords. Aquaculture, wastewater treatment, radial flow settler, land-based aquaculture

Abstract. Wastewater from land-based aquaculture (e.g. recirculating aquaculture systems, RASs) contains large amounts of solids, in particular uneaten feed, feces and other particles (e.g., algae and biofouling). These particulate matters need to be removed as earlier as possible to avoid water quality depletion. The aim of this study was to evaluate the efficacy of a customized device layout of the radial flow settler (RFS).

The prototype was designed according to the existent literature and commercial products. The technical parameters of the RFS were: 1) fiberglass cylindrical tank 1500 mm diameter and 2020 mm height with a conical bottom of 60°; 2) V-notch weir diameter of 1350 mm with V-notch height of 20 mm; 3) diameter and height of stilling cylinder of 400 and 500 mm, respectively; 4) surface-loading rate of 2.1 Ls⁻¹m⁻²; 5) inlet and outlet pipes diameter of 50 mm. The experimental phase lasted four months starting from June 2020 and was conducted in a land-based aquaculture farm in the Central Italy (Orbetello, Grosseto, Italy). The RFS received a part of the outlet flow from one of the rearing ponds of the farm. The inlet flow was set at 2 Ls⁻¹ (66 % of the maximum allowed by this device and approximatively 14 % of the total outlet flow from the pond). Samples of inlet and outlet water and sediments were collected on a monthly basis to evaluate the solids content through gravimetric and filtration methods and the concentration of phosphorous, nitrogen, ammonium, nitrite, and nitrate. The solids (SS) removal efficiency (%) was calculated according to the following equation: $(SS_{inlet} - SS_{outlet}) / (SS_{inlet}) * 100$.

The results suggest that the designed device complied with the intended use. Moreover, the functioning of the RFS required a modest hydraulic load (15-20 cm) and therefore low energy requirement. However, it is necessary to install a cover on the device to avoid algal blooming. The gravimetric methods used did not allow a correct evaluation of the amount of sediments as a difference between inlet and outlet, since the error of the method exceeded the difference between the SS content in the inlet and outlet water. However, a sedimentation efficiency of 15-30% was observed through the filtration of the sedimented material, together with a reduction of the P and N contents.



Environmental impact of fish farming cages under different production and management scenarios

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Keywords: Cages, net, fish farming, off-shore, environmental impact.

Abstract

Aquaculture is the fastest growing agri-food sector globally. Seabass and seabream are among the most important fish grown in Europe in terms of production volumes and value, especially in the Mediterranean basin. The European Union plays an important role in this market and intends to support it more and more through dedicated policies under the Farm to Fork Strategy. At the same time the environmental sustainability of food production is increasingly important for the Commission. Several environmental assessments of seabass and seabream farming have been done, highlighting the criticality of aquafeed as the main impact driver. However, greater attention would also be needed for infrastructures. These are often neglected in LCA studies because considered not relevant or due to lack of data. This study, on the other hand, intends to investigate how different production and management can affect the environmental impact of aquaculture off-shore plants.

For this purpose, a cradle-to-grave LCA of a floating off-shore collar cage (diameter 25 m) was performed, thus considering production, maintenance and disposal. Different scenarios were explored by varying the management of nets and other structures (raw materials used, periodic maintenance, thus including diesel and oil consumption by vessels, and life span). Inventory data were retrieved from the literature (Vázquez-Olivares 2003; Mendoza Beltran et al., 2018; Avadi et al., 2019); background data from the Ecoinvent® database. The characterization method used was the established ReCiPe 2016.

The results confirm that an optimal management of an off-shore aquaculture plant can lead to significant environmental improvements. This emerged for all the impact categories evaluated, even if not in equal measure. Nets management was of particular importance, given their reduced life span compared to that of the rest of the plant. Nets production and maintenance (anti-fouling washing and periodic replacement) were in fact the environmental hotspots of the entire plant impact. The disposal method on the other hand (i.e. recycling of raw materials against generic waste) had a minor role. Considering that off-shore aquaculture is expected to grow in the future, also due to the increasingly lower energy and economic convenience of in-land production, the results of this contribution represent a first interesting survey on how an optimal design and management of the plants can limit the impact of fish production, which is necessary to be further investigated.



Creep properties of polymer films used as greenhouse roof

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Keywords. Multilayer films, Polymer, Mechanical properties, Greenhouse, Creep-recovery tests

Abstract. Polymers are employed in agriculture in several applications, the most efficient and fruitful of which is the protection of cultivations through the use of cover placed over plants while they are growing, providing protection from climatic factors, while at the same time increasing yield and/or extending the cropping season. Plastic films used for covering greenhouses, low and medium tunnel and for soil mulching have reached very notable consumptions all over the Mediterranean area, as well as the rest of the World, posing an important environmental problem connected with the impact that plastic material has on the sustainability of the agricultural production, whose environmental footprint may be deteriorated. Recycling agricultural plastics is a common technique, but it has not yet solved the problem of their re-use in the framework of a circular economy, since many factors are still anyway limiting the mechanical recycling of agricultural plastic materials. Among these limiting factors, the loss of mechanical properties of plastic film, due to its ageing after being exposed to external agents - mainly, solar radiation- plays a crucial role.

In this paper, some polymer films used for greenhouse roof were naturally weathered for 9 months in harsh climatic conditions (Tiaret region, Algeria). The changes in their mechanical properties have been measured by tensile and creep-recovery tests. The measurements were carried out for both monolayer and tri-layer films. The anisotropic character of the films has been preserved during ageing. The improvement in the creep resistance via cross-linking for both monolayer and tri-layer films has affected different deformations. The results revealed that the degradation performance of these new tri-layer films is found to be quite better than that of the monolayer film, with regard to the mechanical properties. Hence, it may be concluded that the erosion of the greenhouse polymer film by temperature, water, sand particles, wind and humidity, leads to extreme lifetime limits. Polymer film may anyway have longer period of use in Mediterranean Europe than in North Africa - where higher temperatures and adverse sand-wind effects occur - with positive effects on reducing the plastic footprint of agriculture.



Plant factory with artificial lighting: innovation technology for sustainable agriculture production

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Keywords. food-energy-water nexus, soilless culture systems, leafy vegetables, artificial intelligence, urban agriculture.

Abstract. Food security and healthy eating are increasingly threatened by climate changes, pandemics, conflicts and economic crises. In the next years, the estimated rapid growth of the world population and the growing urbanization will lead to a global food requirement increase and to a highly complex food supply chain, with worrying environmental impacts. Conventional agricultural production systems have negatively contributed to the decline of the per capita land availability. Plant Factories with artificial lighting (PFAL), in the Urban Agriculture context, can give optimal answers to these issues, according to the UN Sustainable Development Goals. This work aims to provide a holistic assessment of the PFALs functions, to support decision-making processes for an efficient use of the resources with the food-energy-water nexus approach. Firstly, cultivated plant species and their production yield are indicated and the soilless culture technologies and water-nutritional fertigation systems are examined. For optimal plant growth, the thermo-hygrometric conditions and the CO₂ level, as well as the P.A.R irradiation and the spectral composition of the lamps are defined. Furthermore, artificial intelligence for PFALs' integral management and the energy sources to power HVAC systems and artificial lighting are discussed. PFALs can be implemented in disused buildings in urban or peri-urban sites, with a view to a circular economy and 0 km agricultural production. The analysis shows that almost all the PFALs have been installed in countries with high urban population density and harsh climates, such as China, the US, Japan, and Northern Europe, to produce mainly herbs and leafy vegetables. Furthermore, artificial lighting is entrusted to LED lamps, by inducing a 95% decrease in the power emitted per unit area, compared to other types of lamps, thus ensuring higher energy efficiency. Finally, the PFALs' crop yields stand until to 1.1kg m⁻² d⁻¹, about 100 times higher compared to open-field agriculture, thus managing to satisfy the food requirements of the urban populations.



Microclimatic Conditions at the interior of small-sized insect-proof nethouses with tomato cultivation

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Keywords. nethouse, insect-proof, tomato cultivation, microclimate, agricultural nets

Abstract. The use of nethouses as means of crop protection has significantly expanded over the last decade. Insect-proof nethouses can be very efficient especially in the summer period, since they offer protection of the cultivation from harmful insects and environmental hazards. Along with their environmentally friendly character (reduction of insecticides and irrigation needs) they can be a suitable substitute for the open field cultivations which are often severely damaged by enemies and harsh conditions.

Two low-rise steel frame insect-proof nethouses were installed in the field and used for Bellfort tomato cultivation. Open field cultivation was used as control for comparison purposes. Two types of enhanced insect-proof nets were employed as covering materials. The OptiNet 50 mesh (Ginegar, IL) and the 3353BT Biorete 50 Mesh AirPlus (Arrigoni, IT). The first was able to exclude insects by integrating both physical and optical protection through additives which blocked the insects' vision. The second allowed for better ventilation as compared to typical 50 mesh insect-proof nets.

The aim was to measure the microclimatic conditions of the insect-proof nethouses (temperature, relative humidity (RH) and radiation) and evaluate how they affect the cultivation growth and the crop production quality and quantity. Data were recorded during the summer (June - August 2021), when increased temperatures and RH in the interior of nethouses have been reported. The temperature and the RH values inside the experimental nethouses during the specific period were found to be like the corresponding field values. This may be attributed to the small size of the insect-proof nethouses and the small number of the protected plants. The total radiation transmission at the nethouses interior was found to be approximately 60% for the OptiNet and 89% for the AirPlus net of the incoming solar radiation offering mild shading conditions. The average indoor air velocities were lower than the corresponding outdoor value at height equal to the $\frac{3}{4}$ of the nethouse height, by 59% for the OptiNet and by 42% for the AirPlus, respectively. It may be assumed that the combination of shading with lower indoor air velocities reduced evapotranspiration of the protected plants. As a result, the plants in the nethouses appeared to be healthier and grew faster with their height being almost double the height of the open field plants. Fruits of bigger size and a higher total yield were harvested from the protected cultivations than from the open field during the harvesting period (9/8 – 2/9/2021). Total yield increase as compared to open field: Airplus: 60%, OptiNet: 157%. Total number of fruits increase as compared to open field: Airplus: 52%, OptiNet: 79%.



Weed Control By Hot Vegetable Oil And Eugenol Spray

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Keywords. Non-chemical weed control, thermal weeding, vegetable oil, spray.

Abstract. More than one third of the total amount of pesticides used in Europe are herbicides. For this, non-chemical weed control plays a strategic role in achieving one of the major and more ambitious objectives of the Green Deal, i.e. to reduce by 50% the use of chemical pesticides in agriculture by 2030.

Among promising alternatives to chemical herbicides, thermal treatments aim to damage the external tissues of the weed, causing a loss of evapotranspiration control, with consequent breakdown of cellular membranes and plant drying in the field.

In this study, we investigated the phytotoxic activity of a mixture of eugenol, one of the main components in the essential oils of several aromatic plants, with hot vegetable oil. To this aim experimental tests of spray applications of hot soybean oil + eugenol (1.6% w/w) mixture were conducted on white mustard (*Sinapis alba* L.) grown in 30 x 30 cm trays as a surrogate weed. The mustard plants were treated at two stages of growth (2 leaves and 6 leaves) by applying two different volume rates (175 L/ha and 525 L/ha) of: i) soybean oil at two temperatures (120 °C and 220 °C); ii) soybean oil + eugenol (1.6% w/w) at a temperature of 120 °C; iii) water + eugenol (1.6% w/w).

The spraying tests were carried out by means of a laboratory prototype developed for this study, and able to deliver liquid spray at controlled temperature. The effect on plants was non-destructively monitored by imaging techniques during 8 days after treatments, and finally assessed by destructive harvest and manual separation of damaged from healthy plant tissue.

Weight reduction in fresh and in dry biomass, compared to untreated plants was used as quantitative index of the treatment efficacy.

High volume spraying of hot oil was found to produce a reduction in green biomass similar to contact herbicide, while hot oil + eugenol mixture resulted to provide even higher weeding efficacy.

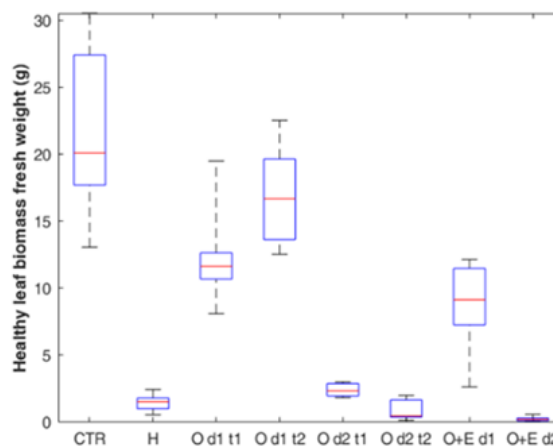


Fig 1. Healthy leaf tissue fresh weight in mustard trays, 8 days after treatments at stage of 2 leaves



A facilitating machine for silkworm rearing

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Keywords. silk, silk machinery, machine design, silkworm breeding

Abstract. Silkworm breeding is an activity that was formerly practised in China and began in Friuli and Veneto between 1400 and 1500. It expanded rapidly in the Friuli and Veneto countryside declining after 1950 and all attempts to revive this industry have subsequently failed for various reasons, not least the lack of adequate technology. The problem of producing silk today is in fact linked to the design and construction of machinery to facilitate silkworm rearing so as to make it attractive to farms in terms of both working conditions and production. The SILK project financed by the Friuli Venezia Giulia region under the 2014_2020 RDP was conceived within this framework with the aim of relaunching silk production. The agricultural mechanisation research group of D14A of the University of Udine took charge of the design and construction of a prototype of a facilitating machine for the first larval ages of the silkworm.

The objectives conceived for the prototype machine were to allow the silkworm rearer to easily and relatively quickly manage the cleaning of the bedding with the aid of stainless steel trays fitted with mesh or perforated paper, and also to have the possibility of keeping the silkworms on stackable shelves so as to rationally exploit the surface area of the available rooms.

The design phase was done in CAD and then the machine was built, assembled and brought to a silkworm farmer where the first tests were carried out to check the advantages compared to the manual operations adopted up to that moment.

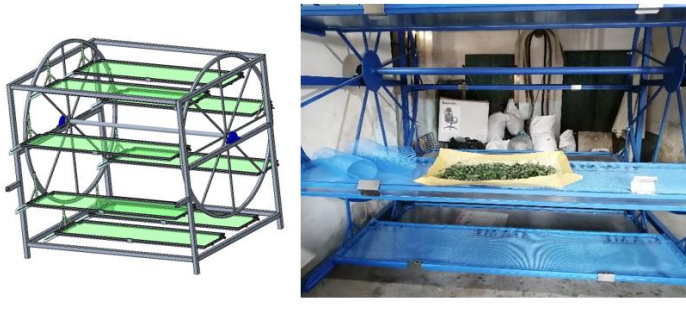


Figure 1- Silkworm machine



SCADA Application to the Malaxer for Obtaining High-Quality Extra Virgin Olive Oils

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Keywords. Control, malaxation, monitoring, oxygen.

Abstract. The supervisory control and data acquisition systems (SCADA) for industrial plants represent self-governing systems, based on the closed-loop concept, used to provide interactions among the devices involved. In the last years, particular attention was paid to the presence of oxygen during malaxation in the Extra Virgin Olive Oil extraction process and its influence on the healthy and organoleptic quality of the product. An innovative machine equipped with a SCADA system for oxygen monitoring and control during the process was realized by the authors. The system was designed to perform a periodic sampling of the atmosphere inside the malaxation machine and to return a reliable measurement of the oxygen concentration in the sample. The measurement cycle was demanded to the main control loop of the PLC, which extracts a gas sample from the headspace of the malaxation machine by means of a micropump and conveys it through a closed-loop pipe to the oxygen sensor. The oxygen measurements were performed every 30 s, and the data collected during malaxation process were displayed in real time on the standard human-machine interface (HMI) constituted by an OMRON 5.7” display. Experimental tests were performed on Nocellara del Belice and Cerasuola olive cultivar comparing unmodified malaxation to modified malaxation managed by the SCADA system. Modified malaxation was obtained by filling nitrogen before the olive paste entry, and then introducing oxygen at 20 min from the beginning of the process. Analytical determinations were performed on the EVOOs to obtain the main quality parameters. The SCADA system application in the EVOO extraction process produced a qualitative improvement of the Nocellara del Belice and Cerasuola olive oils.



Optimization of a new knife crusher to increase olive oil quality

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Keywords. Hammer crusher, knife crusher, phenolic compounds, olive paste temperature, impact energy

Abstract.

Olive crushing is an important phase in the continuous extraction process of olive oil. This operation has the purpose of breaking the olives, creating a paste made up of all the vegetable parts, suitable for subsequent processing. The way in which the olive paste is prepared has a significant influence on the quality of the final product. The crushers hit the drupe violently, transferring part of their kinetic energy. However, the shape, geometry and speed of the crusher tool can also produce a different way of breaking up plant tissues due to the different combination of compressive, shear and friction forces. In addition, the violence of the operation could lead to an undesirable increase in the temperature of the olive paste, with consequence on the quality of the end product. Therefore, temperature control plays a fundamental role in the final result of extra virgin olive oil as it keeps the nutritional properties of the olive intact, and its flavor.

To increase the performance of this stage, a new knife crusher was studied. Specifically, a new knife rotor was studied to replace the hammer rotor and implemented in a traditional crusher. The aim was that of a preliminary optimization of the specific energy based on a new configuration of the blades to crush the olives, so to avoid an excess of temperature increasing into the grid. As a reference the results obtained were compared with those of a traditional hammer crusher.

Test results reported an increase of increase in the phenolic and volatile component when knife rotor has been used, while about the percentage extractability of the olive oil no significative difference was found.



Evaluation of The Overall Heat Transfer Coefficient on Industrial Malaxers Using a Simple Approach

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Keywords. Heat transfer coefficient, malaxation, extra virgin olive oil processing

Abstract. In the extra virgin olive oil processing, malaxation is a key-operation, during which the operative parameters should be strictly controlled both to maximize the oil extraction and to modulate the quality profile. However, the malaxer temperature control is not efficient due to the low ratio between heat transfer surface and olive paste volume and a the high viscosity of the matrix. In this study, the overall heat transfer coefficient U , was measured on 3 type of malaxers, applying the double-pipe heat exchanger model to unsteady-state conditions, according to Leone et al. (2015). The processing temperature of fluids and olive paste specific heat were collected during the experimental trials in order to determine U values, shown in Table 1. These represent a preliminary result on comparing the heat transfer coefficient of different malaxers in a relative way. The optimization of a simple method could be a useful tool for producers in order to assess with small effort the machine performances on an industrial scale.

| | Vertical Malaxer | Horizontal Malaxer | Prototype Malaxer |
|---|--------------------|----------------------------|--------------------|
| Malaxing units | 1 | 1 | 5 |
| Total capacity | 500 kg | 400 kg | 350 kg |
| Tank shape | Craddle | Cylindrical | Cylindrical |
| Size (for single unit) | 80 cm ID, 120 cm H | 150 cm L, 70 cm H, 60 cm W | 30 cm ID, 140 cm H |
| Heat transfer surface or A | 3.0 m ² | 2.1 m ² | 5.8 m ² |
| U (W m⁻² °C⁻¹) | 73.8 ± 7.5 | 101.3 ± 0.9 | 185.5 ± 3.2 |
| UA product (W °C⁻¹) | 222.2 ± 22.5 | 212.6 ± 1.8 | 1077.7 ± 18.6 |

ID=Internal Diameter, H=Height, L=Length, W=Width

Table 1. Malaxer characteristics and coefficient results (mean ± standard deviation, n=3).

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Design of a System for the Mechanization of Subsoil Compost Tea Distribution

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Keywords. Compost tea, Ripper, Localized distribution.

Abstract. Compost tea is an aqueous mixture of organic and inorganic compounds obtained by the compost itself and subsequently fermented with possible air blowing. Although several authors have highlighted how these extracts positively affect the control of pathogens and as a promoter of plant growth, the biological mechanism underlying the effects remains unclear. Similarly, no mechanized agricultural system or machine is designed for their distribution. The application of compost tea is commonly carried out on soil (to support soil microbiota) or less frequently on leaves and foliage (for pathogen control). The distribution of these extracts usually occurs on small surfaces due to their localized but emerging application. Generally, compost tea is distributed on the soil's subsurface to avoid stress to the microbiota of the extract, while foliar distribution is carried out through sprayers. The two critical factors in distribution are represented by: the pressure, which cannot be too high to preserve the microbiota, and the formation of organic films, which can hinder or seal the distribution systems. This study aims to design and test the mechanics of the machine in soil processing sizing in relation to the traction efforts. The project is an implementation of the machine already used in the trials and courses of the Tree Yo educational program. The device was developed from a Keyline plow equipped with four vertical shanks, disk coulters, and a fixed crumbler drum. The basic model was coupled with a broadcasting system (Hatzenbichler Exaktor) and a compost tea distribution system which includes a tank with a single polyethylene pipe that carries the liquid to each coulter by splitting the line (the distribution presumably takes place through a small submersible pump). The machine designed employs the basic structure of a 5-shank ripper. The whole machine has a footprint of 2.5 meters x 8 meters and includes the tow hitch with hydraulic tilt piston, the mainframe, a rear trolley with 500/50 R17 wheels, and a regulating piston built-in C40 steel. The anchors in the central frame have been sized to withstand forces of 30 kN applied to the edge of the tips (front towing effort) and on the lateral face (lateral steering effort), which can occur in steering operations. The processing elements are arranged in two rows at a distance of 48 cm. The maximum working depth is 70 cm, and the anchors (Hardox 600) have a thickness of 35 mm and a depth of 20-12 cm. In aisi 440 stainless steel, the distribution system includes two 300-liter tanks coupled to a 6-element membrane pump that distribute the compost tea on five tubes with a diameter of 40 mm (20 mm internal lumen). The distribution system has been designed to house flowmeters, nephelometer, biofilm monitoring, and capacitive sensors to measure salinity and conductivity of tea compost useful for variable rate distribution.



A Mower with Chains for Under-row Weed Control in the Vineyard

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Keywords. Non-chemical weed control; organic farming, soil conservation; mowing; tillage

Abstract. Among the different agricultural practices required in the vineyard, weed management is crucial to achieve adequate yields. Non-chemical under-row weed control is commonly performed through soil tillage. However, considering the high rate of soil degradation of European vineyards, concerns about the potential negative effects related to tillage are increasing. To date, attention is focusing on strategies which promote organic farming practices and soil conservation, such as the maintenance of a permanent sod under the row with mowing. Most of the mowers cut weeds by means of blades. However, in the Mediterranean Europe vineyards have been planted on soils often characterized by high stoniness, where blades are poorly effective and get frequently damaged. A commercial under-vine mower was modified by replacing blades with chains to achieve more resistance in case of impact with stones. In February 2021 a preliminary cutting test aimed to identify the appropriate setting of the mower with chains was carried out on an open field. The modified machine and the commercial version were compared considering two forward speeds (1.5 and 2.4 km·h⁻¹), and two rotation speeds of the cutting tool (1830 and 2500 rpm). Weed cover percentage, height, and above-ground biomass were evaluated. The setting with lower forward speed and higher rotation speed of the cutting tool obtained the best results in terms of weed control. In April 2021 a three-year comparative test started in the vineyard. The trial is aimed to compare the mower with chains with machines that perform under-row weed control through soil tillage, such as motorized discs, weeder blade cultivator, and rollhacker. Weed cover percentage, height, and above-ground biomass were assessed. At the first weed control intervention the mower achieved a weeds height around vine trunks similar to the motorized discs, but higher compared to the other machines. The mower achieved a lower weed biomass compared to rollhacker, and similar compared to the other machines. Motorized discs obtained best results in terms of weed cover. At the second intervention weeds height in mowed plots was lower compared to rollhacker, while weed biomass was lower compared to rollhacker and motorized discs. Moreover, the mower achieved the lowest weed cover. Overall, at the first year of the test the mower obtained promising results but further years of evaluation are needed to draw conclusions on the comparison.



Environmental Impact Assessment of Hydroponically Grown Wheat Green Fodder

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Keywords. CO₂ emissions, wheat, fodder yield, nutritional values, growing cycle.

Abstract

It is estimated that approximately 70% of all agricultural land is used for livestock production. This represents 14.5% of all human greenhouse gases (GHG) emissions. GHG generated during the animal feed production process account for the largest portion (45%) of these emissions. Needs of animal products for public consumption by using conventional production practices has almost reached its limits. Consequently, new and innovative methods based on modern technologies are becoming necessary to reduce the environmental impact of livestock production. Animal feed production can be considered as one of the leading sources of agricultural GHG emissions. Although promising hydroponic plant production technologies are being developed and improved, their potential impact towards cleaner environment is still a concern.

This study conducted experimental research with the test stand equipped with a nutrient film technique (NFT) system for hydroponically grown green fodder. Based on the fodder yield data obtained in the laboratory, mathematical modelling was performed to predict the potential for industrial fodder production. The aim of this study was to evaluate the impact of different growing cycles (5–11 days, inclusive) on wheat fodder yield, nutrient content (crude protein, ether extract, crude fibre, ash and nitrogen free extract) and environment through Life Cycle Assessment (LCA). Global warming potential for carbon dioxide equivalent (CO_{2eq}) was assessed using SimaPro 9.3 simulation software and the Ecoinvent 3 database by the implementation of the CML-IA baseline LCA method (v3.06).

The results of this study showed that the yield of wheat fodder using 6-day growing cycle was the highest – 28.37 t month⁻¹. Meanwhile, the results of LCA indicated that the hydroponic fodder from the 11-day growing cycle had the least impact on the environment (106.18 kg CO_{2eq} t⁻¹ of fodder). However, in order to achieve not only a sustainable but also an efficient hydroponic fodder growing system, it is still appropriate to choose a 6-day growing cycle where the ratio of yield (28.37 t month⁻¹) and environmental impact (122.47 kg CO_{2eq} t⁻¹ of fodder) was the highest. Based on the results, it is also recommended to choose a 6-day growing cycle for the higher amounts of nutrients and for reducing the environmental impact in hydroponically grown wheat fodder production.



Technological tools for respiratory health status detection in pig farming: comparison with veterinary records

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Keywords. pig farm, cough, respiratory distress, Precision Livestock Farming

Abstract. Respiratory diseases have an important economic impact in intensive pig farming. Swine herds affected by respiratory disorders present increased mortality rate, reduced performance, lower carcass quality and increased use of antimicrobials. Therefore, the early diagnosis and early recognition of symptoms are fundamental to reduce transmission and the need and use of medications. Commonly, cough is the most frequent symptom. To observe it, continuous animal observation is crucial, but requires substantial dedicated manpower that is often not available in intensive farming. Precision Livestock Farming (PLF) could help farmers providing relevant information related to animal status and their environment in an easy and quick manner. For coughs, the technology to be adopted is the recording of sounds and vocalizations through microphones, which have the advantage of recording data on many animals with just one instrument and of being noninvasive, thus without causing stress and affecting animals' normal behavior.

In this context, a commercial product by Soundtalks® was studied with the aim of comparing the warnings of this instrument against the observations of the veterinary and finally evaluate its reliability. This microphone detects automatically sounds, processes data and results the respiratory health status of pigs through a Respiratory Health Status (ReHS) indicator. A user-friendly interface based on colors is available: when yellow and red colors are shown, “Potential Respiratory Health Problems” or “High Risk of Respiratory Health Problems” occur and require veterinary attention. This tool was installed in a commercial fattening pig house in Brescia province, where a gateway that records data and sends them on the cloud, and two microphones in two rooms of about 320 pigs each of the same building were installed. The monitoring lasted 9 months (2 fattening cycles). In total, 13 ReHS yellow alerts and 8 red alerts occurred. In 2% of the cases no medication was used before the alert was given, similarly in 2% of the cases medication was already used. This instrument has a high potential in pig farming, as its use on farms can support the vet in defining when farms need to be visited.



Ammonia and particulate matter removal efficiency of a dry and a wet acid scrubber in pig barns

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Keywords. pig farm, air quality, emissions, scrubber, removal efficiency

Abstract. Air inside pig barns is characterized by high concentration of ammonia (NH₃), particulate matter (PM) and other airborne pollutants, such as odors. The same poor-quality air then dumps into the environment causing pollution in the surrounding areas. Thus, the identification and adoption of mitigation strategies for intensive livestock farming is necessary, both to reduce the environmental impact related to livestock production, and to help solving the issue related to air pollution. Air treatment technologies have the double benefit of abating pollutants emissions and improving air quality inside the barns. In this context, the LIFE-MEGA project intends to reduce NH₃ and PM emissions in pig barns by applying two different abatement technologies: a commercial dry scrubber already used in bakery industry and a wet acid scrubber prototype realized using citric acid instead of sulphuric acid. Citric acid was chosen as it is safer to handle and harmless for pigs and workers. The project started in October 2019 and will finish in September 2023. Both air treatment technologies are being tested in two Italian farms during the fattening phase and in two Spanish farms in the weaning one. The aim is to verify the achievable abatement efficiency of the two abatement systems during different growing phases and with different housing condition, ventilation system and slurry management. In Italy the scrubbers were firstly installed for 12 months (2 fattening cycle) in a farm located in Lodi province, where animals were housed in a naturally ventilated building, on a concrete floor with fully slatted outdoor runs. Pig slurry was removed using a vacuum system. Currently, the two abatement systems are installed in the second farm (Pavia province), where pigs are housed in a naturally ventilated building, on a fully slatted floor, and slurry is removed using a vacuum system. To test the wet acid scrubber NH₃ abatement efficiency the VERA protocol was applied, whereas to test dry scrubber PM abatement efficiency Haz Dust instruments were used as gold standard. According to preliminary results, in the first farm the wet scrubber could reduce NH₃ emission up to 61% and the dry scrubber could abate PM up to 37%. In the second farm the monitoring campaigns are still ongoing but, based on the first data collected, the wet scrubber presents a lower NH₃ removal efficiency (around 22%). Regarding the dry scrubber, due to technical problems, first data still need to be collected. In conclusion, these abatement efficiencies could be considered a promising result.



The Direct Costs for Cover Crops Cultivation: Comparison between Different Agronomical Practices

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Keywords. Cover crops, mechanization costs, tillage, termination.

Abstract. As it is known, cover crops are plants that cover the soil between the harvest of the main crop and the seeding of the later. They are herbaceous species that are not cultivated for their commercial value, but to obtain agronomical and environmental benefits. These species are inserted in the production processes with the primary aim to maintain soil covered by vegetation in periods when the same soil would remain lacking in every cultivation, and therefore subject to damaging effect from pedological point of view.

The limits of cover crops are due to their nature. Indeed, since they are crops which do not have a commercial value, the most significant aspect is related to their production costs therefore the incidence of costs for the purchase of seed, for seeding and for the termination must be limited.

In particular, scientific literature is poor of studies related to mechanization cost analysis for cover crops cultivation. For this, the goal of this study is to experimentally evaluate and analyze in details the fuel consumption, the main operative parameters (i.e. workability and hours necessary to carry out every single mechanized activity per hectare) and costs per unit of area for fuel, labor and agrochemical required for the cover crops cultivation, as a function of different agronomical practices applied. In particular, the study takes into account the following agronomical practices: 1) conventional tillage, 2) minimum tillage, 3) direct seeding and 4) no-tillage and, to destroy cover crop, the mechanical and the chemical termination.

The obtained results suggest that the conventional tillage is the most expensive agronomical practice in terms of fuel and labor (€/ha). Minimum tillage allows a saving of 40.4% in comparison to conventional tillage, whilst direct seeding and no-tillage allow a saving of 75.4% and 69.0% respectively, always in comparison to conventional tillage.

It follows that the most convenient and timely techniques are direct seeding and no-tillage. About cover crop destruction, results demonstrate, in absolute terms, that chemical termination is the timeliest operation, but is not the most cost-effective choice since, to direct costs, must be add the cost of the herbicide. The more convenient termination is that carried out using crimper rolling, but this technique is only apply to a small number of cover crops with a well-defined phenological stage.



Enhancement of Mediterranean Greenhouses facilities: Heat Power Pump assessment for Bedding Plant Production by Coaxial Basal Heating

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Keywords. Energy saving, efficiency, greenhouse, controlled environment, horticulture

Abstract. Protected horticulture is a highly energy-consuming sector where optimizing energy use and cost for heating facilities is strategic to achieve high environmental and economic sustainability of productions. The project's main aim was to evaluate the use of a heat pump (HP) for basal heating as an alternative technology for the production of bedding plants. As matter of fact, bedding plant production for the early spring market is usually characterized by high energy input, as plants are grown in greenhouse condition by maintaining a minimum temperature of at least 15 °C. The experimental trial took place in a greenhouse placed at the CREA Research Centre for Horticulture and Floriculture (Pescia, Italy). The greenhouse consisted of a supporting structure made of galvanized iron, roofing in polycarbonate slabs, and walls of polyethylene sheets equipped with a fully automatized opening system, equipped with twelve concrete benches. The benches were isolated from the ground with polystyrene and a substrate of volcanic lapilli. Then 8 benches were provided with a basal heating system based on four couples of coaxial pipes circulating warm water, while four of them were not heated. Cuttings of *Impatiens Walleriana* 'Buddha F1 Carmine' were transplanted in 1.2 L pots and subsequently grown by comparing a basal heating of 16 °C with no basal heating conditions, for a total of 960 potted plants. According to requirements, all the plants underwent the same agronomic cares (fertigation and pest control) and by maintaining the greenhouse temperature of 5 °C. The microclimatic conditions and the energy consumption were acquired. The experimental results show that the heat pump ensures suitable thermal conditions for such cultivation in the winter period, confirming the possibility of using a conventional heat pump in horticulture as a simple installation in an existing Mediterranean greenhouse. Furthermore, based on the fossil fuel efficiency, the HP installation shall be also evaluated taking into account the used energy source: in greenhouse production systems, even though heat pumps are more efficient than other heating sources, their use shall undergo accurate analysis to assess the resulting economic and environmental benefits.



Using Multiple Correspondence Analysis to Evaluate Milking Parlour Performance

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Keywords. Multiple Correspondence Analysis, Milking Parlour Performance, Milking Efficiency.

Abstract. Modern milking parlours allow the automated collection of many data for each cow being milked that can potentially be used to monitor the overall performance of the milking process. A group of 24 dairy farms from Lombardy (Italy) was visited to collect the following data from the herd management software: cows milked/stall per hour [n]; milk yield/stall per hour [kg]; milking efficiency [%]. Additional information were: number of milking stalls, ratio stalls/milker, exit from milking parlour (rapid or conventional), and type of milking routine (full or partial). 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), and the milking machine settings (42 kPa system vacuum, 60 cycles/min pulsator rate, and 60 % pulsator ratio). Quantitative variables were transformed into 3 classes, using their quantile position with respect to the mean. This provided the frequencies of observations that were within the quantiles: <25%, between 25 and 75%, and >75% of the mean value for a chosen variable. Relationships among variables were evaluated through a multiple correspondence analysis (MCA). Significant differences ($P < 0.05$) between class means were tested by a one-way ANOVA with Tukey–Kramer mean comparison (JMP Pro 16.1, SAS Institute). MCA identified three main groups of related parameters: in the first group large parlours (>32 milking stalls) were associated with a high number of stalls/milker (>15), low number of cows milked/stall per hour (<2.5), low milking efficiency (<31 %), low milk yield/stall per hour (<39 kg). On the contrary, small parlours (<16 milking stalls) were associated with a low ratio stall/milker (<8), high performance in terms of cows milked and milk yield per stall per hour (>3.5 and >52 kg) and milking efficiency (>39 %). Parlours of medium size (16-32 milking stalls) were associated with intermediate performance. Small and medium size milking parlours usually applied a full milking routine (predipping, forestripping, teats drying before milking cluster attachment) while in large parlours teats were only wiped or stripped before milking unit attachment. Rapid exit characterized all large parlours. Small milking parlours showed significant ($P < 0.05$) higher performance in terms of cows milked/stall per hour (+24 % and +28 %) and milking efficiency (+22 % and +30 %) if compared respectively with medium and large parlours. No significant differences were observed in terms of milk yield/stall per hour between parlours of different size. Results suggest that MCA can potentially be used to evaluate milking parlours performance.



Effect of Automatic Feeding System (AFS) on Dairy Cows Feeding Activity

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Keywords. Automatic Feeding System, Feeding Activity, Total Mixed Ration, Feeding Place Index

Abstract. Supplying a total mixed ration (TMR) to dairy cows with a higher frequency is a key factor to have more distributed visits to the feeding fence over 24 h and longer feeding times. All this optimize dry matter ingestion and stabilize the ruminal pH with positive effects on cows' health and milk production. Running up to 16 TMR distributions · day⁻¹, automatic feeding system (AFS) allow to meet the herd's nutritional needs without depending on human labour and incurring additional labour costs. A CMOS monochromatic camera (Lumenera LU125M, Lumenera Corporation, Canada) was used to monitor the effect of TMR distribution and push-up operated by an AFS (Vector system, Lely Holding, the Netherlands) on dairy cows' attendance of feeding alleys. The study was carried out in a freestall-housed dairy farm from Lombardy (Northern Italy) with 121 lactating cows divided in two groups (A and B) and milked by two milking robots (Vector A4, Lely Holding, the Netherlands). Group A consisted of 58 animals and had available 63 feeding places, while Group B consisted of 63 cows with 69 feeding places. The camera was conveniently placed to frame the two feeding alleys and its settings (interval shooting, exposure time, gain) were controlled by a software tool written in Matlab v.R2017B (MathWorks Inc., Massachusetts, USA). Images were acquired at 5 minutes interval from 6 a.m. to 6 p.m. for ten consecutive days in January 2019 and the feeding place index (FPI), obtained by comparing the feeding cows to the feeding places, was calculated at the same interval. The poor lighting conditions of the barn did not allow acquiring neither images nor calculating FPI for the evening and night hours. Significant differences between FPI means calculated at each TMR distribution and push-up were tested by analysing the variances (JMP Pro 16.1, SAS Institute). Results showed that TMR distributions determine significant higher ($P<0.01$) FPI compared to TMR push-up (0.46 vs. 0.26). FPI increased up to 0.54 and 0.51 respectively after 15 and 30 minutes TMR distributions, even if the differences were not significant. On the contrary, FPI reduced significantly ($P<0.01$) to 0.19 after 30 minutes TMR push-up. These results confirm the feeding activity of dairy cows may be influenced by TMR distributions and push-up operated by AFS.



Fertigating maize with proper separation systems for the valorization of digestate

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Keywords. Fertigation, microfilter, nutrients recycling, separation efficiency, vibrating screen

Abstract. In the framework of the project LIFE ARIMEDA “Ammonia emission reduction in Mediterranean agriculture with innovate slurry fertigation techniques” (Life16 ENV/ES/000400) the aim of this study is to give insights about the performance of filtration systems developed to fertigate maize fields with digestate. In general terms, fertigation can enhance the nutrient use efficiency by applying fertilizers during the crop growing cycle, and has the potential to reduce ammonia emissions. To make it feasible, however, a proper solid–liquid separation system is fundamental to avoid nozzle clogging. In this study, the technical performance of four full-scale filtration systems installed in four farms of Northern Italy was evaluated. Of these farms, two were equipped with driplines and two with center pivots. Prior to fertigation, solid-liquid separation of digestate with screw-press separators occurred in all farms. Afterwards, different separators were used to remove the fine solids: for the drip irrigation, a microfilter and a vibrating screen were used, while for the pivot was used a vibrating screen. During field tests were recorded digestate volumes, electricity consumption and manure characteristics along the treatment (total solids and nutrients). Mass balance, Separation index $Et(x)$ and Reduced Separation Index $Et'(x)$ were quantified to assess the performance of the filtration systems.

The resulting performance depended on the type of separator, initial TS content, screen size, and input flow rate. The $Et(x)$ of the separation systems for drip irrigation ranged from 36% to 84% for TS, and from 10% to 79% for nutrients, while the $Et(x)$ reached in farms with pivot systems ranged from 25% to 65% for TS, and from 7% to 52% for nutrients. Electricity consumption was higher for the microfilter (1.77 kWh/m³) than for the vibrating screen (0.12-0.26 kWh/m³). A filtered digestate flow rate of 2.4-7.1 m³/h and dilution ratio of 4-10% can be adequate for both irrigation systems. To implement fertigation effectively using digestate, the separation system and the irrigation system need to be well integrated. Finally, proper management choices of fertigation (e.g., driplines positioned few centimeters below the ground level, use of low pressure sprinklers for pivots) can affect also the overall environmental performance.



Smart roof: preliminary results of a multidisciplinary study on green roofs for rural buildings

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Keywords. Vegetated roof, thermal performance, insulation, air temperature

Abstract. Green roofs are widely used for homes and in the industrial sector. Few applications are reported for agriculture, mainly for wineries. Generally rural buildings are very simple from the structural point of view and have a limited load bearing capacity. For example, dairy cow barns have no walls and roofs with a slope which reaches up to 30%. Also, these roofs require a good thermal insulation and inertia to maintain adequate microclimatic conditions for the cows.

The use of lightweight green roofs in these types of buildings make it possible to improve the negative thermal effects of conventional buildings as in summer conditions they absorb a large part of the solar radiation and reduce the temperature of the roof while in winter they have a good efficiency in insulating the roof and consequently reduce the heat losses.

The aim of the project is to design an innovative low-cost and low-maintenance vegetated roofing covering, with limited permanent structural load, but with adequate thermal inertia, to be used in agricultural buildings. Therefore, a pilot structure for green roof assessment has been set-up and used to test the thermal effect of vegetation with different soil thickness. It consists of two independent pitches of 10 m x 1.2 m each placed on the ground with a slope of 25%. The two pitches are oriented North and South respectively.

On each pitch, 10 panels (80 cm x 100 cm) have been used to compare 3 substrate thickness, respectively 3, 5 and 7 cm, with 3 repetitions with a randomized block scheme and one control test panels (without soil). A mixture of *Trifolium repens* and *Cynodon dactylon*, were cultivated and production performances (yields and phenological state) were studied during the summer period. Temperatures above and below each panel were recorded continuously, and thermal images were periodically recorded in the growing period.

The effect of the vegetation on temperatures has been very clear, as expected. The temperature reduction below the panels due to the soil and vegetation was in average 3.4°C. Among the different thicknesses the 7 cm layer always showed significant lower temperature in the vegetated side probably due to more vigorous vegetation. However, the temperatures below the panels were similar for all panels indicating that also a 3 cm layer can be suitable.

Thanks to a multidisciplinary approach, the first results of the study, that will be continued in the next years, are contributing to the design a smart roofs system to mitigate the heat transfers and the visual impact of the building.



Evaluation of precision technologies approach for the management of an experimental field in organic fruit growing

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Keywords. TSM, precision agriculture, soil compaction, auto-guidance, sustainable tillage

Abstract. The use of geophysical measurement systems is one of the key factors in precision agriculture, given that it enables the understanding of soil mechanics and sustainable soil management. The criteria for adopting precision agriculture are slowly interesting a growing number of farms generally managed according to integrated agriculture principles. The experiences in organic farming, for which CREA has been active at national level, are still limited. With a view to starting a rational process of setting up the activities, this work focused on the characterization of an experimental field of CREA fruit breeding program.

In this work, the ordinary soil characterization, according to standard manual sampling, was compared with the application of the Top Soil Mapper system (TSM). The obtained results were used for the discrimination of homogeneous zones and for considerations on the subsequent targeted set of management operations.

The TSM is an integrated geophysical measurement system for determining different soil parameters. Using modern geophysical measurement technology and automated data analysis methods, measurements of different soil top layers can be accurately obtained with high resolution. TSM relies on the principle of electromagnetic induction for soil conductivity measurement, with a depth of exploration of above one meter. It can be used on every working run and with any mechanical equipment as a result of a contact-free sensor technology system. The sensor enables a digital presentation of compacted areas and it allows correct tillage practices. The available information can also be used in real time for variable and direct machine control (tilling, sowing) combining the two processes (application and mapping).

The test in the CREA field was carried out in a whole working day, the work rate and the data obtained were evaluated. The two system of soil characterization were analyzed and the reasons for this difference are evaluated in detail and reported. The main advantages of TSM are the optimization of equipment use, reduced fuel consumption and reduced machine wear. With this technology, already know in extensive crops, the increase in work rate and soil structure protection through appropriate tillage, fuel cost savings and sustainable yield optimization, could be also achieved in fruit orchard management.



Analysis of spraying equipment performances in olive orchards

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Keywords. Foliar deposit, ground loss, olive growing, plant protection product, sustainability.

Abstract. This paper was performed in the framework of the project "Eco-sustainable control of olive pests _CEbiOI", and reports the outcomes of a study dealing with the evaluation of the equipment used to spray plant protection products in olive groves. Experimental tests were performed in an intensive olive orchard situated in the province of Reggio Calabria to determine under field conditions according to machine operating parameters 1) foliar deposition, from both quantitative and qualitative point of view; and 2) ground losses. Hence, olive trees were sprayed with a food dye solution as to simulate a plant protection product application. Spray quantitative analysis was determined according to the colorimetric method using a bench spectrophotometer, while qualitative analysis was based on water-sensitive paper image analysis. A significant effect of the trial conditions was found at the $p < .05$ level on both normalized foliar deposit D_n ($\mu\text{l}\cdot\text{cm}^{-2}$) [$F(2, 65) = 8.81, p = 0.000412$ ***] as well as on ground losses [$F(2, 25) = 3.931, p = 0.0328$ *].



A Technology for the destemming and fractionation of hand-picked grape

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Keywords. Selection, Quality, Manual harvest, Bunch, Separation, Maturation

Abstract.

The patented solution is based on the inhomogeneity of the grapes entering the winemaking process. This inhomogeneity is found at the level of the average mass of the berries and the relative forces of detachment from the stalk. Therefore, there is a relationship between impressed accelerations and the quantity of berries that detach from the stalk during the destemming operation. It is known that the grape mass increase as a function of the accumulation of sugars, therefore more mature berries contain greater quantities of sugar and have greater masses. At the same time, the detachment force of the berries decreases during ripening because of the normal physiological mechanism that determines the collapse of the cellular structures of the pedicel that connect the berries to the stalk.

The extreme variability of grape ripening is also well-known, both within the same vineyard, a spatial variability, and between contiguous plants, between clusters on the same plant, up to the different level of ripeness that the berries show inside of the single bunch. Based on what has been mentioned above about the link between the ripening state of the berries, mass, and detachment force.

The object of the invention is a system for separating the berries from the bunch, through applying mechanical energy of increasing intensity, in such a way as to be able to divide the mass into at least two portions of berries characterized by different level of ripeness.

This invention aims to obtain, through the separation of the berries, the production (at least two) different musts, starting from the same mass of grapes hand-picked. This operation could be extremely useful for wineries, to manage the quality level of the future blend and to aim the desired oenological targets.



Improvement in durum wheat production using prescription maps from multispectral UAV surveys

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Keywords: UAV, prescription maps, multispectral survey, grain production

Abstract. Precision agriculture has become increasingly central to agricultural production management over the years. The production system of grain crops requires high mechanization and ranges over medium to large areas, which makes the adoption of these precision systems compatible with the management system. The goal of this work is the use of multispectral surveys for the creation of prescription maps in order to improve the production of durum wheat. The work has been conducted in a conventional Italian cereal farm in Southern Italy (Avellino area) with the aim of verifying the reduction in terms of inputs to be used for production. A survey of the cultivation of durum wheat has been conducted, through images obtained from multispectral surveys using UAVs. The images have been processed by specific software to subsequently create vegetation indices (NDVI, SAVI, MSAVI, LCI). The various indices have been analyzed to evaluate the potential causes that led some areas of the field to produce less than others, generating a prescription map that has been used in subsequent treatments (variable dosage of fertilizer) leading to an improvement in production and highlighting a significant saving of fertilizer compared to previous classical treatments.



Figure 1 – Prescription map from multispectral UAV survey



Preliminary Ammonia Emission Factors for Poultry Manure Storage from the DATAMAN database

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Keywords. manure storage, poultry, ammonia, emission factor

Abstract. Poultry production is an important source of ammonia (NH₃) emissions, which is an airborne pollutant and an indirect source of nitrous oxide (N₂O), a greenhouse gas (GHG). The international project DATAMAN (<https://www.dataman.co.nz/>) developed a global database on GHG and NH₃ emissions from the manure management chain. In the MELS project (<https://www.mels-project.eu/>), data are being analysed to develop revised EF values and generate functional relationships between emissions and activity/ancillary variables. The project also aims to estimate the effect of mitigation measures applied to the manure management chain.

In this study, an analysis of the DATAMAN database NH₃ emission factors generated from the storage poultry manure has been conducted.

To enable a more reliable analysis, only studies published after January 2000 were included. In addition, studies were limited to those based on dynamic measurement techniques, with the majority (94%) conducted using dynamic chambers and the remaining studies adopting micrometeorological methods. Following screening of the data, 33 observations sourced from five countries (Sweden, United Kingdom, China, Japan, USA) were found as being suitable for statistical analysis. Two subcategories of poultry were identified in the analysed data: layers and broiler, with emission factors being significantly greater ($p < 0.05$) for layer manure (23% of stored N) compared to broiler litter (11% of stored N). Despite this difference in the farming management of these animals, no significant differences were found between the dry matter content of broiler litter and layer manure. Furthermore, measurements carried out under field studies showed significantly lower NH₃ emission factors than those conducted under laboratory conditions. These are preliminary results and further investigation and statistical analysis will be carried out. The outcomes of our investigation should help to improve our understanding of NH₃ emissions and provide data for models, including an assessment of the impact of NH₃ emissions. The DATAMAN database also contains observations on N₂O and methane emissions from poultry production this will be the subject of further investigation.



AgroForestry Innovation Lab activities on sprayer performance and certification

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Keywords. Spray drift, plant protection, wind tunnel, droplet size, orchard sprayers

Abstract. Plant protection treatments are of paramount importance to the food supply chain, especially with a growing world population. However, they pose serious risks to the health of operators, bystanders and ecosystems, so the products have to be very carefully administered in order to reduce the dispersion to the environment, which also represents a loss of income for the farmer.

The extent of the problem calls for an increased awareness by all stakeholders and new solutions of growing complexity. This, in turn, raises the demand for (i) base research toward new, performance-oriented solutions, (ii) a certification system to guarantee the adoption of good practices to protect functionality and human and environmental health, and (iii) the tailoring of specialized solutions to various operating contexts such as alpine areas.

Within this framework, the AgroForestry Innovation Lab (AFI Lab) is launching a research branch dedicated to sprayer performance and certification in synchrony with local stakeholders, both industrial partners and farmer communities.

Aim of this work is to present the equipment that has been developed in aid of this activity, and some preliminary results obtained, with particular attention to the realization of a wind tunnel for the investigation of atmospheric spray drift, mainly through optical instruments.

The tunnel measures 6x10x30 m (W, H, L) and allows airflows of up to 5 m/s. Within it, vertical and horizontal patternators can be accommodated to characterize the deposition performance of orchard sprayers during simulated treatments with advanced tracing solutions.

A laser Particle/Droplet Image Analysis system is also installed within a dedicated test bench for the characterization of nozzles.

The work is closed with a roadmap of the activities and a panoramic of the potential side-applications of the facility.



Uranine as a tracer for rapid detection of spray deposition

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Keywords. Plant protection, spray drift, vineyard sprayers, spray nozzles, uranine

Abstract. While being virtually mandatory to any sustainable agricultural activity, plant protection products pose sensible risks from the side effects of improper application techniques.

Monitoring of the application parameters is paramount to the characterization of sprayer performance, one of which is the deposition pattern, whose sampling is reportedly time-consuming and unreliable due to uncontrollable test conditions.[1]

We investigated a simplified deposition assessment strategy involving uranine, a non-toxic and low cost fluorescent tracer widely used in other fields[2], to minimize the measurement uncertainties exploiting the well-known phenomenon of optical absorbance.

A nozzle evaluation bench has been used to deposit the fluorescent solution on a matrix of petri dishes, which were then oven-dried and the residuals redissolved in a fixed amount of water. Spectrophotometry was used to retrieve the mass of deposited solution.

After careful calibration against known uranine concentrations, the method yielded results very well correlated to the weight measurements performed prior to drying and allowed to trace back an approximate deposition curve.

The complete evaporation of the deposited solvent gets rid of the unpredictable atmospheric conditions during the test, while the flexibility of the solution allows to easily tailor the technique to different application volumes, deposition rates or collector configuration without losing accuracy.

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Microclimatic Monitoring and Analysis in a Hydroponic Greenhouse

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Keywords. Microclimate Monitoring, Hydroponic Greenhouses, Sensors, Soilless Culture.

Abstract. In the last decades, there is the increasing reduction of per capita arable land and the increasing demand for food [1]. These needs require the development of advanced solutions, like soilless cultivations [2]. In particular, hydroponics represents an interesting and efficient response for sustainable cultivations [3]. Hydroponic greenhouse is the evolution of the traditional one and it needs a different management. This management is not only limited to the cultivation area, but it involves also other factors, for example structural characteristics of greenhouse, microclimate management, nutrients management [4, 5]. To maximize resources efficiency and quality food production it is fundamental to characterize the microclimatic parameters and their distribution inside greenhouses.

This work provides the preliminary study to measure and analyze the main microclimatic parameters in a hydroponic greenhouse, located in Vinchiaturro (Italy), without microclimatic controlling system.

In this work a set of sensors were installed to acquire continuously data. The sensors were managed by a supervision system that allowed also to historicize all measured data.

The analysed data were used to identify an appropriate control logic that could be implemented for a low-cost management to improve greenhouse efficiency.

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Valorizing Agro-Industry Residues to Improve the Environmental Sustainability of Frozen Products

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Keywords. Vegetables, Peas, Biogas, Renewable energy, Life cycle assessment

Abstract. Although processing fruits and vegetables into shelf-stable products reduces losses, proving to be a viable solution, significant losses still occur at various stages. The European Green Deal proposes a circular economy concept based on the perception of environmental and economic benefits, which has led to a push that calls for valorizing agro-industrial residue. Considering the paradigm shift towards renewable energy due to the high ecological impacts associated with fossil fuels, generating biogas energy from agricultural residue for electricity is a smart use. The present study is related to a large Italian agriculture consortium that produces and transforms vegetables mainly intended for the frozen market and operates within Italy's central and southern parts. The main processed product is the pea, distributed to important Italian frozen products brands such as Findus and Orogel. The production takes place in 3 months (April, May, and June). In this period, the agro-industrial pea residues constitute the only fresh plant matrix fed into the consortium's biogas plant. The manufacturer, for peas processing, reports an annual average material loss between 15-30%, corresponding to 1.12E+03 tons. The waste generated goes to a biogas powerplant for conversion to electrical energy with digestate as a co-product. The biogas is produced from co-fermentation feeding with 50-55 tons per day, using a mix of corn silage (44-58%), pea residues (27-40%), and chicken manure (15-16%) as feed during the reference period. Specifically, this study investigates the environmental benefits of using agro-industrial residues as partial replacement of the typical energy biomass (corn silage) and from the partial substitution of fertilizer with digestate, which is returned to farmers in a circular nutrient cycle. As part of the study, the ecological sustainability of the biogas power plant will also be evaluated, along with potential areas for improvement in the production chain. Following the ISO 14040/14044 standards, a life cycle assessment will be conducted. Primary data has been collected from the manufacturer using a well-structured questionnaire and official documents for 2019 and 2020. The CML-IA baseline method will be applied to assess various environmental impacts such as global warming potential, eutrophication potential, and acidification potential. The results from the study are expected to promote the trend towards using renewable energy sources through local circular economy systems.



Heat and mass transfer model of a wet brick simulant during energy test of a domestic electric oven

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Keywords. Simulation, energy, oven, standard.

Abstract. Baking and roasting are generalized cooking methods consisting in heating the food inside an oven at a uniform temperature. In these processes, heat is transferred to the food mainly by means of radiation and convection. Electric kitchen ovens require a great amount of energy and only less than 20% is employed for cooking. The oven energy class (ranging from A+++ to D) is certified by several test regulated by the European standard EN 60350. Such test prescribes to measure the energy requirement to increase the core temperature of a standard wet brick of 55 K, using different oven functions. For manufacturers, performing the tests for different oven models and the trial-and-error approaches employed to design oven control strategies demand a vast amount of time and resources, thus making the use of simulation tools highly desirable. The overall process sustainability would increase, because of a significant reduction of experimental tests and energy.

The aim of this work was to develop a parametric numerical model able to describe heat and mass transfer between oven environment and the brick simulant prescribed by the test standard. Experimental tests were carried out to define thermal and diffusivity properties of the brick as a function of moisture content and temperature. Simulations and experiments have been carried out for different cooking methods (forced air, conventional and ECO) and oven temperatures. Water loss, thermal profiles, and the subsequent energy consumption (load heating and evaporation), were compared.

Comparing model and experimental energy test results, a ratio between the brick energy absorption and the whole oven energy consumption ranging from 20 to 27%, was observed. This depends on the cooking method, but not on the oven temperature. The lower brick energy consumption was obtained with the ECO function, and it is mainly due to the lower water evaporation. Linear relations between oven temperature and brick energy consumption were found all the cooking methods. Furthermore, strong linear relations were achieved between the energies calculated for conventional and forced air methods at different oven temperatures.



Residual heat from district heating plants for forages drying in the Camonica Valley

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Keywords. District heating plant, waste heat, forage drying, circular economy.

Abstract. The aim of the work was to evaluate the possibility to use the waste heat generated by District Heating Plants (DHP) for forages drying in mountainous areas. The Camonica Valley, located in the Alps of the Lombardy Region (Italy), and in which some DHPs are currently running, is particularly suited for dairy farms. During the late spring-summer time – when the users’ thermal demand is quite lower – these plants may have a lot of residual heat.

The study was performed in 2019 and focused on the cogeneration plant of the municipality of Ponte di Legno, which was – among the others of the Camonica Valley – the most interesting to investigate this possibility due to its particular location and technical characteristics. Additionally, natural forages drying for dairy farms located in this part of the Valley is quite difficult because of the altitude, fields slope, and climatic conditions.

The DHP of Ponte di Legno consists of 2 woodchips burners for heat production (thermal power: 5.8 and 4.6 MW), 1 woodchips burner (thermal power: 4.0 MW) linked to an Organic Rankine Cycle (ORC) unit for heat and electricity generation (thermal power: 2.95 MW; electric power: 0.73 MW) and 1 diesel burner (thermal back-up unit). The residual heat (MWh) over the spring-summer period was monthly computed as the difference between the total heat generated by the plant, the one sold to the local users, and the one lost through the distribution grid. In the three periods related to forages production, the total DHP residual heat amounted to: (i) 514 MWh in May-June (maximum hourly power: 351 kW); (ii) 314 MWh in July-August (maximum hourly power: 211 kW); (iii) 229 MWh in September-October (maximum hourly power: 156 kW).

The natural semi-dried forages (residual water content: 40%) locally available for a second drying step – by a centralized round-bales dryer (work capacity: 20 bales in 11 hours) operating inside the DHP – was computed for 8 dairy farms (i.e., 70% of the total farms in the area around the plant) and reached: (i) 840 t (May-June); (ii) 540 t (July-August); (iii) 107 t (September-October). Assuming a useful period for forages cutting equal to 20 days/cut, the current DHP residual heat allowed to dry 25% of the above mass of semi-dried forages. This limit could be solved by slightly increasing the DHP woodchips consumption during the months of haymaking, allowing the drying of all the locally produced forages mass. In this case, besides increasing the efficiency of the DHP, a high-quality cattle feed could be achieved, and this is a perfect example of circular economy.



Agricultural By-products for Biomethane Production: Opportunities for a Sustainable Bioenergy Conversion

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Keywords. Agricultural By-products, Livestock waste, Biogas plants, GIS, Rural environment.

Abstract.

The use of agricultural by-products for bioenergy production can contribute to the achievement of sustainable development goals. In order to evaluate the potential role of such biomasses, an exploitation model for biomethane production has been developed. Thus, this work aims to analyse diet reconversion for biogas plants, based exclusively on agricultural by-products and livestock manure, taking into consideration the actual Veneto region scenario.

Data on crops (AGEA) and livestock (National Livestock Register) available in the study area have been collected and processed in order to map a realistic distribution of by-products on the territory. The study considers exploitation of existing working anaerobic digesters, simulating no construction of new plants, in order to minimize the economic and environmental costs. The Veneto Region offices (AVEPA) has provided support for the description of existing biogas plants location, diet and installed power. A model has been created on QGIS software to associate by-product availability with digestion facilities: such model allowed to characterize the distribution of by-products, with the attractiveness of the plants inversely proportional to the distance from the biomass production areas. Furthermore, the potential energy of by-products for each plant was compared to the energy currently produced. This comparison allowed to determine which plants might exhibit a stable reduced or increased power, based on the spatial availability of the by-products.

Preliminary results indicate that 23% of plants would not maintain their current energy production and should decrease their installed capacity by more than 50%. This result mainly affects larger plants distributed in areas with high plant density even in the case of high grain production availability. A smaller reduction is expected for 30% of the plants, ranging from -50% to 0%. Based on the model, 9% of plants could increase their installed capacity by less than 50%, while for 37% of them might increase more than 50%. The latter result is particularly concerning for small plants, isolated or near areas characterized by intense livestock production.

These results demonstrate the potential of agricultural by-products for energy production and the possibility of converting the production system with low costs for plant owners. Further analysis determine is the most cost-effective locations which should be considered to install upgrading facilities for biomethane production. This analysis will consider the existing methane distribution network and the potential capacity of the plants.



Development of an investment decision tool for biogas production from biowaste in Mediterranean islands

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Keywords. Biomethane, Anaerobic Digestion, circular bioeconomy, digestate, compost.

Abstract. Biomethane is the Renewable Energy Source (RES) derived from the purification of biogas obtained from Anaerobic Digestion (AD) process using biomass, usually as biowaste and agro-industry by-products. Biomethane can be injected into the natural gas grid, thereby complementing towards the energy demands. The first Sicilian AD plant aimed at producing biomethane was built in the province of Caltanissetta in 2021. The innovative Enersi Sicilia plant treats 36,000 tons per year of biowaste (wet and green) to produce 400 Sm³ h⁻¹ of biomethane, that is used as a biofuel or alternatively fed into the regional natural gas grid. This plant yields a yearly total of 3.6 million Sm³ of advanced biomethane, that is equivalent to a yearly travelled distance of more than 46 million km. This translates to over 3,000 methane cars that can be powered every year, thereby replacing 2,798 t of oil equivalent and avoiding the emission of 5,291 t of fossil CO₂ into the atmosphere. The solid fraction of digestate is recovered and processed into compost, that corresponds to approximately 25-30% of the original feed in biomass weight. This compost is – classified as a "mixed composted soil conditioner", that can be used in agriculture within Circular Bioeconomy (CBE). The production and use of biomethane and other renewable gases in existing infrastructures would allow EU to achieve the climate objectives of Paris Agreement, i.e. to save € 140 billions ca. a year by 2050. The interest of the growing market in biomethane mobility demonstrates the great potential of alternative uses of this gas. The aim of this paper is to present an investment decision tool for the economic evaluation of a biomethane plant using biowaste.



A prototype of photovoltaic dryer for nutraceutical and aromatic plants

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Keywords. Oregano, *Moringa oleifera*, Renewable Energy Sources, innovative farm, Circular Bioeconomy.

Abstract. The microbiological quality of aromatic and medicinal plants is an important criterion for buyers. Italian producers impose specific hygiene rules to reduce the bacterial load. These rules mainly concern the operations carried out between harvest and packaging, i.e. the drying process. The drying process takes place at low or high temperatures, from 20 to 50°C. This type of drying can be obtained by means of a device equipped with a heat pump: drying is obtained by applying very dry air (having humidity of 5%) to the dehumidified products and heating them to the desired temperature. This process allows to rapidly dry food, by preserving its aroma, colour and chemical composition, thus obtaining high quality products.

Research performed on some food products, e.g. ginger, mint, onion, chili and bay leaf, show that an appropriate selection of treatment conditions (temperature and time) can reduce appearance alterations, such as global colour change and degradation of molecules of nutritional interest, e.g. ascorbic acid and gingerol.

This work describes a cold dryer powered by renewable energy (photovoltaic and biowaste derived from aromatic plants) for nutraceutical and aromatic species produced in Sicily, such as oregano and *Moringa oleifera*, used as superfood.

The prototype allows to dry by reaching the maximum temperature of 35°C. A biomass boiler is using the biowaste derived from aromatic plants, according to the principles of Circular Bioeconomy (CBE).



A Method for Energy Efficiency Rating of Low-power Tractors Based Also on Intensity of Use

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Keywords. narrow tractors, vineyard, efficiency, specific fuel consumption, gaseous pollutant.

Abstract. The efficiency of the so-called “low-power tractors” is affected not only by their engine and transmission design evolution but also by the usage modes adopted. Especially in specialized crops, such as vineyards and orchards, many tasks do not require high engine power and traction pull. The entire tractor power could be often engaged to the hydraulic system. A customizable method to analyze and evaluate the real efficiency of narrow tractors (N-TRE) have been developed in 2019, taking into account different tractor models working in different scenarios. These scenarios have been characterized in working activity and intensity of usage, along the growing season. The working conditions and the power requirement of the main operations carried out in viticulture were considered on some narrow tractor models, simulated in a stationary mode using electromagnetic dynamometers, integrated with devices for measuring the fuel consumption. The basic output has been a series of engine performance curves (power, torque and Specific Fuel Consumption, SFC), both at full and partial loads. On these curves, some characteristic working points were identified, simulating the typical tractor running conditions in vineyard. The aim of this study is to validate the N-TRE model by testing its robustness with a increasing number of tractors, to build a suitable database, to classify the machines in some efficiency classes identified with letters from A to G, similarly to what happens for example in several electric and electronic household appliances. Furthermore, for each tractor the classes A-G were considered also in relation to the intensity of use (light, medium, heavy), i.e. the power engagement and the working time. The output has been a sort of “alphabetical code” based on 3 letters for each tractor model. These codes could immediately and easily show a comprehensive efficiency in different operating scenarios. Moreover, the codes should be added with a tag in “traffic light” colours (green, yellow and red) to indicate at a glance both the gaseous pollutant emissions level and the environmental efficiency.

| Tractor model | Scenario | | | Colour codes |
|---------------|----------|--------|-------|--------------|
| | light | medium | heavy | |
| 1 | C | B | A | |
| 2 | G | D | C | |
| ... | .. | .. | .. | ... |
| n | F | D | B | |

An example of colour codes related to the tractors' efficiency in different scenarios.



Work Time Study, Productivity and Costs of Felling Trees in Urban Areas

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Keywords. Urban forestry, tree maintenance, residual biomass.

Abstract. Urban trees are key elements of green infrastructure and provide urban dwellers with a variety of essential ecosystem services and benefits. Therefore, the maintenance of trees plays a decisive role in the development of strategies aimed at maintaining urban forestry and biodiversity to improve human health and well-being. In urban environment, numerous factors affect the care and the management of trees and felling of trees in town requires specific technical competences. To remove trees, operators dismantle the plant (i.e. to cut into pieces from top to bottom) utilizing either an aerial lift or ascending the crown with ropes, the so-called “tree-climbing”.

The study aimed at: (1) investigating technical and economic features of felling in urban environment; (2) evaluating the productivity and costs of the observed yards; (3) assessing the potential residual biomass.

The felling operations were analyzed with work time studies in 18 work sites (with a total of 27 trees of 7 botanical species observed) including 8 yards in tree-climbing and 10 yards with aerial lift. Work time was measured from the beginning of operations to the transport of the residual biomass to the collection and loading point, using centesimal stopwatches and video recording for a total observation time of 88.4 hours. Starting from the fuel consumption data of each yard, emissions of CO₂ and energy consumption were also calculated.

The total residual biomass was weighed or estimated, and it resulted in average equal to 4.4 Mg per tree (min. 0.5; max. 15.0 Mg).

Cost calculation for each yard considered the fixed and the variable costs and the costs for the labor force. Multiple Linear Regression analyses, which utilize regressors evaluable before the work, were calculated to predict the total time of the operations, the productivity, and the cost per tree.

This paper can contribute to optimize tree maintenance methods in urban sites and to estimate the potential residual wood biomass attainable from urban trees.



Nitrogen recovery from animal slurries by ammonia stripping process

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Keywords. nitrogen removal; nutrients recycling; ammonia stripping, ammonium sulfate.

Abstract. Although livestock manure is an important source of nutrients for crops, it can become a significant cause of environmental pollution if the manure management chain is not optimal. A nitrogen recovery process could be beneficial to produce a mineral fertilizer that is easy to transport and use on crops. For this reason, physico-chemical nitrogen removal processes such as struvite formation, membrane filtration or stripping of ammonia are more attractive than biological processes, although equally complex in the configurations studied and proposed so far. A simplification of the stripping process is however possible by changing the treatment approach to a slow-release system. The ConservA project (Innovative plant for the Conservative removal of nitrogen from livestock manure and digestate) is an operational group in the EIP-AGRI framework. It involves the design and the construction of a pilot plant that is based on a system where the liquid manure is mixed continuously in a closed reactor where an air flow in the headspace removes the ammonia that is released from the surface of the liquid.

The pilot plant has a tank of 30 m³ to receive the slurry or digestate and a screw press separator to remove the coarse solid. Four reactors of 7.5 m³ each are mechanically mixed and it is possible to heat them by hot water circulation. Each reactor is half filled with slurry and the air flows in the headspace and return to a scrubber, where ammonia reacts with a sulfuric acid solution to form ammonium sulfate. The batch process last from 5 to 15 days according to the type of manure, the temperature and the amount of ammonia to be recovered.

Preliminary test has confirmed the results obtained in laboratory. At a temperature of 40°C (the same of mesophilic biogas plants) more than 90% of the ammonia contained in the liquid can be removed in 10 days of treatment.

The results of the project, which will also be made available on the website <https://costruzionirurali.unimi.it/ConservA/>, will assess the technology in practical conditions in order to provide farmers the cost-effectiveness of the treatment system, which may allow to respond to regulatory requirements and improve the environmental management of the farm, recovering nitrogen as fertiliser.



Use of Heavy Metals Contaminated Industrial Hemp (*Cannabis sativa* L.) for Bioenergy Production

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Keywords. Contaminated biomass; renewable electricity; soil remediation; phytoremediation; sustainability.

Abstract. Worldwide human-related activities, especially those of the industrial, smelting and mining sectors, have caused the heavy metals contamination of large areas. Heavy metals are characterized by their long persistence and serious health concerns in living beings. Nowadays, different soil remediation activities are undertaken to limit and ameliorate contaminated soils. Among the various soil reclamation technologies available, phytoremediation is considered one of the most cost-effective and eco-friendly practices, where the use of industrial hemp (*Cannabis sativa* L.), as a hyperaccumulator plant, has shown promising remediation potentials. However, the proper management and disposal of harvested contaminated biomass represent a key point of the sustainability of the entire remediation process. In fact, the valorization of the contaminated biomass is a crucial aspect to ensure the sustainability of the entire phytoremediation process. This study aims to assess and evaluate the energy and environmental burdens of using heavy metals contaminated industrial hemp for bioenergy production. Specifically, the cumulative energy demand and climate change impact categories were selected from the life cycle assessment methodology. The data sample comes from real heavy metals contaminated sites, located in Sardinia (Italy), which have been subjected to soil reclamation by growing industrial hemp (Futura 75 cultivar). The energy and environmental impacts of using the contaminated biomass as an energy resource were then modeled from a “field to wire” approach. The designed scenario analyzed the processes associated with field level, product transportation and combustion of the contaminated biomass in a biomass power plant for bioenergy production. The results obtained underlined that the field level represents the main impacting process, while the electricity produced from the contaminated biomass allowed to save about 25 GJ ha⁻¹ of primary energy while avoiding emissions of 330 kg CO_{2e} per phytoremediated hectare. The study highlights that the use of heavy metals contaminated biomass for bioenergy production, improved the sustainability of soil reclamation activities turning unproductive lands into productive areas.



First results of digestate spreading trials in Mediterranean crops

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Keywords. Agriculture, Biomass, Organic farming, Waste treatment, Sustainable fertilization.

Abstract. Biogas production by Anaerobic Digestion (AD) is more and more widespread due on the one hand to the large quantity of biodegradable residues and by-products produced by livestock and agro-industrial activities and on the other to the growing interest in alternative energy sources. The by-product of the AD, the digestate, allows closing the production cycle: in fact, it is a stabilized bio-fertilizer with an amount of nutrients, both macro and microelements, dependent on feedstock features, that can be used as an organic soil improver and can contribute to organic soil matter turnover.

Before storage, transport and distribution, digestate is very often mechanically or physically separated into two fractions: a solid palatable fraction and a clarified liquid one. The liquid fraction has a high rate of readily available nitrogen, while the solid portion has more amendment properties. However, to ensure high quality results, digestate as it is or its fractions should be spread at specific rates and at the most suitable time for the best plant uptake, minimizing losses to the atmosphere, ground and water.

In this paper the first results of digestate spreading trials are discussed. The digestate came from an electrical anaerobic digestion plant of 600 kW, which processes agri-food industry by-products, mainly citrus pulp. The digestate was separated into the two fractions by means of a mechanical separator. The solid fraction was spread in a vineyard and a citrus orchard under effective field conditions, using implements provided by a local agricultural subcontractor and with spreader settings and operating parameters usually adopted by him. The liquid fraction, microfiltered at the digestion plant with an experimental innovative plant, was spread, after dilution and a further microfiltration, in another citrus orchard by means of a fertigation plant. First results suggest the need to improve the uniformity of application of the solid fraction and to carefully adjust the parameters of the final microfiltration of the liquid fraction so to reduce water consumption and the overall economic costs.



Using a continuous microwave prototype for disinfestation of mill moth (*Ephestia kuehniella*) on unshelled almonds (*Prunus dulcis*)

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Keywords. microwave, heat exchanger, disinfestation, almonds, specific energy

Abstract. The infestation of mill moth (*Ephestia kuehniella*) on almonds (*Prunus dulcis*) during the post-harvest and subsequent storage causes high product losses. The infestation is mainly due to the presence of insect eggs on shelled almonds; if larvae hatch after packaging and going on the nut, they would make the product no longer edible, with great economic and commercial damage.

In this study, a prototype of a microwave system for continuous disinfestation of unshelled almonds had been developed and used in industrial experimental tests to evaluate the pest control performance.

The machine is composed by a tube (length 3.14 m) with an inner spiral for the advancement of the shelled almonds and 5 magnetrons (each of 1.5 kW electrical power) located along the pipe. All safety devices have been implemented. Residence time and electrical power supplied setting has been manually regulated by PLC.

Operational parameters were investigated during preliminary tests phase to implement a research protocol for disinfestation tests. Eggs and larvae had been conditioned with different data input such as electrical power and residence time. Process condition determined guarantees significant disinfestation for larvae and eggs. The experiments showed the feasibility of the continuous microwave-system prototype as an alternative technique for almonds' condition.



Thermogravimetric analysis for the evaluation of coffee grounds in combustion and gasification processes

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Keywords. TGA, Spent Coffee Ground, biomass, waste, circular economy.

Abstract. Fossil fuels are still widely used, and this generates a lot of environmental pollution. There are many resources and technologies to progressively replace the use of these sources. Among these, agro-industrial residues are of interest. Instead of treating them as waste, they could be recovered to produce energy. Thermochemical conversion processes such as combustion, gasification and pyrolysis are promising technologies for the use of renewable energy resources. Spent coffee grounds represent a high proportion of agro-industrial residues, so that scientific and industrial interest in this raw material is growing.

In this work, after a detailed chemical-physical characterisation, combustion and gasification spent coffee grounds pellets and a variant of combustion coffee pellets to which olive pomace oil was added in the pelletisation process were tested. The tests were carried out using thermogravimetric analysis (TGA) to check the process and the reaction of the biomass at varying temperatures in terms of weight and energy output.

The results provide important information on the properties of coffee grounds on energy production. Spent coffee grounds in combustion are exhausted at 550 °C and in gasification at about 675 °C, while pellets mixed with pomace oil have not yet exhausted their mass at 800 °C. The largest amount of power is provided by the pellets with olive pomace oil with a peak of 247.63 mW, followed by the pellets in combustion 205.64 mW and the pellets in gasification 61.47 mW. Non-parametric tests were applied and significant differences between the factors were observed.

This represents preliminary work within a larger project that will involve the analysis and comparison of many types of biomass used in thermochemical processes. The data obtained are important for using biomass in the most appropriate technology and optimising the process.



Physical and chemical characterization of fruit shells and stones for their energy enhancement

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Keywords. Fruit shells, fruit stones, biomass, energy enhancement.

Abstract. Shells and stones represent the main residues deriving from the processing of nuts and fresh fruit of some tree crops, in particular hazel, almond, walnut, pistachio, olive, peach and apricot. These residual biomasses currently constitute mainly a cost for companies producing nuts, jams and olive oil, for the purposes of their management and disposal.

The present study aims to investigate the main physical and chemical characteristics of shells and stones derived from the processing cycles from various Italian companies, for their use for energy purposes in biomass boilers. Analyzes were carried out according to international and European standards on solid biofuels in order to determine moisture content, calorific value, ash content, bulk density, ash fusibility and analysis of micro and macro elements.

The bulk density is comparable to the values of the wood chips. In particular, it is convenient to mill the material to obtain values of 400- 450 kg/m³. In detail, the shells have lower values than those found in the stones. Overall, shells and stones have good average lower heating value (LHV₀) values ranging from 15.5 to 20 MJ/kg in line with other woody biofuels currently used in medium-large size power plants. No significant differences were found for LHV₀ between samples of the same group (shells and stones). The ash content of all samples is less than 1.5%, a value comparable to wood chips (A1 class). However, as regards the analysis of the ash fusibility, all the species analyzed have deformation temperature (DT) below 1000 °C, except for peach and apricot stones, which have higher melting temperatures. From the chemical analysis, the macro and microelements found in the samples have lower values than those indicated by the EN ISO 17225-1:2021 standard. Apricot stones and walnut shells have a nitrogen content (N) higher than 1%. Overall, fruit shells and stones have the right characteristics to be enhanced for energy purposes. However, it would be appropriate to use them in medium-large size power plants due to the presence of low melting ash.



Simulation of the heating load in a NZEB winery building

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Keywords. Agro-industry, energy efficiency, architectural elements, CO₂ emission

Abstract. The study concerns a NZEB building in the agro-industrial sector. A building was designed integrating architectural and plant engineering solutions for the purpose of containing thermal requirement and obtaining low CO₂ emission. In the building activities of production, aging and marketing of wine take place, and, accordingly, the building is divided into three different areas: commercial, production and seasoning. The cellar is placed underground. A model was developed for obtaining the heat load profiles of the building in winter. The software simulation was performed both in steady state UNI-TS 11300 and in dynamic hourly regime, according to UNI-EN ISO 52016. Figure 1 shows the values of the average hourly power used for the purposes of thermal heating on the coldest day of the season.

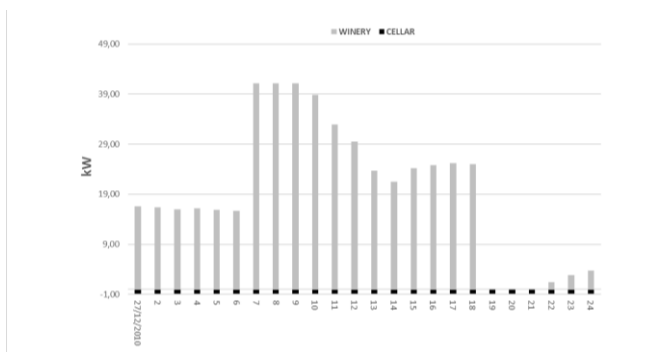


Figure 1: Average power per hour evaluated for the coldest day of the season.



Mapping and Disposal of Irrigation Pipes for a Sustainable Management of Agricultural Plastic Waste

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Keywords. Sustainability, G.I.S., land use, plastic detection, waste valorization.

Abstract. Plastic materials are largely used in agricultural activities. Plastic products are commonly employed as covering in greenhouses and tunnels, for soil mulching, silage, pots and containers and for irrigation and drainage pipes. The use of plastic products provides several benefits for agricultural production. However, the downside is represented by the large amount of generated agricultural plastic waste (APW). There is a need of a conscious and sustainable management of APW from an environmental and economic point of view. APW should be considered as a resource, in the optic of a circular economy. To this end, the definition of a rigorous approach for agricultural plastic detection, mapping, collection and disposal is required. In this study, the attention was focused on the irrigation pipes. An agricultural area, characterized by a variety of crops, in Apulia region (Southern Italy) was considered as case study. The paper proposes a territorial analysis, performed using a Geographical Information System (G.I.S), for mapping areas of use of irrigation pipes and of waste production from these. As a result, a georeferenced database and the quantification of the potential waste were obtained. This allows identifying critical areas for plastic waste production due to irrigation pipes and can be used as tool for planning a proper collection and disposal strategy.



A smart automation system for the management and control of a medium scale digester plant

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Keywords. Automation, biogas plant, by-product smart use, ICT, sensors.

Abstract. The following paper was achieved in the framework of the project Ager 2 - “Sustainability of the Olive - oil System – S.O.S. ”and describes the implementation of the control logic for a medium scale digester plant management through an automation system. Such a digester was developed to produce biogas and biomethane subsequently to anaerobic digestion of agri-food wastes, with a particular interest towards olive mill by-products. Temperature and pH are the main parameters that control the prototype running and automatism. The plants is fed with two matrices having respectively acid (in case of olive mill wastewater) and alkaline pH (i.e. livestock manure). Heating is ensured by a couple of armoured heater elements of 1500 W, while cooling, can occurs thanks to a water main directly connected to the reactor, whenever temperature exceeds the set thresholds. The control logic aims at maintaining temperature and pH within a certain range to guarantee the optimal process parameters. The automatic plant implements three PLC units, which manage the sensors able to acquire temperature and pH data for process control as well as pressure and flow sensors to determine biogas production. The control interface was designed to allow the user to control both manually and automatically the actuators, particularly: feed aspiration electric pump and relative solenoid valves, the mixer, the solenoid valve for the aspiration of cooling water and two resistors for heating. Furthermore, it allows setting process parameters; control process progress of and save data history. The interface enables to navigate between four different windows: manual control, automatic control, parameter setting and trends, which shows the progress of the measurements provided by the sensors in real-time.



Cumulative Energy and Exergy Demand of Agricultural Anaerobic Plants

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Keywords. Anaerobic digestion plant, biogas, exergy, energy performance.

Abstract. Renewable energy production was rapidly increased in the last decades thanks to favorable public subsidies frameworks, and it is expected to continue to grow due to high price of fossil fuels as well as political instability. In this context, in Italy, renewable electricity production from agricultural anaerobic plants (AAP) plays a role. Despite a contribution from 1.5% to 2% of the total electric consumption, this renewable electricity sources involve also environmental benefits and has a positive economic impact on the agricultural sectors.

Over the years, several studies focused on the environmental performances of AAP. Most of these studies, carried out with the Life Cycle Assessment approach, highlighted how electric energy from AAP presents a lower impact on climate change respect to the same energy produced from fossil fuel. Moreover, when the plants are fed mainly with animal slurry and agricultural by-products the environmental results are interesting also for other environmental impact such as particulate matter formation, acidification, and eutrophication.

However, despite a huge interest on the environmental performances of AAP, little attention was paid on their energetic results. This study, using two indicators such as the Cumulative Energy Demand (CED) and the Cumulative Exergy Demand (CExD), deals with the energy performance of 10 AAP located in Northern Italy. CExD depicts total exergy removal from nature to provide a product, summing up the exergy of all resources required. CExD assesses the quality of energy demand and includes the exergy of energy carriers as well as of non-energetic materials. In CExD exergy is used as a measure of the potential loss of “useful” energy resources. Due to the consideration of the quality of the energy and the integration of non-energetic resources CExD is a more comprehensive indicator than CED.

The 10 AAP are in Lombardy and Piedmont, they are dedicated to the production of electricity while the surplus heat is not valorised. The electrical power of the Combine Heat and Power unit fed with the biogas ranges from 100 to 999 kW while, regarding the feedstock utilisation, 7 plants are fed with a mix of cereal silages and animal slurries, 2 only with cereal silage while the last one uses only animal slurries.

Both for CED and CExD, the AAP fed with waste shows best performance than the one fed with cereal silage. Despite this, for some impact categories of CExD and, in particular for, “non renewable, metals” and “non renewable, minerals” the small plants fed mainly with slurry show the worst performances (due to the higher specific volume of digesters per unit of power installed).



Pelletization of composted biochar with residues of the olive-oil extraction process

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Keywords: organic fertilizer; compost; agricultural wastes;

Abstract.

Application of fertilizers in the cropland plays an important role for favouring agricultural production. However, the main agro-environmental impacts related with intensive fertilizer application have been associated with leaching and run off of nitrogen and phosphorous that cause eutrophication. In the last decade, the use of lignocellulosic biomass for energy purpose produce yearly amount of organic residues as biochar. In fact, many researchers proved that biochar can reduce the fertilizer loss to improve soil fertility. Biochar is a porous and carbonaceous material generated through biomass conversion technology under a depleted oxygen atmosphere and contains nearly non-degradable organic carbon with double bonds and aromatic ring. One of the principal problem is the dust production during handling and storage of biochar and for this situation the pelletization can significantly favours field application. At the same time, the production of olive oil represents an industrial activity with several problems due to the management of process residues. A typical solution is the composting phase for agronomic uses or for horticulture. Compost generally has a low density and can take up a great deal of storage volume, so its densification would help to reduce the required storage capacity. In addition, a danger represented by handling compost is the dispersion of dust, which can potentially carry pathogens and toxic organic substances. For this reason, the regional project - RI.MA.CO -, funded by PSR Calabria 2014- 2021 (Calabria's Rural Development Programme) under Project Action 16.2: “*Support for pilot projects and the development of new products, practices, processes and technologies in the agri-food and forestry sector*”, has been aimed to solve several problems in the management of biochar and olive oil residues. In particular, the composting process has been improved with the addition of biochar as a co-compost material. The tests were *i*) to produce compost pellets using biochar in different formulations and *ii*) to observe the quality of different biochar pellets mixed with organic compost with respect to several factors that affect handling, storage, and distribution. The result of this study could be introduced to the actual knowledge to expand and improve techniques of management of residues of the olive-oil extraction process and biochar.



Pruning Combustion and Relative Emissions Sampling for Energy Recovery

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Keywords. Biomass, Pruning, Combustion, Emissions, Energy

Abstract. In Italy, large quantities of lignocellulosic biomass are obtained from pruning operations carried out in fruit plantations. After olive, citrus and grapevine, already treated in other studies, plums are another source of great amounts of prunings every year. The most common practice to eliminate this type of residue is the open burning, carried out directly on the field by farmers, without any emissions control or energy recovery. For these reasons the need of studies able to understand the real energy potential of pruning reuse in combustion plants and the relative emissions produced is rising.

Biomass energy is carbon neutral if growing the biomass removes as much CO₂ as is emitted into the atmosphere from its combustion. Biomass energy is carbon neutral only if the net life-cycle emissions are zero. Since many inputs today are forcing humanity to move forward through renewable resource utilization, the great availability of such lignocellulosic pruning, can really represent an alternative from the energetic point of view, that can be spread to all the farms with such byproducts in their production chain.

In this context combustion trials with plume woodchip were conducted in a 80 kW D'Alessandro GS/GSA boiler with the aim of characterize the biomass and the micropollutant emissions from combustion. The physicochemical properties were studied to determine their influence on combustion emissions. Biomass characterization measurements were conducted in laboratory and subsequently carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂), nitrogen oxides (NO_x), sulfur dioxide (SO₂), and particulate matter (PM) emissions were evaluated during combustion. Due to the relative high humidity (23%) of the input biomass, the combustion process produced high CO emissions, confirming the necessity to dry the biomass and make it more suitable as possible for energy conversion processes. For NO_x, SO₂ and PM the values remain under the limits imposed by the regulations in force.



Thermochemical Behavior and Gas Emission analyses of Olive pomace

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Keywords. TG-GC/MS, Biomass waste, Olive pomace, Thermochemical conversion process, emission

Abstract. Olive oil sector is an important food industry in Mediterranean countries hence large quantities of waste residue are generated as pruning, pomace, pomace oil, and vegetation water, that represents a relevant pollution problem for the industry and oil farms because of their environmental impacts, when not properly treated. For this reason, olive waste disposal is subjected to regulatory limitation, and have additional costs for treatment operations. Therefore, characterizing this residue allows knowing and foreseeing the best strategy to enhance them without causing damage to the environment.

The proposed work concern the behaviour study of olive pomace during the thermal decomposition process coupled to the evaluation of emission profile and volatile products. After characterization, the sample waste was studied by thermogravimetric analysis by TGA/DSC to simulate thermochemical processes, and by GC-MS to investigate the composition of the emissions produced as CO, CO₂, N₂, H₂, CH₄, O₂ and VOC. The experiments of combustion, gasification, and pyrolysis of olive pomace, were performed under a nitrogen atmosphere at different heating rates.

The results showed that the olive pomace had a low ash content, a high carbon content, low moisture and had a good potential, useful as bio-product for energy conversion to its high volatile matter content and the high heating value. The thermal behavior was successfully mostly for combustion process also for low CO, CO₂, and CH₄, emissions.

Olive pomace was considered a sustainable and eco-friendly biofuels with good characteristics for conversion in boilers to solve problem of management, impacts on the environment and economy field.



Towards new sources of renewable energy: Agro-photovoltaic

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Keywords. “agro-photovoltaic”, “green deal”, “renewable energy”, “agriculture”, “energetic policy”

Abstract.

European and international policies, such as the Green New Deal and the 2030 Agenda, have pushed member countries to increase the production of renewable and clean energy in their territories. Agro-photovoltaic systems are a strategic and innovative approach to combine solar photovoltaic (PV) with agricultural production and for the recovery of marginal areas.

The Italian National Recovery and Resilience Plan (PNRR) has allocated over 5 billion euros to this technology, encouraging public and private entities to make this type of technological investment. Agro-photovoltaics will guarantee a series of advantages starting from the optimization of the harvest and livestock production, up to the production of clean energy, with a consequent increase in profitability and employment.

The research carried out will aim to provide agricultural entrepreneurs with more information about the crops to choose, the economic advantages deriving from agro-photovoltaics, the safety and health of operators and the main mechanization solutions of the trackers. It is indeed necessary understanding the factors that act on the choice of crop and/or farming system according to the plant design of the photovoltaic system, as today the investment of an agro-photovoltaics system is very expensive if three main variables are not considered: i) type of panel to be inserted (height from the ground, characteristics, tracker, etc.); ii) type of crop to be used including sustainable mechanization and suitable for design and maintenance and phytosanitary treatments; iii) authorizations and environmental regulations to be respected in order to proceed correctly with the installation of the panels.



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“Biosystems Engineering towards the Green Deal”

Improving the resilience of agriculture, forestry and food systems in the post-Covid era

End of Waste solutions for circular economy value chains in agriculture: a review

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Keywords. “Circular economy”, “value chain”, “value retention”, “bioeconomy”, “green new deal”.

Abstract. Circular economy aims to decouple growth from consumption of raw materials and achieve sustainable competitiveness through broader management frameworks. To reduce the production of waste and ensure better and more efficient management of the same, the European Union (EU) issued in 2018 a new circular economy package made of four legislative proposals. The package sets ambitious goals for EU, like recycling at least 55% of municipal waste by 2025, 60% by 2030 and 65% by 2035. Another important target requires every member state to reach a 65% recycling rate for packaging waste by 2025 and 70% by 2030. Furthermore, to mark the difference from linear economy, new directives aim to reduce landfill disposal to 10% or less of the total amount of municipal waste generated in every country by 2035. Given such a legislative framework, proper paradigms have therefore been shaped accordingly in order to prevent waste production and focus on life cycle assessments (LCAs), looking for shorter value chains.

Value retention of agricultural by-products represents a great opportunity for many farming businesses, leading to innovative solutions for material recovery and sustainable energy production. This research aims to review the most important scientific game-changers which might lead to a feasible scale-up for newer technology: innovations on biofuels, cost-efficient fuel production processes, fertilizers, animal nutrients, wastewater treatments, bioplastics are covered by the state-of-the-art analysis. Additional focus has also been put on integrated approaches for phytoremediation both for market-making solutions of contaminated areas and the creation of renewable energy value chains.

As a result, a taxonomy classification of newer value chains for circular economy has been proposed and analyses of the most promising innovations have been carried out.



Innovation and optimization of the steam distillation process

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Keywords. Steam distillation, optimization, process, yield, bioactive compounds

Abstract.

Steam distillation is a particular type of distillation. It is the traditional method used for the extraction of bioactive compounds from natural sources such as essential oil from plants. Currently, in the contest of scientific research, steam distillation is considered an ancient method to use and often, it is only used to compare with other emerging extraction. However, steam distillation presents some advantages it has over other technologies such as, for example, the simplicity of execution, the relatively low cost of installation, generates solvent-free products and by-products, no need for further separation of final products, extensive methodology know-how is available, and has a wide application on an industrial scale. On the other side, the main disadvantages are the long extraction times, the consumption of energy and sometimes of raw material. Therefore, in this research the steam distillation process was studied and deepened the overall aim to optimize and innovate the whole process. Two main themes were addressed. The first concerned the optimization of the process to minimize consumption and maximize the yield of the essential oil. Two studies were conducted focused on the investigation of the factors affecting the yield of essential oil and, on the development the application of a photoionization detector for monitoring and controlling of the different products in several phases of the distillation process. The second concerned the innovation the process, understood as the possibility of expanding its field of application as a sustainable method for the recovery of bioactive compounds with high added value from the waste of some agri-food industries. Thus, it was possible to establish the best operating conditions to extract the maximum yield of rosemary essential oil. That is, with the steam distillation method for an extraction duration of 120 min. Furthermore, it was possible to develop the application of a photoionization detector (PID) that was able to capture different signals from different varieties of rosemary plants, and a sort of 'fingerprint' for each varieties used was obtained. Thus, it was possible to distinguish different varieties of rosemary plants entering in the steam distillation process. At the end, steam distillation was applied as an alternative and sustainable method for the recovery of bioactive compounds with high added value from the waste of some agri-food industries. It was possible to obtained two fractions. One richer in volatile compounds and another richer in bioactive compounds such as phenolic compounds.



A pilot system to replace fossil energy with renewable sources in pig barns

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Keywords. Renewable energy, Livestock barn, Defossilising agriculture, Energy efficiency.

Abstract. The study was developed within the innovation project RES4LIVE “Energy Smart Livestock Farming towards Zero Fossil Fuel Consumption”, running in the period 2020-2024 under the call “Defossilising agriculture – solutions and pathways for fossil-energy-free farming” of the European program Horizon 2020

Fossil fuel use in farming has negative effects as a major source of greenhouse gas (GHG) emissions, with significant contributions to global climate change. One of the most energy-consuming sectors of agriculture is intensive livestock that is mainly based on fossil fuel use. Both electricity and thermal energy are required to cover strongly diversified energy demand, such as cooling-heating of the indoor livestock buildings environment, powering equipment, lighting and ventilation systems. With declining costs and improvement of reliability and performance of key renewable energy sources (RES) technologies, the opportunities for farmers to engage in RES production are increasing. The objective of RES4LIVE is to develop integrated, cost-effective and case-sensitive RES solutions towards achieving fossil-free livestock farming. To that end, the project adapts and tests promising RES technologies in energy-intensive livestock farming for greatly reducing the fossil energy that is the main source to cover the energy demand. Dedicated, optimal designs combined with energy efficiency and other solutions are proposed, demonstrated in pilot farms, and evaluated technically, economically, environmentally, and socially.

The pilot case presented in this research is a swine farm located in Modena province (northern Italy), rearing 500 sows and 2500 weaners. The de-fossilization project focuses on the nursery barn and consists in the development and installation of an integrated RES system combining a photovoltaic-thermal plant, a geothermal storage, and a modular heat pump. A smart control system was also designed to be installed for indoor environment monitoring and energy management.

The project is presented, and the results of the design phase are reported. The results highlight that the energy demand of a livestock farm can be met by a mix of RES properly designed, which takes advantage of the renewable resources available in the farm context.



Use of Biochar as a slurry floating cover: limitation and perspective

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Keywords. Biochar, manure storage, ammonia emissions, pyrolysis, mitigation strategies

Abstract.

During manure storage, gaseous emissions, especially ammonia (NH₃), play an important role in the environmental impact related to the livestock farm. In this context, the most implemented mitigation strategy is to cover the surface of the manure storage tank with different materials, such as straw, saw-dust, clay, oil. Generally, the permeable floating covers limit the gas transfer into the atmosphere acting as a barrier. A common issue related to the covers is the cost and the maintenance of their action as time goes by. Quite recently, there has been a growing interest in biochar cover application on storage tanks, because of its hydrophobicity and adsorption capacity. This paper explores the possibility of biochar use as a floating cover to reduce the NH₃ emission from manure storage, focusing on the mechanism leading the adsorption and the operative aspects as well as the costs related to the biochar utilization. To this purpose, three different trials were carried out in a climate-controlled room, measuring the NH₃ emissions and manure pH and varying biochar application methods and biochar characteristics. After all the tests, a desorption test of the ammoniacal N adsorbed during the manure storage tests by the biochar, was performed. Results show that biochar is a promising floating cover for manure storage, which reduces emissions acting as a physical barrier. Unfortunately, its cost expressed as € m⁻² is still important. A possible way to make biochar interesting also from the investment point of view is reducing the application cost, mainly cutting the cost related to the feedstocks. When the biochar layer is floating and compact, it also helps to reduce 78% NH₃ released into the atmosphere with 2 cm layer thickness, since it introduces an additional resistance to the gas transfer. This aspect is even more impacting than the NH₃ adsorption in the NH₃ emissions reduction. Moreover, biochar physical and chemical characteristics could be affected by the pyrolysis conditions, such as temperature. Biochar obtained at a lower temperature (<300°C) proved to be more hydrophobic and so more durable applied as floating cover.



Intermittent drying of walnuts: evaluations of warm air consumption on a thin layer

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Keywords. Drying, Heat use efficiency, In-shell walnuts, Shelled walnuts, Sustainability

Abstract. Walnuts trade standards require a maximum moisture of the 8% (w/w) to protect the commercialized fruits during their shelf-life. At harvest walnuts moisture usually exceed that threshold and consequently the fruits have to be dried. Dryers use warm air at 38-40°C to remove the water from walnuts. During drying, the water migrates by diffusion from the inner to the outer parts of the fruits before its transfer to the warm air. However, the diffusion phenomena are slow and only a small amount of water is actually in contact with the warm air flow, resulting in a poor efficiency of the use of the heat in the warm air. The intermittent drying was developed with the aim of improve the efficiency in the use of heat. It alternates periods when warm air is driven to fruits, with tempering periods allowing the water to diffuse to the fruit surface. The aim of the work is to test if the intermittency in walnuts drying could provide advantages in the use of warm air and quantify them.

Two trials were carried out al laboratory scale. In trial1 two different batches of in-shell walnuts were dried continuously, and at two different frequencies of intermittency (i.e., 30 min and 60 min). In trial2, two batches of walnuts were dried continuously and with 30 min intermittency as in-shell and shelled walnuts, for a total of 4 treatments in each replicate. Walnuts were dried at 38 °C in thin layers in both trials. Dring kinetics were followed by monitoring the weight loss of the fruits up to the 8 % (w/w) moisture as required by the trade standard. In trial1 the walnuts continuously dried were the faster to reach the 8% humidity. However, in the 2 intermittent drying methods the heated air was used for the 50% of the time. Thus, intermittent drying allowed to decrease the use of heated air. The more pronounced decrease was found in 30 min intermittent drying, reducing the use of heat air of the 30%, while a reduction of the 25% was achieved with 60 min intermittency. Trial2 confirmed the results obtained in trial1 for in-shell walnuts. Moreover, the continuously heated walnut batches were the faster to reach the commercial humidity, but the 30 min intermittency allowed to save the 32% of heated air. Considering shelled walnuts, continuously dried fruits were the faster to reach the commercial moisture, and intermittent drying allowed to save the 36% of time using heat air.

In conclusion, intermittency in walnuts drying could decrease the use of heat air of the process, and consequently it could improve process sustainability, by decreasing the use of warm air of roughly the 30-35%. Further improvement in the process sustainability could be achieved through the optimization of the intermittency conditions.



Extraction of Olive Oil Assisted by Pulsed Electric Fields (PEF)

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Keywords. PEF, electric field, yield, specific energy, olive oil quality

Abstract.

In this paper a prototype for the extraction of Olive Oil Assisted by Pulsed Electric Fields (PEF) has been developed and its implementation in an industrial olive oil mill has been followed. In particular, the results of experimental tests carried out on this plant are shown. The aim was to analyze the real-scale process, in order to evaluate the differences between the studied case and the traditional process.

The impact of the use of pulsed electric field (PEF) technology on olive oil production has been evaluated both in terms of extraction yield and chemical parameters linked to the olive oil quality. Moreover, industrial feasibility, process variables, design, and operational parameters are evaluated for the industrial olive oil plant processing.

PEF prototype system used during the tests is a semiconductor based positive Marx Modulator design with state-of-the-art semiconductor technology projected for operation with resistive and capacitive type loads, with almost square wave voltage repetitive pulses. Continuous treatment chambers is a DIN40 with three collinear electrode.

Experimental tests were carried out by treating the olive paste continuously with pulsed electric fields (electric field 1.5-20.0 kV/cm, frequency 5.0-25.0 Hz, pulse 2.0-20.0 μ s and specific energy 0.4-1.7 kJ/kg) comparing them with tests without the use of electric fields.

No inherent problems with regard to the availability of the prototype was observed, showed a number of advantages, such as the ease of positioning and installation. Thus, the prototype was readily connected between the crusher and the malaxer machine in an industrial plant. The system, implemented on an industrial olive oil extraction plant, was flexible and technically feasible.



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PEF treatment to the olive paste significantly increased the extraction yield, compared the control. In addition no significant differences were found on the legal parameters of the olive oil, while some differences on the phenolic and volatile component were found.



Statistical Control of the Quality of Decaners Used for the Continuous Virgin Olive Oil Extraction

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Keywords. Two-phase Decanter, Vibrations, Virgin Olive Oil Extraction, Rotation Speed.

Abstract. The most immediate solution to improve the productivity of a decanter for continuous virgin olive oil extraction is to increase the rotation speed of the bowl. Indeed, by increasing the rotation speed, the separation force increases, thus allowing to improve the flow rate of treated pasta keeping constant all other parameters.

The aim of this research was to study the operation of a two-phase decanter focusing on its vibrations, by appropriately varying the rotation regime. It was set up a study of a diagnostic program by means of specific Quality Control Charts. The quality control was carried out on fourteen AMENDUNI REX-250 two-phase decaners; the operating capacity is in the range 30.0-80.0 q/h with an installed power of 45 kW, according to ISO 20816-1: 2016 standards. The machines were studied at rotational speeds of 3000 rpm, 2900 rpm, and 2800 rpm. The tested decaners provided the best performance at 3000 rpm. The machines showing significant anomalies (spurious vibrations) at the maximum rotation speed were those balanced on lower rotation speeds. This practice is usual in the extraction of virgin oil to avoid the risk of paste overheating. It was possible to identify the most stressed sections of the machines at all speeds. These were the closest to the engine and on the left side of the basin (the side where the machine is set in rotation by the duct branch of the belt transmission). The possible causes of the anomalies are: unbalanced bowl due to errors during the assembly phase, incorrect assembly of the bearings and, more rarely, defects and damages in the raceways, balls or rollers. The process carried out by the manufacturing company was adequately monitored, in accordance with current technical standards. However, the control chart tool seems particularly suitable to the production process. Indeed, it showed that through Root Mean Square (RMS) trend, that was easy to track by cyclically and preventively monitoring these values, it would be predicted the behavior of the machine over time and, possibly, increased its "expected useful life". This tool, properly managed, could be a solution to any breakdowns which, during the olive oil season, generate critical deficiency costs and can affect revenues of an oil mill for a whole year.



Technological solutions for implementing sustainable cereal-based value-chains in high mountain areas

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Keywords. Mountain agriculture, minimum tillage, stripper header, cable traction

Abstract. The Brotweg project ("*The Bread path for mountain areas*") aimed to develop radical innovations for cereal cultivation in extreme mountain contexts, on land with very high slopes (even more than 80%) where cereal cultivation has so far been precluded to any form of mechanisation, resulting in abandonment due to high labour demands. The need to identify new development models for mountain agriculture, complementary to the currently prevailing zootechnical ones, has brought the alternative of the "*cereal chain*" (cereal-flour-bread) back to the forefront, compared to the "*forage chain*" (hay-milk-cheese) for the considerable advantages that the former entails in terms of reduced labour and annual workload, investments and environmental impact. However, the implementation of the cereal chain required the prior resolution of the main obstacles to the adoption of suitable technological solutions for field mechanisation and conservation/management in small farms. The Brotweg project therefore envisaged the development of prototypes to be used for the followings: a) cultivation, with new machines suitable for the steep slopes in the most critical operations (sowing and harvesting); b) post-harvesting and storage of the grain directly at the farm; c) processing, with micro-bakery lines. The whole research was based on integrated evaluations capable of taking into account economic and operational performance, safety conditions for operators, control of erosive phenomena and protection of the landscape, and levels of sustainability of the entire chain.

The project activities firstly have led to the prototype development of machines for the integral mechanisation of field operations, based on a tool-carrying tractor already equipped with cable traction (using an on-board winch) to allow transit and workability even in the most extreme conditions. In particular: a) for sowing, combined minimum tillage solutions were developed (rotary harrow + seed drill on hard ground) able to guarantee germination activity without running the risk of erosion typical of conventional tillage and - above all - without compromising the vitality of the herbaceous essences of existing meadows, while limiting their vigour in competition with cereal crops; b) for harvesting, a stripper header was developed, to allow easier management of the biomass on steep terrain and in the subsequent transport phases.

The entire post-harvest and conservation line was adapted from existing architectural structures to avoid the negative visual impact of external plant structures. Most of the energy sources used were of renewable origin. The paper reports the results of the agronomic and operational performance achieved in two production seasons.



Open field Geometric primitives' representation by a 2D low-cost LIDAR for vineyard sprayer application under different conditions.

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Keywords. variable rate sprayer, verdicchio, mobile laser scanner,

Abstract.

Light Detection and Ranging (LIDAR) is the application of Laser to distance measurement of objects. A pulsed light or a continuous wave defines distance through two different principles; Time of Flight (TOF) and Phase-Shift (PS). Recently, 2D and 3D TOF LIDARs found application in the agricultural field for vegetation analysis and distribution of agricultural input, intending to optimize the quantity of distributed active principle. In standard distribution systems around 30 - 50% of pesticides can be lost by drift or deposition on non-target areas. The most used devices are TLS (Terrestrial Laser Scanner), particularly the MTLs (Mobile TLS). LIDAR is considered to be potentially more accurate in point distance definition and more suitable to determine small objects or vegetation gaps with respect to Sonar (the other device commonly applied for the same purposes). The present study aims to test a 2D low-cost LIDAR-based real-time sprayer for vineyards by positioning specific targets and their subsequent recognition in the point cloud analysis. The test was conducted in an open field with different light conditions and speeds. Field tests were conducted in Arcevia municipality, Marche region, Italy (43.517325, 12.966688 – coordinates system WGS84). The prototype used is composed of 4 different interconnected devices. Field trial consists of recognizing circular (10 to 100 cm of diameter) and square (10 to 30 cm side) targets. The targets, 56 in total, are divided into 28 white (to ensure maximum laser reflectance) and 28 green (to simulate the leaves colour). The outward and return speeds varied between 3 and 8 km/h. In addition, the same device was used to define two-dimensional and three-dimensional structures in comparison. The results show that the system can identify objects or gaps in vegetation, even on small surfaces, and with speeds comparable to those used to apply pesticides. Comparing the two-dimensional and three-dimensional targets represented in the figure shows how the device can even recognize three dimensions.



Deep Learning Approach To In-Situ Sustainable Weed Management (SSWM)

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Keywords. UAV, Deep Learning, SSWM, weeds.

Abstract. Biotic threats such as insects, weeds, fungi, viruses, and bacteria can broadly affect crop yield and quality. Among these, weeds are the most impacting problem causing remarkable yield loss worldwide. The most characterized effect of weeds is competition for resources such as light, water, space, and nutrients [1]. Precision agriculture can be effectively applied to weed management using Unmanned Aerial Vehicles (UAV) to gather and process data [1] as well as the application of artificial intelligence to weed control. This work proposes a deep learning approach for selective weed recognition in real time from aerial images that enables targeted treatment of certain weeds, using artificial intelligence to select in the field and in real time the weeds to be treated and/or removed and those to be kept in the field. The developed deep learning algorithm will be able to be used on self-driving rovers (UTVs) for automatic in-field weed treatment according to site-specific weed management (SSWM) principles. The method shows good accuracy in recognizing and discerning the various weeds in the field, as shown in an example in Figure 1 where we can see how the algorithm recognizes and classifies weeds by separating them from the crop (wheat). Further studies are underway to improve the algorithm by training it to the different phenological states of the weeds as well as increasing the training dataset, also expanding it with the spectral signatures of the weeds of interest, through acquisition of multispectral images.



Figure 1 - Weeds classification through Deep Learning approach

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Multispectral UAV-based monitoring of behavior of different wheat and barley varieties

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Keywords. Remote Sensing (RS), Precision Agriculture (PA), Crops Monitoring, Sustainable Cultivation, Cereals.

Abstract. Multispectral (MS) remote sensing (RS) is a powerful tool for crops monitoring in precision agriculture (PA) framework. Due to the high accuracy level requested in this application, unmanned aerial vehicles (UAVs) are the most suitable choice for MS surveys. UAVs allow monitoring crops obtaining data in very high resolution (VHR) and the possibility to have daily-based surveys.

Cereals are the most widely cultivated species in the Mediterranean environment, supporting food chains for bread and pasta as well as livestock production. In these agroecosystems, the development of precision farming techniques is essential to make production more efficient and sustainable, also in order to secure supplies despite volatile food commodity prices characteristic of this post-Covid19 period.

The main object of this study was monitoring the behaviour of different wheat and barley varieties, taking into account their spectral aspects and in situ measurements of plant height and biomass nitrogen concentration. For this purpose, a field experiment, laid out as a completely randomized block design with three replications for wheat and four for barley, was conducted in San Marco Argentano (CS, Calabria - Italy). In particular, the spectral response of thirty wheat and nineteen barley varieties was compared during different stages of plant growth. UAV surveys were conducted by DJI Phantom 4 Multispectral equipped with a 6 bands sensor (RGB, Blue, Green, Red, RedEdge and NIR), obtaining vigour maps. Different vegetation indices (VIs) were tested to monitor differences between varieties after a geographical object-based image classification (GEOBIA).

This work presents the preliminary methodological tests and results of a still ongoing field monitoring.



A convenient remote sensing approach for the dry biomass estimation of the trees in urban areas

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Keywords. Allometric model, AGB estimation, Urban tree, Remote sensing.

Abstract. The severe intensification of atmospheric carbon recognizes the importance of urban tree contributions considering a sustainable urban green planning and management system. Explicit and timely information on urban tree dendrometry and its roles in Above Ground Biomass (AGB) estimation are essential for policymakers to take immediate actions to recover the effects of deforestation and their worsening outcomes. This study will help the prospective research in the case of a non-destructive AGB estimation for the dominant tree species in the cities based on Remote Sensing (RS) data sources. In this study, a detailed methodology on the urban tree AGB calibration was done for two urban areas one of which was in Sassuolo (MO), a smaller city in Italy [1]. The other one was conducted in the capital region of Belgium (Brussels). In Sassuolo, AGB estimation was done utilizing the WV3 image data for a smaller study area of 22 plots (10m×10m each) where the 7 plots were utilized to validate the results. Later in Brussels, the approach was performed with the WV3 image data for a larger study area of 75 plots (10m×10m each) where 20 plots were utilized for the validation of the outcomes [2]. The field estimations of each plot were done utilizing an allometric model based on the field data on tree dendrometry i.e., Height (H) and Diameter at Breast Height (DBH). The results were found quite evident for both cities which did approve the approach as an efficient and convenient way of AGB computation. No doubt, this study will assist the city planners to understand and decide the applicability of remote sensing data sources based on their availability and the level of expediency, ensuring a sustainable urban green management system.

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Remote and proximal sensing surveys on olive tree

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Keywords. Hyperspectral data, multispectral data, UAV.

Abstract.

Spectral data acquisition in olive orchards can be performed applying different technologies, essentially depending on the camera type (multispectral or hyperspectral) and acquisition platform used. The main platforms include Unmanned Aerial Vehicles (UAVs) and the one used in the inter-row. UAVs are often associated with multispectral cameras, while acquisition platforms in the inter-row (side-view) are increasingly associated with spectroradiometers. The aim of the study was to compare hyperspectral data obtained from a side-view spectroradiometer to the multispectral data acquired from a UAV platform in an olive grove. A spectroradiometer with a spectral range of 325 - 1075 nm was used for the hyperspectral data acquisition. The surveys were manually carried out on the four exposures (North, South, East and West). The Phantom 4 Multispectral platform was used for multispectral acquisition at 50 m a.g.l. with a 6-band multispectral camera. The spectral information was compared on the four exposures using the three main vegetation indices mainly used in olive trees: NDVI (Normalized Difference Vegetation Index), MSAVI (Modified Soil Adjusted Vegetation Index) and NDRE (Normalized Difference Red-Edge Index). The results showed very good correlations between the two data sources. In addition, the hyperspectral data allowed to better discriminate the spectral differences of the different canopy portions, despite the considerable presence of noise and uncertainty depending on the exposure and wavelengths used. UAV images appeared to have higher linearity allowing to better describe the average health status of the whole plant.



Using a UAV-mounted multispectral camera for assessing spatial variability in vineyard

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Keywords. Remote sensing, Precision viticulture, Spectral indices, grape yield

Abstract.

Accurate, timely and non-destructive forecasting of vineyard production on a field scale is essential to achieve a good production and quality outcome. Remote sensing may be an effective and practical monitoring tool, as data from on-board of Unmanned Aerial Vehicles (UAVs) sensors can measure vegetative and reproductive growth, and thus directly or indirectly detect variability in quality parameters. The objective of this study was to assess the variability of a wine grape vineyard located in southern Italy, using a multicopter UAV equipped with a near-infrared sensitive digital camera. The data were collected in the 2021 growing season, the flight mission was carried out one week before harvest (September). At harvest, the yield per plant [kg] (N=84) and the average weight of the bunches [g] were recorded. Laboratory analyses were carried out on the musts obtained in order to assess some technological parameters (Brix°; Total Acidity [g/l]). Normalized difference vegetation index (NDVI) and green normalized difference vegetation index (GNDVI) were calculated to find the best correlation with production and quality parameters, using orthomosaic image of UAV. Pearson's correlation coefficient (r) showed a significant and positive correlation between vegetation indices and yield as well as bunch weight, with the strongest relationship observed between GNDVI and yield per plant ($r = 0.84$; $P < 0.01$). However, no significant positive correlation was found between the vegetation indices examined and the quality parameters. The results highlighted the applicability of remote sensing to monitor the vine production variability through vegetation indices.



Stand-alone LED sensors for future field monitoring of grape (*Vitis vinifera* L.) ripeness

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Keywords. IoT, information technology, sensors, optical stand-alone devices, grape maturation monitoring.

Abstract.

In the winemaking industry, the grape maturation control is a complex process that is critical to produce high-quality wines, but currently, maturation control is cumbersome and inefficient. This inefficient control of the maturation is related to a reduced value of the wine. This work aims to develop of a fully integrated stand-alone optical devices for grape quality monitoring directly in field. Ergo, during the sampling campaign 2019 a first prototype version of a fully integrated optical device was developed by INL following a “stripe” design in which the spectrometric components were mounted on a long, flexible substrate which can be placed onto or inside the grape bunch. The multiple spectrometers were placed along the stripe enabling simultaneous measurements at different parts of the grape bunch to have more representative information of the entire bunch. Four optical bands associated to the evolution of the maturation parameters of the grapes such as the development of anthocyanins and sugars, chlorophyll degradation, and decrease of water content were integrated. Four light-emitting diodes (LEDs) in the Vis and SW-NIR range were used for illumination of the grape. Placed close to these, but optically isolated using an opaque barrier, four photodiodes (with an active area of 520 × 520 μm²) assembled with spectral filters to allow intensity measurements at the desired wavelengths have been used. Four PLS models were developed for the prediction of the total solids soluble and for the potential alcohol (R^2 about 0.90 and RMSEP of 2.22 and 1.54, respectively). A very promising model was also obtained concerning the prediction of the titratable acidity (R^2 of 0.93 and RMSEP of 1.39) while a pH predictive model (using 4 LVs) was developed showing a lower performance than previous parameters (R^2 of 0.76 and RMSEP 0.15) but still with potential for being used with further improvements.



Real-time Measurements of Gaseous and Particulate Emissions from Livestock Buildings and Manure Stores with Novel UAV-based System

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Keywords. Greenhouse gases, sustainable livestock farming, drones, dairy farming

Abstract. In the framework of the European environmental policies towards a green transition, the adoption of strategies improving the sustainability of the agricultural system is a key element. When planning actions requiring efforts and investment for the farm enterprise, ensuring the efficacy of these measures becomes crucial. In a perspective of adaptive management where a continuous monitoring process is implemented to meet the goal of environmental and economic sustainability of food productions, new tools need to be developed to provide cost-effective and real time measurements. In this context, a novel system based on Unmanned Aerial Vehicles (UAVs) and on prototypical ground stations equipped with low-cost sensors was designed and developed. The system is based on a flexible architecture which can be adapted to a variety of operational fields and is organized in four levels: 1) sensors; 2) data transmission; 3) data collection, storage and analysis; 4) data presentation. A portable measurement unit was developed to be employed both at ground and as payload on a quadcopter drone. The unit is provided with a sensor board to monitor environmental conditions, gaseous pollutants and particulate matter. The whole system is designed to measure gaseous and particulate concentrations both at specific sites inside or around housing facilities and near known emission sources as manure or feed storage buildings, with the aim to detect emission hotspots and to provide real-time graphic alerts by means of a web-app once preset concentration threshold are exceeded. A prototype version of the system was tested in a commercial dairy farm to assess the feasibility of the project. The results obtained during the field tests confirmed that the designed system can be implemented at farm level, given that further research is required to validate field measurements with reference instruments and techniques.



Affordable soil moisture detectors development

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Keywords. Soil, moisture, sensor, electric technique.

Abstract. Monitoring water content in soil is very important for farmers to define soil conditions and irrigation affecting agricultural efficiency. Cheap and reliable instruments are essential. Traditional drying methods are destructive and time-consuming, not applicable directly in the field. Analysis of the electromagnetic wave's interaction is a way for water quantification in soil. For many years several sensors were developed, but some limits were encountered, such as interferences due to soil constituents and cost not always affordable. In this way, two different instrumental chains were developed based on the response of the soil to the electromagnetic wave in the frequency range from 50 kHz to 3GHz.

Very low-cost components were assembled and used: a miniaturized commercial Vector Network Analyzer and two different handmade probes, a cavity antenna, and a dipole antenna. The cavity antenna should just be placed in contact with soil without being inserted in, while the dipole antenna enclosed in a plastic pipe must be inserted into the soil. Tests were conducted in laboratory conditions on silty clay loam soil with different moisture content from 5% to 28%. Good results in terms of coefficient of determination were obtained: R^2 up to 0.978 and RMSE 1.30 and R^2 up to 0.989 and RMSE 0.57 for dipole antenna (significance of coefficient, p -level<0.05). In the light of the obtained results, a validation will be performed for field moisture soils estimation. The user-friendly devices and the affordable cost can be very attractive for final users.



Potential Of NIR Spectroscopy For The Prediction Of Soluble Solids Content And Discriminating Among Different Cultivars

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Keywords. PCA, PLS, fruit quality, soluble solids content, cultivar selection.

Abstract. Strawberries, as other berries fruits, are widely produced and consumed because of their characteristic flavor, appearance and high nutritive value. Due to their richness in antioxidants, vitamins, minerals and fibre, they play an essential part in a healthy diet and are recommended on the intake of fruits and vegetables. In general, the qualitative analysis of strawberry (as of other vegetables and fruits) are performed with analytical techniques that have the advantage of being fast and repeatable, but the big disadvantage to be destructive, requiring much fruits to obtain a significant result. On the other hand, Near Infrared (NIR) spectroscopy is a rapid, low-cost and non-destructive technique. In addition, it allows to measure several quality attributes at once and it is already widely used in the sector of fresh horticultural products. One of the most important parameter for the assessment of strawberry quality and fruit harvest date is soluble solids content (SSC). This is because SSC contributes to indirect estimations of fruit maturity and quality and is also related to taste and consumer acceptability.

As a consequence, this study will investigate the rapid assessment of SSC of strawberry fruits. To this aim, four cultivars were selected and the fruits were cultivated and collected using a four completely randomized blocks as experimental design. After harvesting, all of the samples were immediately shipped to the lab and were analyzed by means of NIR spectroscopy using a Fourier Transform (FT) NIR spectrophotometer. Later, the fruits were frozen separately and after few days, analyzed for SSC. Principal Component Analysis (PCA) was applied to search for spectral differences among the cultivars and for a separation/trend according to the SSC. As last, Partial Least Squares regression (PLS) technique was computed in order to predict the SSC parameter. The results are promising and showed the possibility to use PCA as a tool for looking at the spectral similarity between different genotypes, also according to the degree of the SSC. This is particular relevant as it could speed up the process of selection and genetic improvement. In addition, this study demonstrated the feasibility to use FT-NIR technique coupled with PLS for the prediction of SSC of strawberry fruits allowing the rapid and non-destructive quality control of the product.

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Innovation in olive-growing. Proximal sensing LiDAR for tree volume estimation.

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Keywords. Olive Tree, Crown Volume, DSS, MLS, Point Cloud

Abstract. The olive tree is one of the most widespread Mediterranean plants, characterizing the historical landscape and deeply rooted in the local traditions. Indeed, among the wide variety of quality foods of the Mediterranean diet, it is possible to find olive oil. The olive tree cultivation requires specific attention and dedicated pruning techniques, which is a key issue in the tradition of olive tree cultivation. The most suitable shape for the tree crown ensures the best harvesting conditions, balanced solar radiation and a good foliage distribution. These conditions get to yield the best tradeoff between the highest quality standard of the olives and the harvested quantity. There are various cultivation forms, and each one requires experienced pruners to decide what limbs to cut, following specific techniques. At the cutting edge of the research in smart farming, LiDAR (Light Detection And Ranging) offers a promising field of innovation (Colaço *et al.*, 2017) of the pruning stages. The point cloud reconstruction of a single olive tree and the acquisition of valuable metrics are critical to innovating the harvesting methods, including creating a dedicated decision support system (DSS). The present study used the “Kaarta Stencil-2”, a Mobile Laser Scanner (MLS) technology, to rebuild and render individual olive trees by point clouds (Fig.1), supporting the pruning activity. The study area is located in central Italy, in the municipality of Cartoceto, in the Marche region, where a Geographical Indication acknowledges the oil produced. Indeed, it is a typical product and it is included in the protected designation of origin (PDO). It is possible to compute the tree’s metrics (i.e. diameters, heights, the wood volume and the crown volume). The crown volume, in particular, was calculated using two algorithms: Convex hull and Alpha shape. The aim is to understand which algorithm performs the best to assess the volume of the canopy after the intervention of a professional pruner. The volumes resulting from these algorithms have been compared with those usually measured in the field, taking crown size measurements and empirical formulas. These latter assume that the shape of the olive tree canopy is either a parabolic shape or a toroidal shape. The toroidal shape is arguably more suitable because the pruning technique applied in the detected olive tree resulted in a canopy similar to this geometric figure. By comparing the volumes obtained, it was concluded that the Convex hull algorithm provides similar volumetric assessment as that computed using the parabolic shape.



In contrast, the Alpha shape algorithm estimated a volume close to the toroidal empirical formula. The wood volume was then calculated using the Quantitative Structure Models (QSM) (Brede *et al.*, 2019) algorithm (Fig.2), which formed a hierarchical collection of cylinders to estimate the total volume after a data cleaning in the open-source software CloudCompare. These processes, if automated, can be used in the future to integrate a DSS that will assist the farmers.

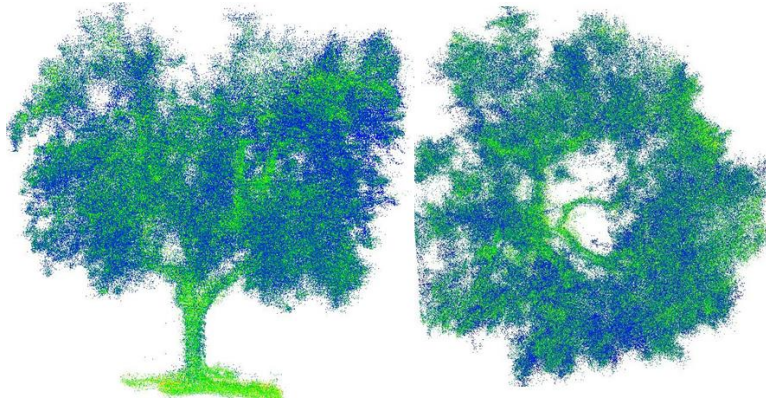


Figure 1 Frontal and nadiral view of the post-pruning olive tree sample

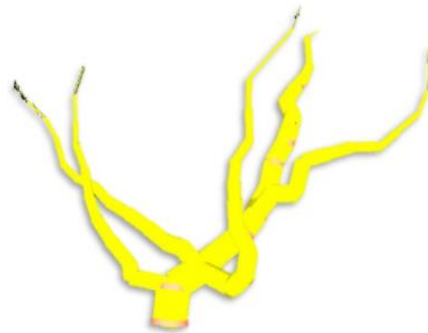


Figure 2 Tree structure reconstruction through QSM algorithm

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Optical sensors for vine water status monitoring

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Keywords. Grapevine, optical device, green technology, vis/NIR spectroscopy, chemometrics.

Abstract. The selection of resistant genetic material, the use of cover crops, and the delivery of water through irrigation are all agronomic strategies for water management in the vineyard. Indeed, irrigation is becoming an important method in various viticultural zones to support production and maintain grape quality. Precision irrigation is a viable technique for improving water management: it optimizes water delivery over time and space, boosting water use efficiency at the field scale. The introduction of innovative technology provides for increased efficiency and quality of production while simultaneously lowering environmental effect. The plant water status is the most important metric for evaluating and managing irrigation techniques.

Water potential (Ψ) has been regarded as a relevant and repeatable indicator of plant water status. Measuring water potential necessitates destructive sampling, which is labor-intensive, time-consuming and subject to operator bias. The employment of optical-based methodologies that are non-destructive and reproducible on a wide scale for entirely networked IoT device development is one of the most promising approaches to break these present methodological constraints.

This study focuses on the definition of optical specifications for the construction of cost-effective sensors. The sampling was carried out on Pinot Blanc cv. grapes: optical data was acquired on leaves. The correlation between predawn water potential (Ψ_{PD}) and moisture content was examined using Pearson's correlation analysis ($r = 0.47$ and $p\text{-value} < 0.05$), revealing a low correlation between the two metrics. The optical data (350-2500 nm) were used to create a PLS-model to estimate Ψ_{PD} (RMSEP = 0.056 MPa, $R^2 = 0.7$).

The most important wavelengths selected by VIP-scores procedure were used to calibrate another chemometric model (an RMSEP = 0.056 and an $R^2 = 0.60$). These results paved the way for the creation of more integrated optical sensors that can monitor vine water condition in the field in a distributed and autonomous fashion.



Characterization of a multispectral camera for abiotic and biotic stress detection in greenhouse

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Keywords. Integrated Pest Management, Image Analysis, Precision Agriculture, Light Conditions

Abstract. The national and international environmental regulation forces the agricultural industry to achieve a more sustainable production system. Nowadays, multispectral sensors and cameras are quite widespread in arable and fruit tree crops, while they are not commonly used in protected crops. This latter point is mainly due to structural features (i.e. columns, pallets), radiance characteristics of the greenhouse covering, which modify the incident light and the presence of an artificial light source. This study describes the application of a multispectral camera for greenhouse applications. The paper investigated the influence of different light conditions and the protocol for the detection of abiotic and biotic stress in three on-farm trials by using an RGB-NIR multispectral camera. Different light conditions were evaluated for their influence on the vegetation index calculation. Images were acquired on white and black calibrated target with natural light, sodium lamps, and in a darkroom equipped with RGB-NIR light-emitting diodes (LEDs), considered a reference. The suitability of the system to identify abiotic stress and vegetation growth were evaluated on a randomized block (5x5) trial of Geranium (*Pelargonium spp.*). Puncture, cut, loss of a cutting and double irrigation damages were simulated on 250 plants and then were monitored for 30 days. LAI and VARI indexes showed to be suitable to highlight the different growth stages of Geranium plants. Finally, biotic stresses were evaluated by acquiring images on *Mandevilla* and *Euphorbia pulcherrima* infested by *Bemisia tabaci*. Significant differences between infested and non-infested plants were found by using EVI and VARI indexes. According to these results, multispectral cameras can be profitably used in the greenhouse environment by I) correcting the incident light, II) combining pixel classification with spectral analysis and, III) identifying suitable indexes for each biotic and abiotic symptoms.



Study of Spray Swath in Relation to Canopy Deposition during Vineyard UAV Spray Applications

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Keywords. Spray application, Aerial drones, Swath, Precision agriculture, Ground losses

Abstract. In the last ten years, unmanned aerial vehicles (UAVs) have been gained a raising interest for spray applications in 3D crops such as vineyards. For traditional UAV broadcast spray applications, that foresee flying perpendicular to the row orientation, the preliminary study of spray swath is a key factor. Indeed, an optimised fly path planned considering proper spray swath overlaps allows maximising the canopy spray deposition along the rows avoiding under- or over-spray situations. Achieving this goal is extremely challenging; furthermore, off-target spray losses, as well as inadequate spray canopy deposition, should be avoided as much as possible to safeguard the environment, food safety and human health.

Our research work was focused on the study of the relationships between the spray swath, the overlapping of different passes, and the canopy deposition during vineyard UAV spray applications. Six configurations were tested in an experimental vineyard (cv. Barbera), based on the combination of different UAV flight modes (1way and 2way broadcast), nozzle type (conventional, 110° 03 and 110° 015), and UAV cruise speeds (1 and 3 m·s⁻¹). Three arrays of thirteen Petri dishes having a 140 mm diameter were arranged 20 m outside the vineyard to evaluate the spray swath. The three arrays of Petri dishes were located 5 m apart and placed perpendicular to the UAV flight path, while within each array, the 13 Petri dishes were placed 0.5 m distant from each other. Measurements of spray deposition in the canopy were performed at three locations along the UAV flight path, and at three heights and three depths per vine canopy, using filter paper discs of 120 mm diameter (90 g·m⁻²). Petri dishes were also placed in the middle of each inter-row to measure ground losses. To evaluate the spray swath effect on canopy deposition and ground losses, two additional sampling points were located at ± 1.6 m apart to UAV flight path (centre line) for each replicate using the same type of collectors (filter papers and Petri dishes).

The obtained spray swath allowed to optimise the UAV flight path planning, obtaining a distance of 2 m between two successive UAV flight paths. However, deposition measured within the spray swath outside the vineyard was higher than that measured in the canopy. Noteworthy, the ground losses were much larger than the canopy deposition values.



Forestry machinery chain productivity in stands hit by the Vaia storm: first results for the Camonica Valley

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Keywords. Forestry operations, machinery chain productivity, working times.

Abstract. Estimating the productivity of forestry operations (OP) is essential to quantify both the economic costs and the environmental performances of the forestry machinery chains. This, in turn, is crucial to improve the overall sustainability of the forest-based sector. The aim of the work was to compute the productivity of a forestry machinery chain applied for wood collection in mountainous stands (1500 m asl) of *Picea Abies* L. of the Camonica Valley (Lombardy Region, Italy), damaged by the Vaia storm in October 2018.

The machinery chain was made up of the following OPs: (OP1) biomass extraction to the landing (“Full-Tree” method using a cable crane with a mobile drive station; distance: 500 m); (OP2) wood intermediate transport (from the landing to the delimiting and sectioning point using an earthmoving machine equipped with hydraulic clamp); (OP3) delimiting and sectioning into commercial assortments (the stem is separated from logging residues using a chainsaw); (OP4) stacking (roundwood and residues are separately accumulated by the machine used for OP2); (OP5) residues chipping; (OP6) loading&transport of roundwood (final destination: sawmills) and woodchips (final destination: local district heating plants). For productivity estimation, for each OP and over a period of 10 days (Autumn 2021 – Spring 2022): (i) working times (h) and (ii) extracted volume of roundwood (m³) and residues (stucked steric meters; stcm) were detected.

The working times were subdivided according to the *Comité International d’Organisation Scientifique du Travail en Agriculture* (CIOSTA) definitions, specifically adapted for forestry operations. The roundwood volume was daily computed at the end of each extraction trip using a volume calliper and a tape measure, whereas the stucked volume of residues was estimated at the end of the day using a tape measure.

The working productivity was then computed for roundwood and residues and expressed as both volume basis (m³·h⁻¹ and stcm·h⁻¹ for roundwood and residues, respectively) and mass basis (t·h⁻¹ of fresh matter; t·h⁻¹ of dry matter). Starting from these results, the average productivity of the machinery chain was calculated for each day and for the whole monitored period.

Despite being preliminary, these results are useful to understand machinery chains performances under complex and dangerous working conditions and can be used to support logging companies and forestry consortia in setting proper operations tariffs.



On the Correlation between Power Harrow Energy Requirements and Tilled Soil Aggregates Dimension

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Keywords. Power harrow, tillage operations, soil aggregates, energy consumption

Abstract. Among all the agricultural operations, tillage is the most energy-intensive operation. In literature, the energy demand of several implements was reported based on different operating conditions (working depth, tractor speed, etc.) and different chemical and physical soil properties. However, tillage operations cannot only be evaluated according to the energy consumption, but the benefit in the soil structure and the consequent agronomic benefits such as crop yield have to be considered. For example, when power harrows are used, soil cloddiness can be adjusted by varying the machinery ground speed and the angular speed of tine rotors as both control the number of tine revolutions per meter (denoted as C). The aim of this paper is to get a deeper insight into controlling the soil structure and finding a correlation with the energy requirement of the power harrow based on different setups. Field tests were conducted at the experimental farm of the University of Bologna on a 3 m working width power harrow coupled with a tractor (107 kW of rated engine power). Two different field tests were performed named Constant C trials (denoted as CC) and Variable C (denoted as VC) trials. Constant C trials were carried out to evaluate the effect of the tractor speed on soil loosening maintaining C fixed at 4 m⁻¹. Variable C trials allowed to evaluate the effect of the number of rotor revolutions per linear meter travelled by the tractor, so tests were performed varying C from 2 m⁻¹ to 13 m⁻¹. Tractor parameters such as speed, engine power, engine speed, fuel rate consumption and Power Take Off (PTO) speed were acquired during the tests through its Controlled Area Network (CAN) SAE J1939 diagnostic port with a datalogger. Moreover, the draught force and PTO torque absorbed by the power harrow were acquired with load pins and a torque meter, respectively. After harrowing, soil samples were sieved, then the granulometric parameters (Mean Weight Diameter -MWD- and Geometric Mean Diameter -GMD-) were calculated and correlated to data acquired from the tractor-power harrow system. The results show that the fuel consumption per hectare is inversely proportional with the increase of the tractor speed in the CC trials and directly proportional with the increase of C in the VC trials, as expected. Regarding the soil structure, MWD and GWD values show that finer aggregates were obtained with the increase of tractor speed in the CC trials and with the increase of C in the VC trials.



Evaluation of the efficiency of fully mechanized wood harvesting system based on fleet management system data

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Keywords. Industry 4.0. Digital forestry, FMS, telemetry, Poland

Abstract.

The European Union has been increasingly developing and implementing ambitious strategies such as the European Green Deal, EU biodiversity strategy for 2030 or the new EU forest strategy for 2030. Simultaneously, over the last few years, economy and society have been experiencing challenging changes in terms of digitization and technological advances (hardware and software) that are increasing the performance of data acquisition, processing and transmission. The implementation of the term Industry 4.0 has been shaping the discussion about how ecosystem and, more specifically, forestry can benefit from this development.

The advancement of the mechanization processes in the forestry sector have enabled to achieve higher productivity, efficiency and safety levels. The "Precision forestry" aims to evaluate the performance of these technologies and exploit modern tools to obtain more detailed information in order to improve the decision-making process. In addition, in order to have a clear idea of the work context, the availability of the data about the forest plans is necessary.

This study aims to evaluate the effective benefit of automatic data collection through the fleet management system (FMS) of two forest harvesters and two forwarders in Pine forests in Poland. The study also aims to determine how the use of a FMS can help forest companies to manage their fleet and take advantage of long-term monitoring. Focusing on performance indicators of fuel consumption and CO₂ emissions, as well as on the engine parameters, combining the StanForD data and the Can Bus data.

The exploration of data was performed following a Big Data approach, from the creation of an aggregate dataset, pre-elaboration (data cleaning, exploration, selection, etc.) using GIS



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and R software. Linear models were used to understand the influence of the StanForD and Can Bus data on the work element obtained from the automatic time study..



Autonomous Mowers: a Smart Solution for Turfgrass and Conservation Agriculture

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Keywords. Robot mowers, floor management in vineyard, living mulch management, mechanical weed control, field vegetables.

Abstract. Autonomous mowers are battery-powered automatic machines able to cut the grass without the need for a human operator. Autonomous mowers can save labour time, reduce noise when mowing, eliminate local emissions, cut in rain, reduce soil compaction due to the low weight, mow safely on slopes (up to about 70%), follow a daily mowing plan to keep the turfgrass height constant, reduce the energy consumption. The most common commercial models can mow an area from 250 m² to 5000 m² and are made for private, albeit very complex, gardens. However, the interest in the application in industrial green areas, public green areas, sport facilities and sod farms is increasing. In the latter cases, specific models are able to cut a few hectares. The working area is commonly defined by a buried electric boundary wire which works like a fence, but more advanced models can use the RTK GPS technology to set up a virtual boundary without the physical wire. The trajectories are usually linear and random, as the turning angle is random when the mower reaches the boundary or an obstacle. Models for large areas and sport turf can mow systematically using the RTK GPS technology. Autonomous mowers can also be used for weed control and cover crop management in orchards, vineyards and vegetable crops in conservation and herbicide-free farming contexts. Since 2015 the Department of Agriculture, Food and Environment (DAFE) of the University of Pisa (Italy) has been testing autonomous mowers in different scenarios like cool season and warm season turfgrass species, vineyards and vegetable crops. The first studies on Tall Fescue grass showed that a daily mowing plan of the turfgrass with the autonomous mower was able to increase the turf density and quality and decrease the primary energy consumption with respect to a weekly mowing plan with an ordinary walk-behind mower. Good results on overall turf quality and shoot density were also obtained with a prototype for low cutting height (1.2 cm) on Manila Grass. A prototype provided by Husqvarna AB (Sweden) showed a better turf quality using systematic vs random trajectories in case of very high cutting height (90 mm) in Tall Fescue grass. Promising results were also obtained in organic and conservation agriculture for cover crop and weed management in vineyard, globe artichoke, cauliflower and eggplant. In these case studies the autonomous mowers with random trajectories were able to reduce weed biomass and energy consumption compared to the ordinary strategies.



Performance Evaluation of a Computational Design Tool for Three-Point Hitch Geometry Optimization

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Keywords. Optimizer design tool, constraint minimization algorithm, Three-point hitch geometry, engineering design process.

Abstract. During tillage operations or implement maneuvering, the efficiency, comfort, safety, and operational performance of agricultural tractors are directly affected by the distribution of the dynamic loads resulting from the interaction between the implement and the soil and transmitted to the tractor chassis through the three point-hitch (TPH) attachment system. The correct design of the hitching system allows to increase tractor-implement performance during agricultural field operations. In this context, a computational design tool for TPH geometry optimization (the *Optimizer*) was recently developed by Avello Fernandez et al. [1]. The tool is based on a constrained minimization algorithm which allows to search for optimal TPH geometries that respect all the design constraints established by the ISO-730 Standard functional requirements and other design requirements while reducing the weight transfer effects on the front axle of agricultural wheeled tractors.

Based on the aforementioned research [1], the present study is focused on testing the robustness and potentialities of the Optimizer as well as its feasibility for practical applications. In order to do that, a set of four different commercially available TPH geometries were used as starting points for the Optimizer. Results show that even though starting from different TPH configurations, the tool converges to similar optimized geometries that reduce the weight transfer effects at the tractor front axle by about 15% for each configuration. It was demonstrated that the resulting geometries respect the established linear and non-linear design constraints since the algorithm converges to a feasible geometry solution in a low number of function evaluations within the defined constraint tolerance. The computational processing time was about thirty minutes for each configuration, considered an adequate convergence time for the numerical algorithm running in a quad-core Intel Xeon CPU at a 3,30 GHz of working frequency. Simulation results suggested that the Optimizer is an effective and efficient tool able to simplify the exploration of the design parameters conforming a three-point hitch geometry and thus demonstrating that it could be applied in practical applications, improving the efficiency of the engineering design process and consequently the overall dynamic performance of the agricultural tractors.

1. Avello Fernandez, L.; Maraldi, M.; Mattetti, M.; Varani, M. Computational Tool for Three-Point Hitch Geometry Optimisation. *Agriculture* **2022**, *submitted*.



LLL strategies for new educational approaches in Smart Agriculture from an agricultural engineering perspective in Italy

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Keywords. Lifelong Learning, Smart Farming, Agriculture, Hybrid Learning, Industry 4.0

Abstract. Lifelong learning (LLL) is a well-known approach to further and permanent education of employees and has become very important also within the agri-forestry sector. This is especially relevant for farm machinery manufactures in order to adapt to a rapidly changing technological environment. In fact, agriculture and agricultural machinery industry, like many others, are affected by massive changes. The term Industry 4.0 is repeatedly mentioned in this context and is intended to describe the current industrial revolution. In the agricultural sector, all these processes are included in so-called Smart Agriculture, which shares with Industry 4.0 the methodological and cognitive approaches of Knowledge Management 4.0. In short, this is about the independent interaction of different technological systems into a self-organizing overall system, through an intensive and integrated applications of electronic devices, ICT, interconnected and cloud architectures and machine learning approaches (the latter mainly based on AI strategies). It is assumed that this will bring about similar structural and social changes as previous industrial revolutions. In this transformation process, the role of work and thus also of humans involved into the system will change deeply. As such processes are taking place very quickly, the qualification for any worker cannot take place in the context of generational change but requires the current workforce to continuously qualify and adapt.

Compared to industry, however, agriculture has an additional weakness in this situation. While the phase of Industry 3.0 represented for the industrial sector the advent of the IT revolution, for the agricultural sector this phase has been largely skipped for economic, financial, cultural and other reasons. Technological progress between 1970 and 2021 introduced, albeit very slowly, many mechanical and electronic innovations, which then led to the high level of automation of many solutions in Precision Farming, but failed to bring about the maturation of a solid IT culture in farm management processes. It is believed that today this gap is still the cause of many of the delays in the diffusion of Smart Agriculture practices.



In this sense, Universities can become key players in helping to overcome this gap, taking full advantage of LLL approaches and opening up to all possible decision-makers operating in Smart Agriculture and related industries.

In a joint project of the University of Natural Resources and Life Sciences (BOKU)/Austria, Free University of Bolzano/Italy, Swedish University of Agricultural Sciences/Sweden and Technical University of Munich/Germany (USAGE Project – Erasmus+), a concept on LLL in Smart Farming is currently being developed and implemented in several courses. The paper will present the main experiences from the Project with particular relevance to:

1. Results from a needs analysis/ survey among professional companies, associations and organizations active in agriculture and agricultural engineering.
2. Educational approaches developed by partners on how to teach relevant content for Smart Farming (online/ hybrid courses).
3. Topics and problems selected by partners to develop LLL modules on Smart Farming/ Smart Agriculture.
4. Educational activities to be shared among different types of experimental/ living labs, for enhancing new practical experiences.

These experiences also aim to develop new approaches to training professionals in the field of agricultural engineering.



Requirements and challenges in the design and potential of smart and efficient winch assisted forestry machinery

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Keywords. Forestry-mechatronics, smart forestry, electrification, hybridization.

Abstract.

Recent regulations on greenhouse emissions and pollutants are forcing forestry machinery companies to target new solutions for limiting emissions while maintaining performance through electrification or hybridization. Moreover, thanks to the availability of new and affordable mechatronic and IoT technologies, concepts such as sustainable, smart and precision forestry are gaining credit. The desire for new advanced equipment is further driven by the need to harvest more timber in alpine regions to meet the objectives of sustainable forest management and operations [1]. In this work, the activities on winch assisted forestry machinery carried out at the First and AFI labs of the unibz are reported. These are firstly revised in terms of requirements and constraints. Then, with electrification being still in its infancy in this sector, design challenges for electrification/hybridization are discussed focusing on duty-cycle studies, understanding autonomy requirements, ideal drivetrain and control architectures. Finally, mechatronic solutions for making them ready for smart and precision forestry are presented. The analysis includes several winch/rope assisted systems for applications in steep terrain, including sled winches, self-driving skyline cranes (e.g. see Fig.1) and tower yarder systems. Results clearly demonstrate the huge potential for: (i) energy efficiency improvement with consequent fuel savings and emission reductions, (ii) significantly improved uptime due to few parts requiring service and generally longer maintenance intervals, (iii) the implementation of a real-time performance and operational monitoring system as well as (iv) the enabling of optimized working strategies.



Fig. 1 Leitalpin self-driving carriage prototype

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Definition of a Porous Media Model Simulating the Presence of a Small Canopy Crops in a Greenhouse

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Keywords. Plant canopy, microclimate, Computational fluid dynamics, Energy balance models.

Abstract. Controlling the indoor microclimate condition in a greenhouse is very important in order to ensure the best conditions for both crop growth and crop production. Therefore, to properly assess the indoor microclimate conditions in a protected environment with presence of crops, it is necessary to also consider the plant effects and the possible exchanges between plants and indoor air. To this regard, the present paper provides the results of a study aiming to define a porous media model simulating the crop presence and to evaluate the thermal energy exchange between crops and greenhouse environment.

As first, an experimental campaign has been carried out to evaluate temperature and air velocity distributions in a naturally ventilated greenhouse building with sweet pepper plants cultivated in pots. Then, the main aspects of energy balance, in terms of mass transfer and heat exchange, and both indoor and outdoor climate conditions have been combined to set up a computational fluid dynamics model. In the model, to simulate the crops presence and effect, an isotropic porous medium following Darcy's law has been defined based on the physical characteristics of the plants. The outcomes of the numerical simulations were then compared with the experimental one. The results show that the porous medium model could accurately simulate the heat and mass transfer between the crops, the indoor air, and the soil. Moreover, the adoption of this model helps to clarify the mechanism of thermal exchanges between crop and indoor microclimate and allows to assess in more realistic way the microclimate conditions close to the crops.

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Low dose precision distribution with micro-granules fertilizer using different spreader machines

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Keywords: aminoacid fertilizer, centrifugal fertilizer spreader, precision distribution

Abstract. This paper is the first of a series of works devoted to the general issues of organic fertilizer spreading machines.

In any agricultural and horticultural crop, the rapid development of a strong root system is a fundamental condition for fully expressing the productive potential; this is due to a better exploration of the soil by the roots and to the formation of more vigorous reproductive structures. The distribution of trace elements and a targeted amount of nitrogen are an important factor in this process. Furthermore, nitrogen fertilizers play a fundamental role in the development and growth of the plant. Their importance is relevant since nitrogen is a basic component in the formation of plant tissue cells. It also influences the metabolism of the plant, entering the formation of substances such as amino acids and enzymes, as well as a large number of hormones and vitamins.

With reference to mineral fertilization, it can be carried out with fertilizer spreaders with localized distribution on the row using "pneumatic systems and machines with release systems for fertilizers in the form of micro-granules" or by broadcasting using, among the numerous types on the market, machines for "centrifugal" drive for open field crops.

The objective of the experimental test was to analyze the distribution in the field (with variable dosages of fertilizer from 5 to 20 kg / ha) of a mineral fertilizer that comes in two different production types - micro-granules and cylindrical tablets.

For this purpose, three types of fertilizer spreading machines were used. A precision fertilizer spreader, equipped with microgranulator, from Kverneland and two solid fertilizer spreaders from Kverneland and Amazone respectively.



Efficiency Of Plastic Nets For Greenhouse Shading

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Keywords: plastic nets, windbreak, recycled plastics, mechanical properties, tensile test.

Abstract. Agricultural production is influenced by extreme weather phenomena, accompanied by major global changes, such as the increasingly sudden and frequent appearance of new types of insects, the transformation of eating habits (e.g., "smart/super foods"), etc. Thus, the concept of crop protection under greenhouse, understood as a mere passive defense (from hail, sun, insects, wind, birds, etc.), is gradually being overcome: no longer a shelter "against" or "in defense", but rather an intelligent structure "for" or "proactive". Coating materials used to cover a greenhouse for the purpose of crop protection can play a crucial role on the quality of light hitting crops, controlling radiation in different ways, especially in the PAR wavebands (400-700 nm). Different covering materials can affect crop performance through selective filtering, which modifies incoming radiation, as well as plant physiology, entomological and metabolomic aspects. Covering materials and shading strategies can be proactively selected and implemented in many mild climate areas, as well as in warm regions where spring/summer solar radiation levels are often too high for proper greenhouse management. To study the shading effect of nets, the radiometric characteristics of several plastic nets were determined by laboratory tests. In addition, some field tests were coordinated with the aim of comparing the material. In these field tests, few different small-scale tunnels were covered with plastic film and protected with an external plastic net (PRISMA HDF[®]), fixed at different distance from the plastic film for each tunnel. Experimental activities allow comparison of the values measured inside the two tunnels with each other. Air temperature, relative humidity, soil temperature covered with a layer of black mulching fabric, solar radiation were measured. The results confirmed that plastic nets play a considerable role in selective filtering of solar radiation, as well as in improving the thermal efficiency of the greenhouse and its overall thermodynamic behaviour.



Recycled Plastics Used In The Production Of Agricultural Nets For Crop Protection

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Keywords: plastic nets, energy-saving, recycled plastics, mechanical properties, tensile test.

Abstract. The sustainability of agricultural systems is critical for the rural environment, as well as to future generations. The creation of closed-cycle farming systems would lead agricultural production to have less impact on the rural environment, while also reducing the plastic footprint of agriculture. The use of innovative nets for crop protection is increasing more and more adding benefits not only to production, but also to agricultural operators and, most importantly, to the surrounding ecosystems. In fact, thanks to the use of nets for crop protection it is possible to control all production parameters inside a greenhouse or a tunnel. In addition, these nets are significantly energy saving by helping protect the crop by reducing and optimizing the use of fossil fuels and plant protection products, thus limiting their impact on the environment. The purpose of this experimental work is to analyse eco-sustainable innovations, taking into account nets produced with partially recycled plastic material. These nets have been analysed and subjected to mechanical tests of longitudinal traction and transverse traction, to spectrophotometric tests in order to verify the transmittance and reflectance of the fabric in the UV/PAR/NIR spectrum (200nm to 2500nm), as well as tested for air permeability, ventilation reduction and shading effect. The results allowed the potential use of partially recycled nets in agriculture to be evaluated and discussed.



Assessing potential water savings achievable by implementing variable rate sprinkler irrigation in a maize farm in northern Italy

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Keywords. Precision irrigation, maize, agro-hydrological modelling, weather forecast

Abstract. The Po valley, in northern Italy, is characterized by a strong agricultural and zootechnical vocation; the Lombardy agricultural area is about 700,000 ha, of which the 70% is irrigated. The prevailing crops are cereals, with maize covering half of the total area, usually cultivated as fodder crop. Due to the abundance of water, irrigation in the area has been based on gravity-fed surface irrigation systems for centuries. However, as a consequence of the increasing in the occurrence of dry spells and of possible future water scarcity predicted by the IPCC scenarios, farmers are introducing more efficient irrigation methods to meet the crop water needs and at the same time to reduce the water use.

The SOS-AP project (Sustainable SOLUTIONS for Precision Agriculture in Lombardy: variable rate irrigation and fertilization in maize and wine-growing - RDP Regione Lombardia Operation 1.2.01) aims at demonstrating the applicability of precision agriculture approaches in the Lombardy context. With regard to precision irrigation in the maize sector, the objectives of the project are: 1) the demonstration in a ‘pilot’ center-pivot of the possibility of implementing a variable rate irrigation (VRI) based on soil characteristics in the 2021 agricultural season: in the pilot pivot, the irrigation input was differentiated over circular sectors through a change in speed (“*sector control*”), with an economic investment to adapt the pre-existing pivot lower than the one needed to implement a true ‘*zone control*’ which would require the independent management of individual (or groups of) nozzles; 2) the simulation of the VRI in a 300 ha maize farm where irrigation is performed through center-pivot and linear irrigation systems which apply water in a uniform way on a fixed calendar. Both at the scale of the pilot pivot and for the entire farm, water and energy savings are compared with those found in the current management.

A soil monitoring survey through an electro-magnetic induction (EMI) sensor was used to produce a map of the homogeneous management zones for the whole farm. A semi-distributed agro-hydrological simulation approach based on the SWAP model (<https://www.swap.alterra.nl>) was developed and applied for: 1) the real-time VRI management during the 2021 season in the pilot pivot by using 7-day weather forecast data (<https://www.abacofarmer.com>) which led to a water saving of about 20%; 2) the simulation of the water saving that could have been achieved at the farm level if the VRI approach had been adopted in the period 2016-20.



The Effect of Adjuvants in Reducing Potential Spray Drift

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Keywords. Droplet size spectra, nozzles, spray patterns, wind tunnel measurements

Abstract. Drift containment during spray application of plant protection products is essential to achieve sustainable pesticide application accomplishing the EU directives and strategies. Adjuvants are designed to perform specific functions involving the mixing and application of pesticides (i.e. buffering, dispersing, emulsifying, spreading, sticking, and wetting), but they can also reduce evaporation, foaming, volatilization, and spray drift. Interest in using adjuvants as an additional tool to increase the spray application efficiency, by concurrently increasing the spray deposition and reducing the spray drift risk, is on the rise as the European Green Deal, within the Farm to Fork strategy, strives to reduce by 50% the overall use of agrochemicals within 2030. In this context, laboratory trials aimed to measure the capability of different adjuvants to reduce potential spray drift were performed.

Two commercial adjuvant formulations were tested separately at two dosages (minimum and maximum according to their label) and mixed with pure water. Also, three types of nozzles were considered in this study: conventional hollow-cone and flat fan nozzles, and air-inclusion flat fan nozzles. The effect of adjuvants on the obtained droplet size spectra (accounting for VMD, D10 and D90) were measured using a Malvern laser diffraction system. Furthermore, adjuvants effect on potential spray drift was evaluated measuring the distortion of single nozzles spray patterns. For these purposes, an *ad hoc* designed “wind-tunnel horizontal patternator” was used to generate a controlled cross-airflow to the nozzle spray and concurrently measure its spray pattern when adjuvant mixtures were sprayed. Pure water was used as a spray liquid reference for the evaluation of (i) changes in droplet size spectra and (ii) the potential spray drift reduction attributable to the adjuvants.

Both tested adjuvants increased the droplet size spectra of the three types of tested nozzles to a different extent, in the range of 10-70% for the VMD. The variation of droplet size spectra was reflected in the reduction of potential spray drift, which ranged between 20 and 60%. Also, the air inclusion nozzle type showed less benefit in using adjuvants if compared to the conventional nozzles. Finally, the adjuvants dosage generally did not affect considerably either the droplet size or the drift reduction figures.



Can a variable-rate sprayer be efficient and economic? Testing and economic analysis in viticulture

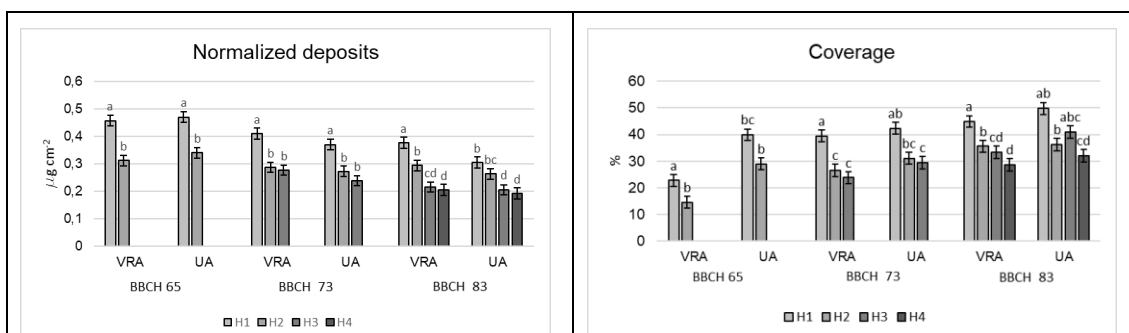
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Keywords. VRA, optimization spraying, pesticide, ultrasound sensor, specialty crops

Abstract. The European Union pointed out ambitious goals in terms of the reduction of pesticides in agriculture. These goals could be achieved in different ways e.g. by variable-rate application (VRA) technologies. Present work aims to assess the spraying performance of a VRA sprayer and its economic sustainability. To evaluate the operating performance, three trials (BBCH 65, BBCH 73, BBCH 83) were performed in a vineyard following a profile sampling strategy (BS ISO 22522:2007). A randomized complete block design was performed with three replications for each treatment (uniform and variable - UA and VRA). The variables (normalized deposition and coverage) from artificial targets by spectrophotometry and image analysis techniques respectively, were extracted. Moreover, the economic performance of VRA sprayer compared to UA one was performed for the whole vegetative season in two plots.



Results of the two-way ANOVA for the normalized deposits (mg cm^{-2}) and spray coverage (%). Different letters mean statistical differences (Tukey HSD test; $\alpha = 0.05$).

Normalized deposit results showed differences between detection heights (H1, H2, H3, H4) rather than between treatments (VRA vs UA). Therefore, VRA and UA efficacy was confirmed, given the similar values of deposit. The same trend was shown in coverage results, even if UA coverages were higher than VRA, usually exceeding the overspray threshold [1]. The economic performance highlighted for VRA average volume saving of 35%, ranging from 76% in the first session to 10% in the last one. The resulting economic saving was €2600.0, consisting in: €2502.5 of pesticides, €52.7 of water and €44.8 of fuel. Overall, VRA system showed good spraying performances reducing the application volume significantly and enhancing economic sustainability.

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Deep Learning Approach To In-Situ Sustainable Weed Management (SSWM)

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Keywords. UAV, Deep Learning, SSWM, weeds.

Abstract. Biotic threats such as insects, weeds, fungi, viruses, and bacteria can broadly affect crop yield and quality. Among these, weeds are the most impacting problem causing remarkable yield loss worldwide. The most characterized effect of weeds is competition for resources such as light, water, space, and nutrients [1]. Precision agriculture can be effectively applied to weed management using Unmanned Aerial Vehicles (UAV) to gather and process data [1] as well as the application of artificial intelligence to weed control. This work proposes a deep learning approach for selective weed recognition in real time from aerial images that enables targeted treatment of certain weeds, using artificial intelligence to select in the field and in real time the weeds to be treated and/or removed and those to be kept in the field. The developed deep learning algorithm will be able to be used on self-driving rovers (UTVs) for automatic in-field weed treatment according to site-specific weed management (SSWM) principles. The method shows good accuracy in recognizing and discerning the various weeds in the field, as shown in an example in Figure 1 where we can see how the algorithm recognizes and classifies weeds by separating them from the crop (wheat). Further studies are underway to improve the algorithm by training it to the different phenological states of the weeds as well as increasing the training dataset, also expanding it with the spectral signatures of the weeds of interest, through acquisition of multispectral images.



Figure 1 - Weeds classification through Deep Learning approach

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Quantity and type of logging residues following cut-to-length and full-tree salvage logging systems in damaged mountain forests

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Keywords. forest disturbances, organic carbon, nutrients, full-mechanized harvesting, wood

Abstract. Extreme disturbance events, such as climate change-driven ones, have increased their frequency, upsetting the ordinary management of the forests, and impacting large forest areas with severe damages. As a consequence, when productive forests are hit, salvage logging operations represent the common way to recover part of the economic loss. However, salvage loggings can lead to negative impacts in terms of soil erosion as well in terms of variation of soil carbon stock and nutrients. Commonly, in the European Alps, salvage logging operations in largely damaged forest area can be referred generally to two basic harvesting systems: i) Cut-to-Length (CTL) and ii) Full-Tree (FT) extraction systems.

The application of the two harvesting methods can have a different effect on the type and quantity of logging residues left on the forest ground, which in the short-medium term it can be reflected in terms of quantity and distribution of organic carbon and nutrients in the soil. The aim of this study is thus verify if there is a difference in terms of logging residue type and quantity according to the used harvesting system.

Logging residues were sampled in 2021 in three forest areas in the Province of Trento (NE Italy) windthrown in 2018 and harvested in 2019, 2020 and 2021. The logging residues were sampled and classified as fine wood debris (FWD) and coarse wood debris (CWD). A chemical analysis was also carried out on wood and soil samples to obtain the carbon and nutrients estimation.

Preliminary results show a higher amount in the areas harvested with the FT system, while a higher CWD in areas harvested with the CTL system. Significant difference with respect to the quantity of residues was found only for 2021 ($p < 0.05$). The chemical analysis reveals a higher amount of organic carbon stored in the soil (up to 85 Mg C/ha) than in the residues (up to 29 Mg C/ha). For the major nutrients considered (N, Ca, Fe, K, Mg, Mn, P and S), their concentration decreases with the increment of the residues diameter, resulting higher in FWD. The results confirm the potential for CTL to be more depleting in terms of nutrients removal but not in terms of material recovered.¹



Smart Glove: Development and Testing of a wearable RFID reader connected to Augmented Reality Smart Glasses

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Keywords. Augmented Reality Smart Glasses, HoloLens, RFID, Animal identification, Digital Farming

Abstract. The evolution of Precision livestock farming (PLF) has given the possibility to the farmer to obtain a large amount of information. However, to access the database, the operator often is forced to use PC or mobile devices, losing time during on-fields activities. In this context, the use of Augmented reality Smart Glasses (ARSG), such as HoloLens (Microsoft, USA), represents an interesting tool to consult the information in real-time leaving the operator hands-free. The work's aim was to decrease the technological gap between the animal's electronic identification to all the information linked to a specific animal. Specifically, the research focused on developing a smart wearable system composed of a prototype, called SmartGlove (SG), capable to link the RFID tag and ARSG, via Bluetooth connection. The ARSG displays all the information related to the animal stored in an online or offline database thanks to the development of a dedicated software. The use of the SG system allows the operator to visualize, monitor, and modify the information related to the animal during on-field activities. From the preliminary experiments, the system shows promising results in reducing the required workforce and improving productivity in farm management. Future works will aim to improve the reading capability of the SmartGlove, improving the antenna performances, expand the battery life, and to upgrade the ARSG software. The SmartGlove system will allow farmers to make timely decisions in the management of the animals, in line with animal welfare and precision livestock farming principles.



Feasibility study of tractor electrification using real-world data

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Keywords. Fuel saving, electrification, tractors, real-world data

Abstract.

In 2020, the European Commission (EC) presented the European Green Deal which is an ambitious package of measures aiming to transform Europe into the first climate-neutral continent. Agricultural mechanisation is responsible for around 70 million tons of CO₂ of yearly emissions. To significantly reduce CO₂ emissions, hybrid powertrains are under investigation from industry and researchers. This paper aims to investigate a few hybrid powertrain architectures and to report the advantages of such solutions on the basis of real-world data in order to obtain the potential benefits perceived by farmers. Real-world data were collected with a CANBUS data logger on a row-crop tractor rated of approximately 190 kW. In this tractor, engine and transmission operating parameters were recorded for more than 1000 hours of field use. Data were firstly classified into tasks, and then a series of inefficiency index were defined. This permitted to highlight the operational inefficiency of each type of task. Four different hybrid architectures were studied and evaluated with the load-point shifting principles. The studied architectures are engine start-stop, PTO-electrification, accessory electrification, and P4 hybrid powertrain. The most inefficient operations are idling and transportation since the engine operate at a low load which is an operation where the specific fuel consumption is below the optimum. The tractor was run on idle for 25% of the entire use and accessories are responsible of 13% of the used fuel. The hybrid architecture with the greatest advantage is the P4 hybrid powertrain where 15% of the fuel can be saved. The second greatest is the PTO-electrification where 2.4% of the fuel can be saved. The architecture with the lowest fuel saving is the start-stop where 1.8% of the fuel could be saved. However, it is the easiest one to implement on tractors. The methodology adopted permits to outline the potential benefit of hybrid powertrains using real-world data and therefore, to estimate the benefit perceived by farmers and not based on reference cycle such as DLG Power-Mix.



Application of Local Ecosystem Readiness Level: a case study

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Keywords. Precision farming, TRL, index, technologies, policies

Abstract.

Introduction - Precision Agriculture (PA) application is scarcely in the south Mediterranean area. This could be due to different causes, such as the lack of a systemic vision of the institutions and/or subjects needed in a precision agriculture system. This deficiency makes it difficult, or even impossible, to evaluate the effectiveness and consistency of the adoption of Precision Agriculture Technologies (PAT). In order to better understand the presence and solidity of networks between the agricultural system entities, a composed index was developed. Materials and methods - The local ecosystem readiness level (LERL) was structured in nine indicators concerning all actors involved in PAT adoption, and it was measured on a normalized scale from -20 (low) to +100 (high). In this paper, an extensive case study was carried out to understand better the index soundness, representativeness, accuracy and usability. The update of assessment methods and index criteria was performed through this case study. The case study took place in Italy to evaluate and measure the drivers of the PAT. The data necessary to calculate the index were obtained through specific surveys on the local ecosystem actors, farmers, technicians, consultants, and educational centres. A context evaluation was carried out to assess PA local infrastructure, governance and providers. For the latest, a database was created to identify local PA providers easily. Results and discussion – The application of LERL showed a framework in which many weaknesses were come up due to the lack of competencies in the Educational System and substantial structural deficit with few infrastructures at disposal for farmers. The LERL index results in the case study showed a low level, identifying a status between the first (Absence) and second (Emergency) level. Conclusion – This index makes it possible to identify and quantify, in a territory, what may be gaps, excellences and needs for a profitable introduction of the PA. It is a tool that both farmers and policymakers can use to plan investments and business strategies and comply with international policies. In future perspectives, a worldwide application of LERL will be made to make it a robust index, able to evaluate the adoption of PAT.



Assessment of soil and vegetation index variability in a traditional olive grove: a case study

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Keywords. Precision Agriculture, data collection, olivegrowing, innovation

Abstract. Precision Agriculture (PA) is nowadays one of the most feasible solutions to reduce input and pollution in agriculture (EC, 2019). One of the most important techniques of PA is the identification of in-field spatial variability. Multiple techniques can be used to identify the variability: soil analysis and vegetation index identification are two of the most applied. In this study, the variability of an olive grove was assessed to evaluate the best option for creating variability maps and assessing the relationship between soil and vegetative variability in the case study. The study was carried out in two olive orchards, with a 6x4 m planting layout; the mean plants' height was 3 m. To assess soil variability an EMI analysis was performed. The field was completely mapped at 0-50, 100 cm deep. After the evaluation of the electric resistivity, maps were created. The proximal OptRx Crop Sensor (Ag Leader, Iowa, USA) was used to assess the plant vegetation index. This sensor was mounted on a tractor and positioned at a height of 2 m from the ground to assure the acquisition of the vegetation index for all the assessed plants. NDVI and NDRE index were measured. To georeference all the acquisitions, a GNSS system was installed on the tractor (Ag Leader GPS6500 GNSS receiver, Ag Leader, Iowa, USA). Through this method, site-specific olive canopy NDVI NDRE data gathering was performed. Soil characterization maps revealed significant in-field differences in electric resistivity for all the evaluated depths, through this analysis a homogeneous resistivity-value map was created. The data points of every soil sampling were interpolated within the whole plots by ordinary kriging through the GIS software QGIS (GNU General Public License). NDVI and NDRE predictive maps were developed using ordinary kriging fitting the best variogram. An exploratory correlation analysis was performed between NDVI, soil proximal sensing (ECa1, ECa2, TC_gamma), and soil strength, to highlight the statistical relationships between the main parameters used for this study. Collected data were analyzed and interpolated by k-means clustering to make thematic maps. Results showed maximum R-squared correlations of 0.24 ($p < 0.05$) were found between the value of soil variability and proximal vigour measurements.

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Olive tree canopy assessment based on UAV multispectral images

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Keywords. Remote sensing, UAV, vegetation index.

Abstract.

Unmanned Aerial Vehicle (UAV) is widely used to acquire data on the biometric and spectral characteristics of olive trees through multispectral cameras. Several flight parameters and image processing techniques can be applied in order to obtain this information. The aim of this work was to study the variability of the main biometric parameters and multispectral characteristics of olive trees through multispectral images acquired from a remote platform (UAV) at three different flight altitudes (30m, 50m and 70m), in two acquisition periods, with and without the use of differential coordinate correction (RTK), also applying different image segmentation techniques. Phantom 4 Multispectral UAV platform was used for the two flight campaigns. The photogrammetric processing was carried out using the software Agisoft Photoscan Professional, version 1.2.6. The biometric and multispectral data extraction processing was carried out through the software Qgis, version 3.2. Different segmentation techniques were applied on the acquired images, starting from the main vegetation indices maps as Normalized Difference Vegetation Index (NDVI), Normalized Difference Red-Edge Index (NDRE) and Modified Soil Adjust Index (MSAVI). The results showed that the olive tree canopy can be accurately studied using the crown spectral information obtained by the UAV multispectral system.



Detecting Coffee Leaf Nitrogen with UAV-based Vegetation Indices and Machine Learning

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Keyword: Random Forest, Remotely Pilot Aircraft, Nitrogen Management and Coffee Crop

Abstract: The development of new approaches to determine the spatial variability of nitrogen (N) in coffee leaves is essential to increase productivity and reduce production costs and environmental impacts associated with excessive N applications. Therefore, this study evaluated the potential of vegetation indices (VI) based on UAV and machine learning to estimate N content in coffee leaves.

The study was carried out in a coffee plantation located in the municipality of Santo Antônio do Amparo, MG, Brazil. Ten sampling points were demarcated in this crop, consisting of 5 plants. The sampling points were classified as N deficient (<2.5%), N critical (2.5 to 3.0%) and N adequate (3.0 to 3.5%). The images were captured using a commercial RPA 3DR Solo, equipped with a Parrot Sequoia multispectral camera. Image processing was performed in Agisoft PhotoScan® Professional software and Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI) and Normalized Difference Red Edge Index (NDRE) vegetation indices were calculated in QGIS 3.16 software. The classification of N content in coffee leaves throughout the crop was performed using the RF machine learning method. The classification was done in R, using the R Random Forest package. For the training of the RF, the values of the vegetation indices and of the N analyses were extracted in the plants of each sampling point. The RF performance was evaluated using the metrics global accuracy and kappa coefficient.

In general, the classification showed a high performance in the evaluation of N in the coffee leaves, with global accuracy and kappa coefficient values ranging from 0.81 to 0.91 and 0.70 to 0.86, respectively. The NDVI presented the best results among the evaluated indices, while the NDRE was the worst. In addition, it was possible to estimate the special distribution of N classes throughout the crop. The NDVI also presented the best class definitions, demonstrating that 22% of the crop had N deficiency, 52% critical N and 26% sufficient N.



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This study showed that the RF machine learning method applied to vegetation indices from UAV multispectral images could provide a promising approach for mapping N status in coffee crops and localized application of fertilizers.



Evaluation of Precision Sprayer Technologies practical application.

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Keywords. Tractor, agriculture, variable rate, auto-guidance, operator comfort.

Abstract. The difficulty of appreciating the benefits of precision agriculture (PA) is among the main reasons for its low adoption rate. Concerning crop spraying, the present study focuses on analyzing both economic and ergonomic advantages in adopting precision spraying technology and the approach for a farmer to perform precision spraying tasks. The purpose of the work is to underline that PA management can result in various levels of precision and complexity: some operations may even now be ready for implementation; however, others could require additional economic efforts or consultants.

The study starts with the description of the necessary technical requirements for erbaceous crops. Then, it considers the tractor-implement coupling to manage specific PA sprayers. In practice, upgrading the system precision requires the adoption of a double frequency antenna on the tractor (L1 and L2) for geolocation; it requires also auto-guidance, a virtual terminal and ISOBUS implements. RTK antenna would be preferable for this operation, but not mandatory. Even the software could require upgrading (with an additional fee, too) to have the possibility of managing additional tools.

The experiment compared crop spraying with a conventional 63 kW tractor and sprayer and a 65 kW PA tractor with an ISOBUS sprayer boom, 15 m width. The ISOBUS sprayer worked with variable sections at fixed rates, not using prescription maps. The operators carried out a whole working day, and the field efficiency and the distributed product were evaluated. The PA operator resulted in a field capacity of 40% and a product saving of about 10% higher. The reasons for this difference are analyzed in detail and reported.

Literature reports mean advantages of 20-30% of product and time saving, but these data have to be fitted on the specific kind of performed operation, but they cannot be generalized.

The methodology of the tests conducted with the PA machines also requires attention and the reasons are given. Finally, the cost analysis of the two different fleet management are reported. Results highlighted that the tractor's technological level is fundamental to achieving the desired level of PA.



Quality evaluation of filled and covered wafers during storage: destructive, spectroscopic, and hyperspectral methods

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Keywords. confectionary, hyperspectral image, NIR, chemometric, packaging.

Abstract. The aim of this study was to evaluate the quality of a wafer based sweet product during storage by using destructive, spectroscopic, and hyperspectral methods. Two packaging types were compared. The samples were vanilla cream-filled wafers (three layers) covered by a thin layer of dark chocolate packaged by using the packaging standard adopted by the involved company and vacuum-pack made by multi-material layer (PET and aluminum). The samples were stored at 18°C (RH=50%) and analyzed after 2, 4, 5, 6, 7 and 8 months of storage. Concerning the destructive analyses, three-point bending test were used to evaluate the mechanical properties, while the water activity was measured on the most internal wafer sheets. The sensory acceptance was directly assessed by a trained staff. The samples were analyzed by a FT-NIR spectrophotometer (MATRIX™-F, Bruker Optics) in the range from 833 to 2500 nm and by a push-broom linear array hyperspectral camera working from 400 to 1000 nm (Nano-Hyperspec, Headwall Photonics). Spectroscopic and hyperspectral data were subjected to chemometric elaboration. PCA analysis was used as explorative technique to group the samples as function of packaging type and storage time, while PLS model were developed to estimate the storage time. The water activity significantly increases during the storage and good linear relations (R^2 up to 0.84) were found between water activity and mechanical parameters, confirming the dependence of the mechanical behavior on the effect of the water in wafer sheet. The sensory acceptance linearly decreases with the storage time; this reduction is more pronounced for the samples stored in standard packaging. The acceptance limit corresponds to wafer sheet water activity of about 0.44. This value was defined the limit to describe “good” and “compromised” wafers, in terms of sensory (textural) properties. Results suggests that adding a multi-material packaging layer, the storage time significantly increases.

PCA analysis of NIR and HSI spectra, showed a clear separation between the samples acquired at time 0 and those analyzed during the storage. Particularly for the NIR spectroscopy, the X-loadings suggested that the discrimination is mainly due to the region from 1850 to 2000 corresponding to the O-H absorbance in water. Considering only the samples acquired during the storage, the score plots showed notable sample distributions according to the storage time, passing from 2 to 8 months. PLS results showed R^2 in cross-validation ranging from 0.926 (RMSECV=0.63 months) to 0.980 (RMSECV=0.36 months). The best performances were achieved considering separately the samples stored in standard and vacuum packaging, for both NIR and HIS data.



Digital Technologies for the Sustainable Management of the Olive Orchards in Central Italy: the Farmers' Perception

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Keywords. Digital agriculture, innovative technologies, olive oil, precision farming.

Abstract.

Digital agriculture can play a major role in agricultural production, as a range of technologies are now available to be implemented at different scales and for a multitude of objectives, supporting farmers and other key actors in decision making. Examples include the assessment of soil nutritional and plant water status at field scale, monitoring of diseases at farm and territorial scale, or tracing products from the farm to the market, along the supply chain. In the olive oil production, which is at present mainly carried out in Italy implementing business as usual no-digital solutions, the growing availability and accessibility of specific digital technologies enable wide opportunities to out scale the adoption of innovations to enhance sustainability.

This paper aims at investigating how much current and future advances in the so-called digital agriculture is known and perceived by the olive growers. A specific survey addressed to farmers active in Central Italy was conducted by means of a questionnaire including 20 five-point rating scales and multiple-choice questions divided in four main sections ((1) exploring the knowing of digital solutions and applicability; (2) actual use; (3) perception and ambitions in the field; (3) farm and farmer profiles). The questionnaire was responded by 96 target farmers.

The results of the survey showed several aspects of the penetration and perception of the potential of digital agriculture in olive oil production in Central Italy. Among others, the interest of olive farmers in innovative digital technologies resulted high (average score of 4.3 out of 5). Anyway, most of the respondents did not show an exhaustive knowledge of the proposed technologies and only few of them already adopted some digital solutions in their own farm (11.4%).

The sustainability of the implementation of the questioned innovation technologies is finally discussed.



Monitoring forest condition in a protected Mediterranean coastal area by the analysis of diachronic NDVI data

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Keywords. Remote Sensing, Protected Area, NDVI, Sentinel-2, Vegetation indexes

Abstract. Climate change and human activities in particular, are important causes of the possible variations in Mediterranean basin forest health conditions. As a consequence, today, increased forest vulnerability is being reflected in a larger number of severe decline episodes associated mainly with drought. In this context, the Mediterranean area shows high forest vulnerability and a subsequent decline in its natural renewal rate.

In this scenario, multi-spectral analysis of remote sensing data today represents an efficient tool for monitoring vegetation in a Mediterranean environment, where spatial resolution often represents a limiting factor due to high fragmentation and spatial distribution of forest stand.

The aim of this study has been to map the health conditions of the Castelporziano coastal pinewood forest (Roma). To this aim, we used a diachronic NDVI index, provided by ESA Sentinel-2 images and field observations, to monitor the health status in a historic pinewood forest that has recently been affected by a rapid diffusion of pests (*Tomicus destruens* Woll.).

The monitoring performed allowed us to map the pinewood forest in risk classes and at the same time to provide data concerning the localization of areas showing a strong decline. Thus, we provide information useful for the correct management and planning of forestry thinning to preserve those areas of the pinewood forest not involved in the decline process.

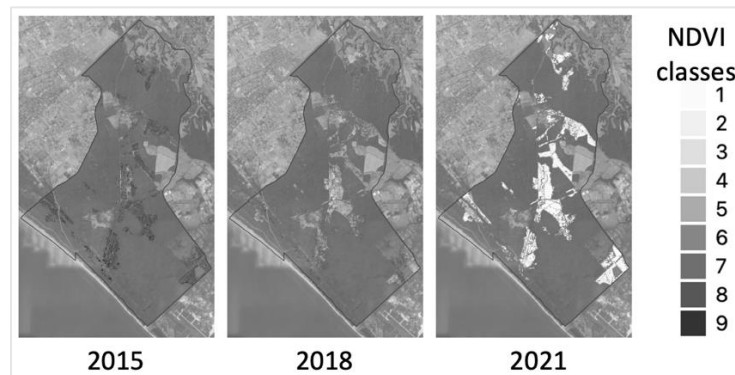


Figure 1. Pinewood forest: NDVI classes and their evolution for the period 2015-2021



Feasibility of two MEMS-NIR spectrophotometers for characterizing different biofuel origin

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Keywords. Precision bioenergy, NIRS analysis, PCA, quality, pellet

Abstract. The European Union effort to reduce fossil fuel consumption paves the way to enhancing interest towards renewable resources. Solid biofuel could play a key role, but its properties and origin are fundamental issues affecting energy conversion efficiency and supply chain sustainability. At the moment, laboratory conventional analysis require huge economic and timing efforts. Moreover, it is fundamental to obtain rapid and real-time quality information along all the supply chain. In this context, Near Infrared Spectroscopy (NIRS) is able to satisfy these requirements, minimizing the time delay of the lab analysis and promoting on site analysis along the whole process. The main aim of the present work is to evaluate the performance of two different portable MEMS (Micro Electro Mechanical System) NIR spectrophotometers for identifying the raw biomass of which pellet is made. Thus, samples of different categories have been collected and in detail: i) the most relevant Italian softwood and hardwood species, ii) different wood processing industry residues and iii) four bioenergy crops. Ten replicates for each sample have been performed and different spectral pretreatments have been tested to reduce noise and scattering effects. Principal Component Analysis (PCA) has been used to investigate the spectral variability and look for groupings among the different samples and categories. According to the spectral range, the C12 revealed a fair separation between virgin and treated wood than the C13 due to detection of chemical bonds related to glue presence. On the other hand, softwood and hardwood differences are better shown by the C13 because of C-H bonds related to wood components. A good separation between virgin and herbaceous samples has been achieved with both instruments, showing slight spectral differences in herbaceous. More interesting results could be obtained by widening the biomass samples in order to manage stronger dataset for chemiometric analysis. Nevertheless, the results of the research aimed at introducing NIR sensor, coupled with chemiometric, onboard pellet combustion devices to improve combustion efficiency and environmental performance.

The project leading to this application has received funding from the "Bioenergia di precisione" research and innovation programme under the CARITRO Foundation.



Predicting the bending properties of poplar wood using non-destructive testing methods

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Keywords: sensors; universal testing machine; wood quality; Modulus of rupture

Abstract. Research and development efforts are currently underway worldwide to examine the potential use of a wide range of non-destructive technologies (NDT) for evaluating wood and wood-based materials, from the assessment of standing trees to in-place structures. As many studies have focused on measuring the stress wave of standing trees, application and extension of the results for the entire stem are not widespread. Further research is therefore needed to establish sufficient data on MOE_d variation in tree trunk length.

The tests were conducted in the Vibo Valentia province (Calabria region, Italy). It extends over an area of about 3 hectares, mainly flat, and only in some points, there was a slight slope. The area under consideration was planted with *Populus canadensis*, clone I-214, having a 6 x 6 m spatial geometry.

This study aims to determine the MOE_d in 55 standing trees, and trunks, of same clone (I-214), and to evaluate the relationship between the MOE_d and the MOE of sawn wood. This relationship is studied at three stem heights, H1 (30 - 130 cm), H2 (130-230) H3 (230-330 cm) from base to top, to establish their effects. This survey was carried out employing two different nondestructive control approaches: the time of flight (TOF) of the acoustic stress waves and the acoustic velocity acquired on standing trees, and the measurement of the acoustic velocity in the longitudinal direction on the logs. Following the height classes chosen on the standing plan, 80 specimens measuring 2x2x40 cm were used to conduct the four-point bending tests to obtain global MOE_m and $F_{m,k}$.

Considering that the optimal transformation path of wood in the sawmill is determined by the quality of a log, and therefore also by the prediction of the elastic modulus combined with the size of the log, it follows that the inherent qualitative characteristics of the logs greatly affect the commercial value of derivative products. Another objective of this study is to evaluate the sawing yields of the finished product as a function of the dynamic elasticity module of the standing trees and the logs.

The result of this study could be introduced to the actual knowledge to expand and improve techniques of management of poplar plantation.



Environmental performance comparison between optical and wet-chem analyses to assess quality parameters of grape (*Vitis vinifera* L.)

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Keywords. Optical technique, prototype, chemometrics, technological maturation, sustainability, LCA

Abstract.

Grape quality composition at harvest is one of the most important factors that determine the future quality of the wine. By measuring certain grape quality parameters (sugars content, total acidity and pH-value), it's possible to determine the optimum harvest timing ensuring the production of high-quality wines. These parameters are usually obtained through traditional analytical methods, the wet-chem analyses, which require samples to be sent to geographically distant laboratories and waiting long time before achieving results. All these procedures imply also the use of chemicals. As a solution to destructiveness and slowness problems, optical methods can be suitable alternatives to monitor the technological maturation of grapes.

In this context, the work aimed to evaluate and compare the environmental impact of three different analyses carried out to determine technological parameters (sugars, pH, and total acidity) using three different approaches: the wet-chem method, the optical method using benchtop devices and the optical method using innovative, smart, and cost-effective devices. The Life Cycle Assessment (LCA) methodology was used to identify the most sustainable solution and propose actions to reduce the impact along wine supply chain in a “from-cradle-to-grave” approach. The functional unit was identified by the execution of the analyses necessary to obtain the three technological parameters.

Results demonstrate how firstly the wet-chem analyses should be carried out in triplet to obtain technological parameters while for the benchtop and the innovative ones the three quality parameters can be obtained with only one single analysis. Moreover, the optical analysis results the most suitable and green solution resulting 3.2 times more sustainable respect the wet-chem analyses. If innovative optical method can be identified as the best solution, its performance may not be so reliable in obtaining precise and trustworthy results. For this reason, the performance factor was included in the evaluation and results have been normalized confirming what obtained in the previous scenario. Results obtained demonstrate how innovations in agriculture and the development of smart solutions could represent advantages in managing and monitoring agri-food products quality in an industry 4.0 approach by proposing green solutions.



A pellet weeding flamer machine

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Keywords. Weeding control, flame weeding, flaming, biomass-fuelled flamer design, vineyard

Abstract. Weed control is an important practice both in vineyard management (particularly in the case of organic farming) and in urban environments such as roadsides, gardens, public buildings, etc. In both of these environments, efforts are now being made to reduce or eliminate the use of plant protection products as they are potentially dangerous both to human health and the environment. In both these environments, efforts are now being made to reduce or eliminate the use of plant protection products as they are potentially dangerous to both human health and the environment. One method of controlling vegetation without using chemicals is to use flame weeding using a pellet stove.

The machine made by CS Thermos is a model that can be attached to the tractor's three-point hitch, and consists of: a 300-litre pellet tank; a feeding screw with a rotating grate; a horizontal flame outlet chimney, which is directed towards the ground via a special "bell", curved downwards to concentrate the heat produced on the under-row. The burner has a maximum heat output of 150 kW and is of the modulating type, with effective power adjustable from 30 kW to 150 kW. Two centrifugal fans, with a capacity of 700 m³/h and 250 m³/h respectively, provide the air necessary for both combustion and conveying the flame towards the ground.

From 2018 to 2021, the University of Udine set up a series of field trials to compare the effectiveness of biomass flame weeding with that of traditional techniques in two vineyards, one with traditional management, the other organic.

The results obtained highlighted the numerous advantages of flame weeding compared to traditional techniques: it avoids knocks and damage to the roots and vines, and the need to replace damaged plants, as well as loss of production; it is easier to choose the moment of intervention, without waiting for the soil to dry out after the rains.

Compared to traditional gas flame weeding, biomass flame weeding has the advantages of using a renewable energy source, and thus contributing to the reduction of emissions and the greenhouse effect linked to climate change; - it allows a certain saving in fuel costs: in our tests, the average pellet consumption was 50-60 kg/ha, with a cost, depending on the price (from 0. It can allow further savings in the prospect of using pellets from vine wood, obtained from pruning residues and therefore "self-produced" on the farm with possible recourse to inter-company services or contractors for the management of pelleting equipment.



Grape-HAND: a smart optical prototype for measuring grapes' qualitative parameters

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Keywords. viticulture 4.0, chemometrics, portable device, field measurement, vis/NIR spectroscopy.

Abstract. The possibility to control the ripening stage of the grapes directly in the field has become increasingly important, both to ensure high-quality raw materials and to assist winemakers in their decisions. Sustainability is another crucial factor to consider. Chemical analyzes, which are used in laboratories to evaluate qualitative parameters of grapes, require chemical reagents, as well as a significant amount of time and trained personnel. Optical analyzes, on the other hand, constitute a valid alternative. Nowadays, the majority of commercially available spectrophotometers are extremely expensive bench instruments that cannot be utilized for in-field measurements. For these reasons, research is focusing on ensuring that this type of optical analysis maintains its high performance using simplified, portable and easy-to-use tools.

Grape-HAND is a cost-effective visible/near-infrared prototype tested to quantify qualitative attributes of Chardonnay grapes using a combination of spectroscopic data and the building of predictive models. The optical acquisitions were acquired directly in the field using 12 wavelengths in the visible/NIR range: 450, 500, 550, 570, 600, 610, 650, 680, 730, 760, 810, and 860 nanometers. The qualitative parameters were predicted using a multivariate model through the Partial Least Square regression technique, which was developed using the real values of the parameters (total soluble solids, titratable acidity, and pH) as determined by the reference laboratory analyzes. Two harvest years were included in the sampling. The results showed that the optical prototype is capable of providing relevant information in order to support operators in rapid and objective decision making promoting a sustainable approach and viticulture 4.0.



Fine-tuning the set-up of a photo-acoustic multigas analyser for gas monitoring in an open dairy barn

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Keywords. Repetitions, gas concentrations, open dairy barn, measurement set-up.

Abstract.

The estimation of emission rate of ammonia and greenhouse gases from livestock buildings requires measurements of gas concentrations. Research studies on how to collect data and obtain reliable measurements can optimise the strategy for gas monitoring in open and semi-open dairy houses.

Since the photo-acoustic spectroscopy system (INNOVA by LumaSense Technologies A/S, Denmark) is widely used for scientific purposes, especially in livestock building, the present study aims at improving knowledge on the measurement set-up of the instrument with in-field experiment. Measurements of gas concentrations (NH₃, CH₄, and CO₂) at different sampling locations (SLs) and set-up were carried out in a semi-open dairy barn. Starting from a continuous monitoring of the gases, two datasets were selected to compute the error associated to different set-up of the instrument related to the Sample Integration Time (SIT) and the number of repetitions for each SLS. Then, the one-way analyses of variance were applied to assess significant differences for groups of data.

The results showed that the INNOVA set-up affected the measurement strategy as well as the localisation of sampling locations (SLs). In detail, the Sample Integration Time (SIT) set-up of INNOVA influences the duration of a measurement cycle by the device. Since there was not a significant difference between the errors on concentrations with SIT5 and SIT20 ($P > 0.05$), the set-up with SIT5 is more suitable than SIT20 because it allowed to complete a measurement cycle in less than one hour with 12 SLs and 3 repetitions. The number of repetitions performed for each measurement had a significant influence on the design of the measurement campaign.



Combining Smart Glasses and thermal imaging as a tool for water stress detection in greenhouses: A preliminary study

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Keywords. Augmented reality, AR headset, Digital farming, Precision Agriculture, Protected cultivations

Abstract. The aim of the study was to combine low-cost thermal imaging camera with smart glasses to evaluate the feasibility of augmented reality system for monitoring water stress under protected conditions. The tests were performed in a greenhouse on 208 Petunia hybrid 'Surfinia' plants arranged in 4 rows. All the plants were irrigated to reach field capacity,



Figure 1. Operator wearing Smart Glasses combined with thermal imaging camera during on-field tests

while 15 of them did not received irrigation water for seven days before the trials. Three qualified operators had to identify the plants in water stress condition, using 3 operative modes: naked eyes (NE); thermal imaging camera (Thermal Compact Pro, Seek, USA) associated with a smartphone (TSP); thermal imaging camera associated with smart glasses (TSG, M400, Vuzix, USA). For each operator was recorded the operative time, the success rate and the number of errors in identifying the plants under water stress. The results showed a general low rate of water stressed plants identification in the three operative modes considered (NE: 13.3%; TSP: 6.6%; TSG: 6.6%). On the other hand, the unsuccessful detection of the plants in water deficit made by the operators was reduced about 40% when adopting the TSG as compared to NE operative mode. Moreover, the time needed to complete the task was higher adopting the TSP solution (4.60 minutes) than TSG and NE (2.63 and 1.85 minutes respectively). These outcomes represent a preliminary study concerning the implementation of augmented reality devices to support operators detecting plants in water stress, in order to improve work performances during on-field activities. It is therefore important to carry out further studies to evaluate and improve the use of thermal imaging cameras combined with Smart Glasses in different working conditions, to highlight limits and opportunities of this wearable solution.



Application of geospatial models for suitability and distribution potential of citrus: a case study in eastern Sicily.

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Keywords. geostatistical software, citrus, spatial distribution, land cover

Abstract.

Climate changes are responsible of considerable effects on agriculture due to the variation of temperatures and weather patterns. Policy makers have implemented different actions for a transition towards sustainable food and agriculture reducing the impacts on the environment. The environmental monitoring is of utmost importance in the identification of these actions as it allows to protect the resources monitored, mitigate impacts and ensure a sustainable use of the natural resources.

Advanced technologies such as remote sensing (RS) and geographical information system (GIS), coupled with statistical tools, are helpful in determining the variation in the land cover due to climate changes. Based on the literature, the geostatistical tool *Software for Assisted Habitat Modeling Package* (SAHM) is a promising tool for environmental monitoring.

On this basis, this study contributed to monitor changes in suitability of a specific vegetation over time in a territory by using the SAHM tool. In the case study, the aim was to predict the citrus coverage variation in Eastern Sicily by the application of different geospatial models available in SAHM. Based on the bioclimatic data, current and future species probabilities of occurrence were studied in the Syracuse area by using different models (e.g., Maxent, BRT, Mars, GLM, and Random Forest). Comparisons between the results obtained using the different models were carried out and accuracy measures were analysed.

The results were provided through thematic maps and plots, showing the current and future suitability of the plants' presence at different bioclimatic conditions. The outcomes of this study are relevant for companies as well as to support territorial administrations in land use planning.



Hazelnut harvesting machines: recent advances and new trends

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Keywords. Agricultural machinery, hazelnut, harvester, agriculture 4.0.

Abstract. In the last decade, world hazelnut production has increased by about 25%. Italy is the world's second largest hazelnut producer after Turkey, the total area invested in our country is just over 92,300 hectares, marking an increase of over 20,000 hectares in the last ten years. The coriliculture production remains very concentrated, with 80% of the invested area located in only three regions, Piedmont (29%), Lazio (28%) and Campania (24%) and 19% in four other regions, including Sicily. There is, however, an increasing trend also in other regions: among these, Tuscany and Veneto stand out.

In order to meet a growing demand from the market, the development of newer harvesting machines in the hazelnut sector became mandatory. Italy is one of the main producers of hazelnut harvesting machinery. The need to adapt to different production areas, to business dimension which significantly vary among regions has resulted in a larger market offers with diversified solutions for both small and bigger farmers. The leading companies in the hazelnut harvesting mechanization sector have been therefore identified and their main products have been examined.

The purpose of the paper is to describe the innovations and technological advances implemented on these machines in recent years. All these improvements mainly aimed to increase their productivity and to improve safety and comfort for the operators.

Consequently, a taxonomy of the systems adopted for the hazelnut harvesting operations is presented, differentiated according to the type of machines used (tractor mounted mechanical harvesters, trailed vacuum harvesters, self-propelled vacuum and mechanical harvesters). The research also aims to present early applications of agriculture 4.0 technologies in hazelnut mechanized harvesting, with a specific focus on possible applications of precision agriculture technologies.



Obstacle avoidance safety system for agricultural tractors and autonomous vehicles based on Bluetooth and passive RFID

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Keywords. “agriculture”, “smart farming”, “work safety”, “obstacle avoidance”, “tractor”.

Abstract. Proper interaction of workers on foot and machines is a key aspect for safety analysis of agricultural and forestry operations. Autonomous vehicles might utterly increase accident probability and severity, meaning that such vehicles must rely on inherently safe designs and that better safety devices for workers should be developed.

An attempt to address these challenges for safer working contexts in future is represented by the “SMARTGRID” project, funded by the Italian National Institute for Insurance against Accidents at Work (INAIL), which designed a brand-new wireless safety network based on Bluetooth Low Energy (BLE) devices and passive Radio Frequency IDentification (RFID) tags. The whole point of its design is to rely on a multilayer infrastructure made of two wireless networks with very different performance levels, where the strengths of a system can fill the gaps of the other and vice versa.

SMARTGRID involves antennas placed on every vehicle in order to scan for the presence of nearby RFIDs attached on workers’ personal protective equipment. To complete the system, BLE beaconing systems are also placed on vehicles: such systems will both deliver alerts to nearby workers as they enter a higher-risk area and notify all the occurrences to a backend server to store statistical data for safety purposes.

System’s range of detection spans within 8 and 12 meters, but it may vary depending on tractor’s height and field conditions. Further test programs are underway in an experimental farm and will provide additional results by the end of 2022.



Evaluation of different flight courses with UAV in vineyard

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Keywords. Precision Agriculture; Unmanned Aerial Vehicle (UAV); Crop Surface Model (CSM).

Abstract.

Precision farming has consolidated the use of Unmanned Aerial Vehicles (UAVs), which have confirmed their role as excellent tools for data acquisition and analysis. These systems have wide operational flexibility, good flight autonomy and excellent spatial resolution of multispectral images, these prove to be more competitive in data acquisition than satellite systems, especially on small areas typical of Italian viticulture. Unfortunately, low know in literature about the flight course influence the extraction spectral and biometric information of canopy. For this reason, the aim of this work is to compare the different flight directions that can be performed with UAVs, to assess the differences in the acquisition of the spectral response of vineyard canopy and biometric characteristics. The vineyard is located in Camporeale, (Sicily, Italy); with only one typical cultivar (Catarratto). The surface area of the experimentation field is 8 ha. The distance between the vines is 2.2 by 1m. The vineyard has a rows orientation of NE-SW and the field presents two different orographic area. In specific, one of this area is flat and the other is hillside with medium-high slope. Remote images were acquired with a multi-rotor UAV, equipped with a camera with six multispectral bands, one RGB for visible light images and five monochrome narrow bands for multispectral image. A sensor has a field of view (FOV) of 62,7°, and downwards of 90° was used. The over-lap in front and side were 70%. Two flight courses were carried out, one direction was perpendicular and the other was parallel to the orientation of rows. The flight has done with a perfect weather; condition without wind. The results show there are difference in the reconstructions image that induction a variability in multispectral data and biometric parameters in the plants.



A Three Climbing-Robot for Spruce Pruning Operations

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Keywords. Climbing-robot, tree-pruning, mechatronic design, forestry-robotics, forest management.

Abstract. In recent years, the sustainable forest management has become a topic of great interest due to its potential to cope climate change. Indeed, forests act as a storage for CO₂, which is trapped as carbon in the creation of organic material, as well as they mitigate some of the adverse effects of climate (e.g., soil erosion, flooding, etc.). In addition, if wood is used as construction material, it still keeps the CO₂ trapped while, indirectly, it avoids the emission of new CO₂ as no other building materials are produced (e.g. concrete, plastic, etc.). It is therefore necessary both to preserve the forest (e.g., ensuring regeneration, wildfire protection, etc.) and to promote and made more remunerative the use of its products as construction materials. In spruce forests, a proper pruning operation could contribute to the ecological health and fire prevention. It also tends to increase the quality of timbers, especially if executed on live branches, as it reduces the generation of dead knots [1]. In this work, the design and development of a climbing robot for pruning spruce trees is presented. The system consists in a circular ring frame able to close and embrace a tree trunk. From this frame, three evenly space legs, equipped at their extremities with actuated-wheels, close against the bark through the action of elastic elements. This assures a proper contact force between the wheels and the bark (i.e., the platform is stable and capable to climb along the tree), whereas it allows the adaption to different trunk diameters. On the top of the frame a cart, carrying the cutting tool, moves around the trunk guided by a circular rail. In order to guarantee a proper branch cutting, the pruning shear is maintained at the right distance from the bark and in the right orientation by a passive system. A series of sensors collect information about the external environment and the branches to be cut (i.e., localization and diameter) [2]. This allows the control system to manage autonomously the pruning operation, while the operator has only to initially fix the robot to the trunk. The system is powered through an extensible cable from a battery located at the foot of the tree.

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A systematic analysis of new maintenance elements and factors of farm mechanization to be checked in the era of smart technologies.

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Keywords. Maintenance, tractor, precision agriculture, checklist

Abstract. The progressive digitalisation and electrification in agricultural yards require a rearrangement of the current management and maintenance models of tractors and implements. A checklist and guidelines for the maintenance of the digital electrical-electronic components of agricultural yards have been developed. The research focused on specialised tractors as they have always been one of the most essential agricultural machines to acquire a deep knowledge of their characteristics and components in three case studies: hybrid tractor with on-board monitor and VRA fertiliser spreader, tractor with on-board monitor with VRA sprayer, fully automated tractor (robot).

Booklets of the use and maintenance of machinery or singular components have been analysed and considerations on the increase of maintenance because of the higher technological level have been done. As it was possible to observe, there are some critical aspects due to the passage from traditional farming to 4.0. Many valuable resources, like computers, monitors and actuators, have been introduced, but this complicated the maintenance process, which is often producers' responsibility. This aspect has caused an increase in users' distrust of the so-called smart farming. The article discusses the issues and benefits of electrification and digitalisation of farm machinery and presents the challenges in its implementation for agriculture in Italy. The cases considered have demonstrated the high operational capacity of autonomous, electric or hybrid tractors and at the same time, they have highlighted the urgency of adopting innovative maintenance strategies, new tractors drivers' skills, and modern agricultural practices to maximise the operational efficiency of these agricultural machinery and studying new maintenance and repair coefficient now obsolete.



Concept of a Foldable Transmission Chain Used on Tobacco Leaves Harvesting Machine

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Keywords. joint; roller chain, transmission efficiency, tobacco harvesting.

Abstract. In several mechanical applications are used different kinds of articulated chains and within these probably the most used is the articulated roller chain. In a typical roller chain, a sequence of external and internal links is alternately arranged, and solids pins are used to link each of the plates of these links. Internal links are made up of two plates separated by mean of two bushes on which two rollers are free to rotate (Figure 1).

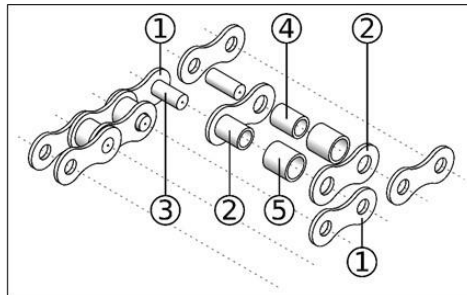


Figure 1. Main components of roller chain. 1 outer (external) plate; 2 inner (internal) plate; 3 solid pin; 4 bushing; 5 roller.

This paper highlights the main characteristics, the study and the engineering phase of a simple and low-cost different kind of joint that allows to fold any articulated roller transmission on a plane different from the operative one. The effectiveness and performance of this kind of joint, the modified roller chain has been used on tobacco leaves harvesting aiding machine during Kentucky Black tobacco harvesting operations. A Finite Element Analysis using Ansys Mechanical 2019 R3 software (Ansys, Inc., Canonsburg, PA, USA) was performed on the modified roller chain used in the work-aid machine employed in field tests by mean of a 3D model of two roller chain links and of the first element of the ring chain at the interface between roller and ring. The good performance of the tobacco leaves work-aid harvester in which roller chains fitted with the created articulated joint have been mounted, did not show any deterioration in terms of productivity, strength, efficiency, and reliability and therefore highlighted the correct behavior of the aforementioned device.



Improving combine harvesters management through CAN-BUS data analysis

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Keywords. CAN-BUS, Task classification, Real-world data, Combine Harvester

Abstract.

In a global market, where the prices of agricultural commodities are so volatile and the prices of the inputs increase, it is very difficult for farmers and agricultural contractors to obtain at the end of the agricultural season a consolidated profit.

To help them to achieve this aim, over the years the agricultural manufacturers have designed increasingly efficient agricultural machinery in terms of capacity and reliability, but this solution is not sufficient. It is also important to carefully plan the actual usage of the machines, for example in the case of harvesting, where the harvesting time must be optimised in order to reduce the waste of time and input that at the end could increase the costs. The aim of this study is to evaluate the operational efficiency and energy performance of two selected combine harvesters, during harvesting time, and provide to farmers and contractors information that help them to make operational and economically informed decisions regarding optimal fleet management during harvesting time, in order to reduce the harvesting costs and sustain overall profit.

The data for the study was acquired as CAN-BUS data, from two New Holland harvester combines, operating in real world condition, during harvesting season 2020 in the Province of Bologna (Italy). The data was analysed, by using the MATLAB® suite, to obtain information about fuel consumption [$l \cdot ha^{-1}$], operational capability [$ha \cdot h^{-1}$], yield per field [$t \cdot ha^{-1}$], worked area [ha] and operational state identification.

The results show that the harvesters spent about 20% of their time in the idle operating state, about 66% of the time on actual harvesting and about 7% of the time on in-field transport, the 2% of the time for road transport, about 6% of time on unloading and less than 1% of the time on harvesting and unloading contemporarily. The large amount of time spent in the idle state instead on harvesting, potentially depend on inadequate work planning, especially the planning of the transport logistics, which forced the combines to halt operation several times. The sum of these forced stops, inevitably impact the overall cost of harvesting and on the operational capability, and this causing increased harvesting costs and a reduction of the end-of-year revenues for farmers and contractors.



Legal Framework for Autonomous Machinery

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Keywords. Legal framework, autonomous machines, environment, agriculture, economic benefits

Abstract. The progress of Artificial Intelligence, robotics, and Remote monitoring systems has enabled the development of agriculture machines to intelligent Autonomous Machine (AM) level. Still many decisions on field applications depends on the machine operators. The decisions may vary from driver to driver and can still be a range of requirements. Talking about AM, they must be constructed to make their own judgment according to the natural, road or outdoor conditions. The AM must decide how to behave in different situations and do the job as human operator does. Furthermore, these machines constructed to communicate with other vehicles and surrounding environment. Although autonomous machinery should be capable carrying out the assigned work. Currently, the autonomous machines are not capable to handle all possible failures and unexpected situations. Secondly, computer science has to play a significant role for implementing the objectives and goals for the autonomous machines. To make machine self-aware the certain norms, rules, restrictions must be implemented too.

Another important issue is the legal basis. Economic analysis indicates that autonomous machinery positive economic and environmental benefits for agriculture, but those benefits will only be realized if policy and regulations are enabled. Autonomous machines now is constructed under a standard for industrial equipment (ISO 3691 4). This standard does not require on site supervision, does limit speed to 0.8 km/h. The main question is who takes the responsibility for the accidents caused by autonomous machines, the impact on people and the environment. The target is, make autonomous machines conform to the rules, but not to structure the rules so that they can conform with autonomous machines. Currently, rules governing autonomous field equipment varies from almost none to quite restrictive. Some example shows that human supervision requirements could reduce the economic benefits from autonomous field equipment, especially for small and medium scale farms. In general, regulation of autonomous machines will influence adoption to the technology and determine who benefits.



Pig farming in the Abruzzo Region and hepatitis E virus detection in swine slurries.

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Keywords. Foodborne viruses, waterborne viruses, zoonotic transmission.

Abstract. Hepatitis E virus (HEV) infection is a recognized emerging zoonosis whose sporadic autochthonous cases, unrelated to travel in endemic areas, are rising in industrialized countries. Pigs and wild boars are considered its main reservoirs. The ongoing project "*Improving understanding of autochthonous Hepatitis E transmission routes: a focus on foodborne and waterborne pathways*" concentrates on the Abruzzo Region in Central Italy, where a high prevalence of anti-hepatitis E IgG (48.9%) was shown among blood donors. Herein we summarize the preliminary outcomes from monitoring campaigns and the organization of swine farming in the Abruzzo Region.

Based on the National Zootechnical Register (data as at 31/12/2019), pig husbandry is mainly a family business, and pig farms often host few animals. For most animals, rearing occurs in a minor number of specialized structures mainly devoted to reproduction (open cycle) and fattening of animals. A statistical survey showed that the territory features affect the distribution of pig production structures (53% of the fattening pigs occur in six municipalities while three other municipalities host a large part of the animals in reproduction facilities).

Samples of swine slurries taken from the storages of chosen specialized production sites throughout the Region underwent analysis to identify the presence of HEV strains. The results showed that some sites were positive for HEV belonging to the zoonotic genotype 3 and displayed a high degree of genetic identity with the strains detected in autochthonous HEV cases. The simultaneous detection of HEV RNA genotype 3 in the urban wastewaters of Abruzzo, which reflects a not negligible viral circulation in the population, opens issues to the potential connection between the findings. Further monitoring campaigns will clarify this and will be helpful to set out guidelines to improve husbandry and farming practices, and to increase population protection from HEV.



Optimizing sprayer setting for ozonated water to improve plants disease control efficacy

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Keywords. Integrated Pest Management, Ozone, Spray Droplet Size, Air Speed

Abstract. The environmental and socioeconomic constraints force the agricultural sector to find alternative plant protection solutions. As a result, several alternative plant protection products (PPP) have been developed in the last decades. Ozonated water sprayed on the vegetation proved to be a partial alternative to agricultural chemical PPP for fungal and bacterial plant disease. The ozonated water efficacy is related to the production of reactive oxygen species (ROS). At the same time, ozonated water showed no significant phytotoxicity when the spraying was carried out under well-ventilated conditions.

In the present study, an electrolytic ozonating water tool was installed on a commercial mist-blower axial sprayer then the redox potential was measured to assess the sanitizing effects on plants due to ROS concentration. First, the redox potential (ORP) was measured inside the tank, after the pump, at the nozzle level, and on a test bench that simulates the vertical wall of the plant. Next, the redox growth rate was measured at each point to assess the system's latency. Then, different nozzle types and fan speeds were used to measure the effect of different droplet sizes on redox potential.

According to the result, redox potential decreases by 7%, 15%, and 11% after the pump, at the nozzle, and the test bench, respectively. These losses are affected by the droplet size and they increase in the case of a smaller droplet. The use of air-inclusion nozzles decreased the redox potential loss by reducing the exchange between the ozonated water and the atmosphere. The founding presented in the eventually accepted paper delineates essential considerations for applying ozonated water as an alternative to conventional plant protection products.



Stability of Agricultural UGV prototype

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Keywords. Precision agriculture, autonomous vehicle, tipping, angle, safety.

Abstract. The work aims to evaluate the stability of an Unmanned Ground Vehicle (UGV) prototype, developed by the University of Bologna for precision orchard and vineyard management. The peculiarity of the machine is in the driving part moving autonomously in the field combined to a tank to store water and pesticide mixture for crop protection together with an additional structure to carry agricultural implements. The study concerned evaluating the stability of the agricultural UGV without implements and mounted with a mulcher and a sprayer. In the case of the sprayer, the stability behavior was evaluated with empty and full tank. Stability has been studied both laterally and longitudinally to the machine. A theoretical model was developed based on the upstream side forces measured during experimental tipping tests. The results of the experimental data were compared with the theoretical predicted results to validate the model. The results of the model were statistically correlate ($R^2 > 95$). The results obtained showed that the most stable condition occurs was the case of UGV fitted with mulcher in longitudinal tipping position, while the most unstable condition was the case of naked UGV always in the longitudinal tipping. The stability angle was in between 40 and 56 degrees. Although the stability problem is not directly connected with the operator, as these machines do not require a driver, the lack of stability can lead to the UGV overturning with consequent problems for the surrounding environment and for the UGV itself.



Design, Setup and Test of a 3-section Foldable Rear Rollbar for Low-Power Tractors

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Keywords. Low-power tractors, vineyard, ROPS, 3-section foldable rollbar, virtual and real tests.

Abstract. In Italy, vineyards are cultivated mainly on slope terrain; moreover, the viticulture mechanization is typically characterized by low-power, narrow-track tractors, showing a lower stability than the traditional models. This combination leads to a high probability of overturning, made often worse also for the coupling with heavy implements and/or wrong maneuvers. The most effective measure, recognized from decades worldwide, to protect the driver in case of overturning is to fit a roll-over protective structure combined with the diligent use of the safety belt. On the narrow-track tractors, a two-pillars front mounted tiltable rollbar is frequently fitted. Sometime, as an alternative, they are equipped also with two-pillars rear mounted partially folding rollbar. In any case, the tilting/folding function is normally used when travelling among the vineyard rows, to avoid damaging of the canopy and in particular the grapes, due the unexpected contacts with the rollbar. Moreover, the tilting/folding is useful to make possible the entering in sheds or garages with low height doors. Theoretically, only in these two operating conditions the rollbar could be in horizontal or folded (rest) position, while in all the other working situations it should be in vertical (protection) position.

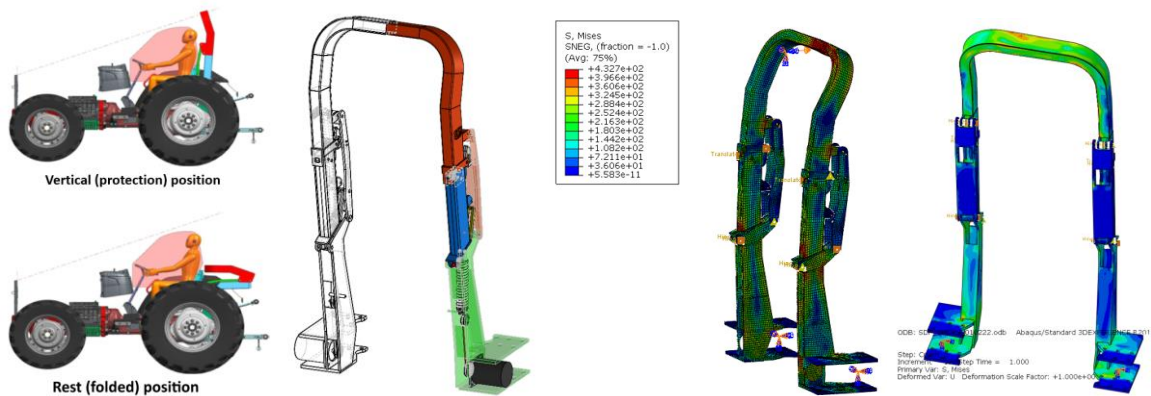
The transition between the rest and the protection positions is normally carried out by hand, but this task is very often neglected, because generally considered tiring and time consuming. Therefore, the rollbar remains in rest position at any time, so assuring absolutely no protection in case of overturning. This occurrence was recorded as being the main reason of tens of fatal accidents of tractor overturning happened every year in Italy.

The introduction of automatic or semi-automatic systems to manage the rollbar position depending on the working conditions, such as slope, travelling speed, steering angle, etc. could solve the problem. For this purpose, a new 3-sections folding rear rollbar was designed, to be fitted on a new narrow-track tractor model to be launched soon on the market. The movements of the rollbar are driven mechanically, using a four-bar linkage solution, and are based on the release of the unlocking system, the lifting step (i.e. the activation of the actuator) and the locking step (engagement of the locking system). For



the transition from safe and rest positions the same steps are provided, of course in opposite order. To assure a suitable strength in case of overturning, the rollbar was conveniently sized, taking into account the reference mass of the heaviest tractor model on which the ROPS will be fitted.

Later, the prototype was subjected to a virtual test using Abaqus software for dynamic analysis following the requirements of the corresponding OECD Code. After this research step, a physical specimen of the rollbar, conveniently fitted on the tractor, was subjected to a real test, consisting in some horizontal and vertical loads. The only requirement for the positive outcome of both the virtual and real tests is that the so called “clearance zone” (i.e. a volume representing the driver’s position normally placed on his/her seat and grasping the steering wheel) is protected against the entering of any ROPS structural component and any possible terrain interference. Particular attention was devoted to the devices executing the various movements of the 3 rollbar sections, to assure the highest robustness in case of overturning and the best reliability in the time.



From left to right: vertical (protection) and rest (folded) positions of the 3-section rollbar; detail of the folding mechanism; discretization of the rollbar; an example of colour output showing the dynamic stress and strain condition of the ROPS after a strength test.



Environmental Impacts of Real Gaseous Pollutant Emissions of Agricultural Tractors

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Keywords. Agricultural tractors, environment, gaseous pollutants, particulate matter, nitrogen oxide and dioxide

Abstract. The gaseous pollutants produced by the internal combustion engines fitted on vehicles powered with fossil fuels are considered one of the main sources causing the global warming and consequently the climate change. The main pollutants found in gaseous emission are carbon monoxide (CO), unburned hydrocarbon (HC), nitrogen monoxide and dioxide (NO_x) and particulate matter (PM). In this scenario, the agricultural self-propelled machinery, in particular tractors, are believed to have a significant role, due to the generalized fitting of diesel engines, producing important amounts especially of NO_x and PM.

From 1996, the EPA (Environmental Protection Agency) in USA and the European Commission issued roughly at the same time parallel standards containing a sort of road map for the massive reduction of these gaseous pollutants. The Standards were based on steps (respectively named TIER and Stage followed by a roman numeral suffix) referred to the time, defining progressively stringent emission limits relevant NO_x and PM for diesel engines, in terms of g/kWh, classified in some engine power classes. The compulsory application of these limits engaged at the highest level the engine manufacturers for reducing the emissions amount: just to give an idea about the effort made, passing from Stage I to Stage V the limits of the pollutant decreased by 98%. Nevertheless, the compliance of an engine to a given step is referred to specific homologation tests. At present, no subsequent tests are provided to check the conformity of the engine along its service life. Consequently, there is no assurance that the engine is respecting the emission limits provided by its homologation step, especially in case it is heavily used and is not submitted to a diligent periodical maintenance. To ascertain the real pollutant gaseous emissions of used tractors, some models equipped with engines respecting different Stage/Tier levels were tested, using a dedicated instrumentation chain, by measuring in detail the PM and NO_x emissions, in comparison with an old tractor model, which engine is out of the standard application period. Moreover, the pollutant gaseous emissions were evaluated applying the Life Cycle Assessment tool, to assess environmental impacts associated with the flora and/or fauna, such as climate change, destruction of the ozone layer, toxicity, acidification, etc.



Development and Experimental Evaluation of a Tractor Roll-Over Stability Model

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Keywords. Stability model, machinery stability, roll-over stability, static stability test, stability on sloping terrains.

Abstract. The roll-over stability is one of the main issues that affects agricultural tractors/machinery, and earth-moving machines operating in hilly or mountainous environments. Indeed, on average, there are more than 100 fatal accidents every year in Italy due to tractor roll-overs. In the best cases, when operators are not or only minimally injured, they cause considerable damage to the vehicles as well as the loss of income from missed work [1]. Therefore, creating stability models to study the behavior of existing vehicles operating in hazardous conditions results very important, especially if they are designed to work in flat surfaces. These models can then be integrated into the vehicles control systems in order to warning the operator when instability is approaching, or to implement automatic countermeasures to prevent it [2]. In this work the model for determining the stability of a generic agricultural vehicle is presented. It is developed in Matlab environment and it is based on the determination of the forces discharged to the ground by the wheels/tracks. Different vehicle configurations can be considered such as conventional tractor, tractor with isodiametric wheels, tracked tractor, vehicles with rigid or articulated chassis, presence or not of implements, etc. Moreover, a multitude of slope conditions can be studied, evaluating for example the most common lateral roll-over, or the motion of leaving a crop row and entering in the next one. The model has been validated through a series of experimental tests on real machines, considering some reference case studies. For this scope, a rig for testing the stability of vehicles available at the Agro-Forestry Innovation LABORatory (AFILAB) of the Free University of Bolzano has been exploited. It consists in a rotating platform able to move a machine positioned on it (up to a weight of 10 tons) according to two rotational degrees of freedom: (1) support plane inclination, (2) support plane rotation around an axis normal to its surface. Moreover, the support plane can change its conformation and simulate uneven terrains with presence of bumps or potholes. A series of load cells, integrated into the support plane, measure then in real-time the forces discharged to the ground by each wheel/track.

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Whole-body vibration for tractor drivers

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Keywords: Body index, effect vibration on health, tractor driver vibrations, vibration

Abstract. This Among the main health risks for operators in the agricultural sector, exposure to mechanical vibrations is certainly one of the most difficult factors to quantify, in relation to the continuous and heterogeneous use of agricultural machinery during the agricultural year. According to data provided by the European Agency for Safety and Health at Work (EU-OSHA), 24% of workers in the European Union are exposed to mechanical vibration. At national level, 21% of Italian workers are exposed to the risk of this physical agent.

In the light of this data and in order to avoid the consequences of exposure to vibrations on workers' health, it is therefore necessary to carry out a risk analysis in the workplace and, where necessary, to take appropriate preventive measures.

The aim of the following work was, therefore, to measure vibration exposure and disturbances that can be transmitted while driving agricultural tractors. In particular, the vibrations transmitted to the seat at the lumbar spine, lumbosacral spine and cervical-dorsal junction were assessed.

The results showed that the vibrations were evenly distributed over the entire spinal column without statistically significant differences depending on the areas sampled. In some cases, higher accelerations were observed in the cervical-dorsal area, probably due to the vibrations transmitted by the steering wheel.

The analysis of whole-body vibration transmission in relation to the different fat mass (BMI) of the operators involved in the tests showed no significant differences.



Risk perception in forest utilizations: experimental analysis in the Basilicata forest sites.

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Keywords. Injuries, Risk perception, Occupational, forest utilizations.

Abstract. The present legal framework for the protection of health and safety in the workplace, established by Legislative Decree 81/2008, has identified the “work-related stress” as one of the risks to be assessed, according to the contents of European Agreement of 8 October 2004, and the importance of its management.

The present analysis deals with an important subject as the workplace safety, in particular the risk perception and the work-related stress of the operators in the agro-forestry sector.

The sampling plan was based on the delivery of structured questionnaire.

A total of 378 operators participated in the survey (171 women and 207 men).

The overall response rate for the survey was 100%.

Results showed that the accident and safety sector cannot be and should not be considered only as a repressive instrument to identify specific violations or responsibilities to be punished.

It must instead be considered as a tool for better identifying measures and strategies to eliminate or to minimise the risk perception and the work – related stress in the same or in a similar working environment.



Development of a test bench for vibration measurements of hand-held harvesters for olives

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Keywords. Hand-arm systems, ISO 5349-1, safety, health, HAV.

Abstract. Olives harvesting is the most expansive activity among cultural operations, so its mechanization is essential to reduce production costs. For this reason, especially where full mechanization is not possible due to structural conditions such as low tree density, old trees, irregular spacing, and terraced fields, which are very frequent in many small Italian farms, the use of hand-held vibrating harvesters is quite wide spread. However, these machines expose the operators to high vibration risks of their hand-arm system, often underestimate by the users themselves, mainly interested in productivity.

The transmission of the vibration and its propagation in the organism through the hand-arm system is a complex phenomenon that involves several factors among which the working conditions (idling or full-load) and the operator characteristics (weight, grip force, ability). So, the assessment of the effective risk requires direct measurement under real working conditions or the definition of standardized procedures able to provide reliable acceleration values.

Although this need has been known for some time, there is still no a unified regulation for this purpose. Consequently, at the Section of Mechanics and Mechanization of the Department of Agriculture, Food and Environment, a test bench has been developed to simulate the effect of the branches during the measurement of the acceleration produced by hand-held harvesters. In the design of the test bench, the experience carried out with the device developed by Deboli et. al. (2014) has been considered. The test bench has an aluminum frame with a working area of about 1.5×1.5 m positioned at a minimum height of 1.5 m and allows testing all the main models of held-held harvesters available on the market. The working area consists of vertical and horizontal nylon threads with adjustable spacing and tension to simulate the crown of the plant and to provide the load during the test. The threads are stretched by means of springs and simultaneously preloaded by moving a vertical and a horizontal bar of the frame to which the same springs are attached. By fixing the space between the threads and their tension, the load conditions for the machine under test should be almost constant and the measurements should be reproducible over time.

Deboli, R.; Calvo, A.; Preti, C.; Inzerillo, M., 2014, Design and test of a device for acceleration reproducibility of hand held olive harvesters. *Int. J. Ind. Ergon.* 44, 581–589, <http://dx.doi.org/10.1016/j.ergon.2014.05.007>.



Buildings for citrus juices and essential oil manufacturing: the floor design

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Keywords. Essential oil, safety slipperiness, floor materials, wear safety, agri-food industry safety.

Abstract.

It is essential to pay equal attention in the agroindustry buildings design to all systems and components, but the floor design is very often neglected. The hot oils, greases and chemicals used in processing invariably end up on the floor and corrode the surface. Thermal shock from hot water wash downs crack and disintegrate weak surfaces and frequent impacts from heavy machinery, foot and vehicle traffic dent, damage and destroy unprepared floors. In particular, within the processing area of citrus juices and essential oil, floors can be subject to spillages of water, essential oil, citric acid, natural chemical substances contained into citrus products, generating both a slip and hygiene risk. These substances can generate safety problems related not only to slipping and cleanability but also wear, and deterioration, which they put down to a choice of the wrong floor material.

The essential oils on the market are mainly obtained from vegetable substances and in particular from citrus fruits, using low-value materials such as rind, pulp and seeds, remaining parts of the production activities. The fruits of all citrus species constitute a potential source of essential oils and are of commercial interest, such as lemon, orange, grapefruit and other more particular ones such as bergamot, a typical citrus fruit of the south Italy, whose essences are used in the food, cosmetic and pharmaceutical industries.

Essential oils are composed of a volatile and a non-volatile part, the latter consisting of numerous substances such as: fatty acids, waxes, coumarins, psoralens, flavonoids, etc.

A study was carried out on the right solutions design of the floor in the buildings for citrus juices and essential oil manufacturing. Were analysed the floor main performances, in respect to workers safety, hygiene risk and management in use, to choice the more suitable floor material. Were evaluated the effects that a spillage of citrus essential oils and juice has on the surface characteristics of flooring from more traditional ones, such as ceramic ones to the most innovative ones such as resins.

The test were carried out in accord to international standard or national rule as the Italian Ministerial Decree 236/89 to evaluate the dynamic friction coefficient for slip risk, measured with the Tortus tribometer, or specific tests, to assess the level of cleanability and wear resistance of the flooring.



Influence of surrounding gas composition during clarification using a vertical disc stack centrifuge separator on the final quality of EVOO

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Keywords. EVOO, Clarification, Modified Atmosphere Plant, Oxidation

Abstract. The disc stack centrifuge separator (DSCS), used to clean the extra virgin olive oil (EVOO), is one of the main source of oxidation occurring during the extraction. It is due to the intimate contact between the oil and the environmental air-oxygen caused by the action of the high rotational speed of the disk stack inside the drum. Despite many studies highlighted the negative effect of the use of DSCS on stability, oxidation level, nutritional quality and the storage time, industrially valid solutions have not yet been proposed. In this study, a disc stack centrifuge separator prototype working under modified atmospheres (MA) was designed and modified by the Authors and two working conditions were tested: a. unsealed DSCS using $O_2=0$ kPa, $N_2=95.00$ kPa, $CO_2=0$ kPa; b. sealed DSCS in air; $O_2=19.76$ kPa, $N_2=74.86$ kPa, $CO_2=0.028$ kPa. The results obtained with MA separation were compared with those in standard conditions (c. unsealed DSCS in air; $O_2=19.76$ kPa, $N_2=74.86$ kPa, $CO_2=0.028$ kPa). The comparison of EVOO by treatments have been calculated and compared as relative variation percentage (RelVar%) for each quality parameters with respect to the standard condition, making in this way the treatments comparable with respect to each parameter. The results unravelled as there has been a prominent improvement of the oxidative state compared with control. The highest ranked treatment was related to the sealed DSCS, corresponding to lowest number of peroxide (4.67 mEq O_2 /kg), acidity levels (0.19%), and conjugated dienes ($A_{232}=1.19$) and trienes ($A_{270}=0.08$). The control treatment was characterized by a lower turbidity index, carotenoids and water content. As consumers are increasingly interested in the health properties of EVOO, companies are investigating new approaches to improve quality and this study provides for hints to design EVOO clarification systems.



Hi-power Ultrasound Machine to improve the efficiency of olive oil extraction process

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Keywords. Sonication, ultrasound, olive oil quality, extractability, olive paste.

Abstract.

The present research aimed to improve the performance of the olive oil extraction plant, using an innovative hi-power ultrasound machine. Starting from the positive results obtained in other researches carried out by the same authors,[1,2,3] an automated hi-power ultrasound machine (HUM) has been developed and installed in an existing olive oil extraction plant, placed between crusher and malaxer machine. The machine was composed by 4 treatment cells in series arrangement, housing a sonotrode each one. Each sonotrode was controlled by a power unit and a control panel. A PLC controlled all units and managed the olive paste flow passing through the machine and, also, a pneumatic valve installed at the output section of the machine in order to assure a constant pressure inside the treatment cells. Experimental tests were set up to evaluate the HUM, in comparison with the conventional arrangement. The machine was tested to work at high flow mass rate of olive paste and permitted to condition the olive paste in addition to a short malaxation phase. The extractability values registered higher values than those obtained by the conventional arrangement of the plant. The hi-power ultrasound treatment permitted to obtain a better quality of final oil. In conclusion, the HUS shown good capability to condition the olive paste improving the separation phase. This technology could be a promising tool to improve the olive oil extraction process performance in terms of extraction yield and quality of oil obtained, and by simplifying the layout of plant.

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Potential application of hyperspectral imaging and FT-NIR spectroscopy for discrimination of soilless tomato according to cultural practices

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Keywords. Water use, sustainability, PLS-DA, spectroscopy

Abstract. This study was aimed to evaluate the suitability of hyperspectral imaging (HSI) and Fourier Transform (FT)-NIR spectroscopy for classifying sustainable-produced tomatoes according to applied cultural practices. Three different cultivation management strategies for water and fertilizer use were applied: i) free drain open cycle cultivation (OPEN); ii) open cycle cultivation with on-demand sensor-based fertigation (SMART); iii) closed cycle cultivation (CLOSED), across two cultivation cycles for two varieties (cv Carminio, for the autumn-winter cycle and cv Mose for the spring-summer cycle). Reflectance spectra were acquired using two HSI spectrographs in Visible-Near Infrared (Vis-NIR) and NIR ranges, and a FT-NIR spectrometer, for about 300 fully ripe tomatoes per variety. For each cycle and variety, a partial least squares discriminant analysis (PLS-DA) was first aimed to discriminate for the management cultivation system and then for water and fertilizers use efficiency (WUE and FUE), having only 2 levels for cycle. The final objective was to propose a general model for discrimination of 3 levels of WUE and FUE, merging the data of the 2 varieties, which was further optimized for the number of variables. Model performance were higher when using FT-NIR and HIS in the Vis-NIR range, but the last one was preferred in term of number of latent variable used. Good performance on external prediction sets were obtained for discriminating tomatoes from three cultural practices (Accuracy = 81%; Specificity = 86%) for each variety. In addition, an excellent performance was reached by classifying tomatoes in two different levels of WUE and FUE with accuracy, specificity and sensitivity higher than 95%. Finally for the general models, based on 3 WUE levels, over the 2 experiments, only 20 significant wavelengths were selected using Vis-NIR spectra using IPLS variable selection method and a repeated double cross validation (rDCV) technique yielding accuracy and specificity of 89.8% and 91.7%, respectively. Results of this study indicate promising potential of these techniques for the authentication of agricultural crop grown with low inputs, which need further validation across different production environments and years.



Experimental analysis of chainsaw emissions in chestnut wood operations

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Keywords. Injuries, chainsaw, forest utilizations, occupational health, noise.

Abstract. In the Italian primary sector, especially in the forestry, portable equipment, and in particular chainsaws, are widely used.

The chainsaw is the main machine for felling, limbing and sawing logs and timber.

We can state that the widespread use of chainsaws in Italy is due to the orography of the territory, the small-medium size of the farm and the composition of the woody capital (prevalence of broadleaf trees governed by coppice).

The wood material is therefore generally of low quality and does not allow investment in "high" mechanisation.

However, with the spread of chainsaws, there has been an increase in the incidence of diseases caused by exposure to physical agents (noise, dust and vibrations), chemicals agents (volatile compounds of various kinds), and an increase in serious accidents.

The updating of occupational health and safety regulations in Italy has followed several stages, most notably the approval of the U.T. 81/2008.

The present work pursues the following objectives

1. To assess whether the concentration of pollutants contained in chainsaw exhaust gases complies with the limits set by current legislation during operations on a chestnut coppice;
2. To evaluate the noise emitted by the chainsaw during the exploitation of a chestnut coppice.

A professional dosimeter (phonometer) was used to assess noise, and it was found that the legal limits were exceeded during all chainsaw operations, with peaks of over 110 dB.

For the assessment of volatile pollutants, a multi gas detector capable of detecting different types of gas was used.

The analysis showed that only during the limbing operation were the legal limits respected.



Effect of Image Binarization on Drop Diameters Measurement

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Keywords. Image analysis, Threshold, Droplet spectrum, Pesticide application.

Abstract. The measurement of droplet size spectrum of nozzles is a very complex task that has been addressed in multiple ways over the years. Referring to agricultural nozzles for pesticide applications, the drop size affects both biological efficacy of a phytosanitary treatment, environmental pollution, and operator safety. According to the International Standard ISO 25358, the droplet size spectrum can be measured with any non-intrusive measuring system, appropriate for the range of droplet size and velocity. Examples of non-intrusive systems are Phase Doppler Particle Analyzers (PDPA), laser diffraction, and imaging principles (also known as shadowgraphy methods). Intrusive methods are also quite common in the literature, which include the liquid immersion technique and the use of Water Sensitive Papers (WSP).

Both intrusive and non-intrusive techniques allow measurements with different degrees of uncertainty and each measurement method produces results significantly different, depending on measuring protocol, settings and type of measuring equipment. Measurement methods based upon image analysis, such as high-speed imaging, WSP and liquid immersion, have to solve the problem of recognizing the drops and separating them from the background. This is known as “binarization” or “segmentation” of the image, and usually it is accomplished by setting one or two (upper and lower) cut-off value(s), referred as threshold, separating specific pixel intensities from each other. The choice of the threshold value is a key aspect and it may be manual or automatic, by applying different algorithms.

In this research the drop size spectrum of an air induction hollow cone nozzle TVI 8002 at the pressure of 1.0 MPa was studied. Measurement of the drop size was based on the liquid immersion method. A starting threshold value was selected based on the average gray level of the image. Variations of $\pm 5\%$ with steps of 1% were considered and their effects on the measured volumetric diameters were analyzed. The first results showed that the corresponding variations of volumetric diameters ranged from -0.20% to 0.16% for D_{v01} , from -0.03% to 0.85% for D_{v05} and from -0.52% to 1.03 % for D_{v09} . This means that, once the image acquisition system is established, the binarization process may be made automatic and operator independent.



NEW TECHNOLOGIES AND SAFETY IN AGRICULTURE: SAFETY AR

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Keywords. "safety at work", "technologies", "augmented reality", "normative compliance", "agriculture"

Abstract.

New technologies, such as augmented reality or artificial intelligence, are able to offer contributions to delicate sectors of our society, such as the world of safety at work.

Suffice it to say that in 2021 in Italy accidents at work increased significantly and fatal cases were 1,270, 181 more than the 1,089 in 2019 (+ 16.6%). Against a reduction in deaths of about 30.1%, those occurring at work have in fact increased by over a third (+ 34.9%). Important numbers that make us reflect on the importance of correct training and information on safety at work as required by the European directives implemented by Legislative Decree 81/2008 in Italy.

One of the main problems in the world of agriculture appears to be the total negligence of employers in respecting the training and information obligations towards workers. For this reason, the University of Tuscia has developed, at the end of intense research, an augmented reality system called Safety AR, through which workers and also employers, pursuant to the very recent d.l. taxation and safety (146/2021), can train and inform themselves about the risks present in the workplace and avoid injuries or, in the most serious cases, white deaths.

Safety AR is an innovative multifunctional tool, which identifies the real needs of every single production process with an interactive and functional approach. Safety AR is accessible thanks to one of the most innovative technologies of the moment, recognized by the national development plan among the enabling tools of industry 4.0 because it increases real-world interactions without replacing it.

The Safety AR allows you to reproduce the safety pictograms on "markers", that is aluminum signs, which once framed by the workers through a phone / tablet and an application, will be animated in augmented reality explaining the meaning of the pictogram and the various risks and dangers. The data extracted from the Safety AR will be treated with the utmost respect for the confidentiality of the worker. Through this system, an important decrease in accidents at work is estimated.



Potential application of Vis-NIR Hyperspectral Imaging for online sorting of defective Goji Berry (*Lycium barbarum* L.)

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Keywords. Water use, sorting, PLSDA, spectroscopy, fruit quality, damage

Abstract. Goji berries are widely recognized for their outstanding health benefit and antioxidant properties. The fruit is very susceptible to mechanical damage and physiological disorders leading to quality depreciation and rapid loss of marketability. Therefore sorting high quality goji berries is very critical also for the small dimensions of the fruit which make the manual selection on conveyor belt impracticable. Hyperspectral imaging (HI) was used for the detection of main common defects. A panel of expert divided the fruit in 4 classes, sound, mild damages (i.e. visual damage, softening, bruise), moderate damages (i.e. pitting, initial mold), and severe damages (i.e. severe mold). Partial Least Square Discriminant Analysis (PLSDA) with repeated double cross validation was used with the aim of discriminating 2 classes (sound and defective) and for 4 classes (sound plus 3 defective classes) of fruit. The model with 2 classes gave excellent result (sensitivity and specificity higher than 96%), were the model with 4 classes gave higher error, particularly for the intermediate classes (sensitivity around 70% and specificity higher than 86%), while sound and severely damaged fruit were discriminated with higher accuracy. Considering that the main objective of sorting is to discard defective fruit, results of this study are very promising for developing non-invasive and reliable methods for early detection of common disorders in goji berry fruits and generally in small berries.



A Deep Learning Artichoke Plants Identification Approach for Site-specific UAV Spraying

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Keywords. Single Shot Detector, Multi-target Object Detection, Multi-temporal Tracking, Site-specific Management, Precision Agriculture

Abstract. Precision Agriculture practices allow input management optimization, environmental impact and production cost reduction, and product quality increase. The new approach derived using Unmanned Aerial Vehicles (UAVs) in combination with Deep Learning techniques is leading to a significant improvement in the management practices of agricultural systems. The aim of the study is the precise identification and the georeferencing of individual artichoke plants as a first step to develop an on-the-fly UAVs aerial spray treatment system. Furthermore, all the gathered information is used to monitor spatial and temporal crop development. During the 2021-2022 season, a large number of images were acquired by an RGB sensor mounted on a DJI Phantom 4 Pro UAV within an artichoke field located in the countryside of Uri (Sardinia, Italy) in different growth stages of the crop. From the data collected in each mission, an orthophoto of the entire field was generated and labeled to train an object detector capable of identifying artichokes inside the field. The trained SSD object detector was developed from a Feature Pyramid Network structure, a type of convolutional neural network that is particularly efficient for dealing with multiscale features and detecting objects at different scales that allows the UAVs to fly at different heights without losing detection performance. The experimental results, computed at the different stages of the study, showed a high detection level with an average F1 score of around 90%. This value, a measure of accuracy, is widely used in the field of object detection. Furthermore, the evolution of the growing index was evaluated, confirming, as expected, that the growing process is stronger during October, reaching the maximum at the beginning of December. The presented results highlight how the proposed approach contributes to designing reliable site-specific UAV prescription maps and can lead to a precise identification of critical zones.



Assessment of vine and cover crop vegetation indices using high-resolution images acquired by UAV platform

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Keywords. Precision viticulture; spatial analysis; sustainability, vineyard management

Abstract.

In recent years, there has been an increasing need to implement sustainability in agricultural systems, especially for the risks associated with soil degradation. Cover crops are widely recognised and adopted for sustainable vineyard management, reducing soil and water losses, restoring organic matter, and increasing soil fertility. Therefore, it is necessary to determine the biomass development of cover crops using alternative and innovative methods. High-resolution UAV-based multispectral images can be used for this purpose, giving significant information for monitoring the seasonal growth variation of crops. The aim of this research was to study the biomass vigour spatial variability of cover crops and vineyard evaluating the possible correlation between cover crop and vineyard vigour values. Cover crop biomass was monitored by sampling during flowering, measuring fresh weight and dry weight. The vine vegetative growth and yield were measured during the growing season. The multispectral images were obtained with the use of a UAV before the cover crops were buried (March); the spectral response of the vineyard was evaluated with UAV flights during the summer period. The analysis of the vigour maps obtained showed a degree of variability for the vegetation indices examined. This variability was found both on the cover crop biomass development and on the vegetative growth of the vineyard. The results showed the applicability of remote sensing to monitor cover crop and vineyard biomass development, explaining the overall variability of the field. This information allows the application of the appropriate agronomic techniques to improve the quality of the production.



High and medium resolution, optical and SAR satellite data fusion for aquaculture ponds mapping in Brazil

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Keywords. fishponds mapping, aquaculture, land use land cover; google earth engine (GEE); SNIC; GLCM; random forest (RF); machine learning

Abstract. In the last decade, aquaculture in Brazil has grown substantially due to the high request for fresh fish products in the national markets. This activity can threaten wetland habitats without proper environmental and landscape planning and management. The uncontrolled introduction of dams along the stream network may profoundly change or deplete the ecosystems' biodiversity and related functions. Moreover, conflicts may arise between different and competitive water users since it relies on scarce resources. In this context, aquaculture ponds mapping, and monitoring can be very relevant for analyzing the environmental impacts of this activity and pursuing a more effective rural landscape planning and management. The application of geographic object-based (OB) image analysis techniques in the Google Earth Engine (GEE) cloud environment has increased rapidly due to the broadly-recognized advantages in applying these approaches to medium or high-resolution images. In this context, this work aims to assess the fusion of high and medium resolution satellite data, available both in the optical and SAR (Synthetic Aperture Radar) domain, to implement an OB approach for aquaculture ponds mapping within GEE. To this aim, we compare various classification approaches (both pixel- and object-based, all based on the Random Forest, Machine Learning algorithm) where the satellite datasets are used according to different levels of integration and combination. The study areas in Rondonia State, Brazil, were selected considering the high presence of fishponds mixed with other surface water bodies. The OB approach produced a sensible improvement in the classification accuracy with all the dataset combinations. Integrating high- and medium-resolution data in the OB approach improved classification accuracy substantially. This study demonstrated the applicability of the OB approaches in GEE even in vast study areas and on high-resolution imagery. The methodology can be applied in future diachronic analysis to assess and monitor the introduction of aquaculture ponds to address sustainable planning and management of these human activities.

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Chestnut burrs detection in UAV aerial imagery

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Keywords. Remote sensing, UAV, Image processing, Image clustering, Machine learning.

Abstract. In the last years, remote sensing techniques based on unmanned aerial vehicles (UAVs) have been proved to be a valuable tool to acquire extensive data of crops, which are essential for feeding innovative decision support systems aimed at improving growers' farm management. In this context, the capability to automatically monitor and assess chestnut fields production, exploiting UAV remotely sensed imagery, has been considered a valuable service by farmers to properly plan the harvesting tasks and the pricing. To this aim, a specific mapping system and processing procedure have to be designed, to acquire high-resolution aerial images, merge them to create a georeferenced orthomosaic map and detect chestnut burrs in it.

In this work, an innovative image processing method to automatically detect and count chestnut burrs in RGB aerial imagery is presented. The method is based on a Region Based Convolutional Neural Networks (R-CNN) customized for object detection. The developed method was tested on the imagery of a chestnut field located in Dronero (Piedmont region, Italy). The aerial imagery was acquired on September 2021 at noon, using a MAIA RGB-NIR camera installed on a DJI Matrice 300 RTK drone. The flight altitude was maintained close to 25 meters from the terrain during the whole mission, and the obtained ground sample distance (GSD) was 10 mm. In order to define and label the training and test datasets, a specific software was implemented in the Matlab programming environment, which allows the manual detection of burrs. For this preliminary study, a set of 10 sample trees was selected from the map, and, for each tree, the position and number of automatically detected burrs were compared with manually obtained ones. The accuracy in the burrs detection process was assessed by measuring the number of properly detected burrs, the extension of the image regions wrongly classified as burrs, and, finally, the number of not detected/missed burrs. Results obtained by processing the considered dataset show the feasibility of the proposed approach, which aims at exploiting RGB imagery. The image processing method here presented is an essential phase of a wider research activity, which is aimed at developing a decision support system for chestnut growers, with a particular focus on the growing, yield estimation and harvesting phases.



Big data for farm machines: an algorithm for estimating tractors' operating costs

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Keywords. Tractor operating costs, big data, artificial intelligence, agriculture, precision farming.

Abstract. The estimation of operating costs for agricultural tractors is a key element for decision-making processes in every farming business, contributing to assess the feasibility of investments in machinery and hence the impact on farming's profitability indexes, like the return on investment (ROI). However, the variation of a series of parameters over the years, such as environmental conditions, technological innovations, field capacity and agricultural machines performance, have led nowadays to a different impact on these indexes.

The goal is to provide new tools for precise estimation of tractor's operating costs based on information gathered from machines through CANBUS interfaces and geospatial data processing. To do so, GPS data from machines have been gathered and matched with European's Copernicus digital elevation models (DEM) in order to accompany the dataset with elevation data, distance and average speed information.

As a result, after data aggregation, the algorithm made it possible to determine the working times, fuel consumption and areas worked for the open field operations examined. All the information can also be displayed on geographic information systems (GIS) or Earth browsers.

Such parameters could provide detailed estimation of operating costs for any farming business. Further developments can include maintenance alerts, performance analysis for equipment, and also enable additional activity classification (ploughing, mowing, pesticide distribution, fertilization, etc).



CANBUS data for tractor performance analysis in vineyard treatments

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Keywords. Big data, artificial intelligence, machine learning, agriculture.

Abstract. Tractors' working performances in agricultural treatments can be affected by many environmental variables. Such aspects interact with other performance parameters like power take-offs (PTOs) utilization, torque, fuel consumptions and drive system. Since these parameters can have a significant impact on operating costs and business outcomes, understanding the relationship among them can be a reliable tool for machinery performance analyses.

This paper provides a solution for tractor performance analysis based on machinery data that can be collected from tractors right as they carry out their daily activities, by one minute intervals amounting to 60 entries per working hour. Such dataset relies on CANBUS information from tractor's electronic control unit (ECU) which report data from various on-board sensors (GPS, wheel speed, temperatures, etc.) and engine parameters (PTO speed, engine speed, oil and coolant temperatures, torque, etc).

The result of data analysis generated a dataset containing comparable information on specific agricultural activities performed at different environmental or working conditions. Comparisons can thus be made on tractor's field capacity, fuel consumptions, torque, at different moments on the same field, or at the same external conditions on near fields.

Such analysis model can represent a major achievement for farming businesses, allowing finer analysis of previous data and the definition of the most suitable working set-ups for their agricultural machinery based on site-specific environmental and terrain types. Future developments of this work might include performance predictions based on artificial intelligence or machine-learning algorithms.



Analysis of Attractive Sources related to airport Wildlife Strike by using Geospatial Tools

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Keywords. Wildlife Strike, sustainable management, Remote sensing, GIS.

Abstract

Territorial development and landscape transformations around airports determine changes that may have an effect on the increase of risks for aviation as well as on wildlife protection. In both the rural and urban environments, the presence of wildlife attractive sources (e.g., vegetation, water bodies, landfills, livestock buildings, and feed mills) in the airport surroundings increases the risk of 'Wildlife Strike'. Therefore, the investigation on attractive sources at the airport surroundings is needed to contribute to the 'Wildlife Strike' monitoring in order to activate efficient countermeasures for limitation and control in view of aviation safety and at the same time increase wildlife protection.

The main aim of this study included the acquisition of basic knowledge useful to control "Wildlife Strike" phenomenon around airports in different seasons. To this aim, supervised classification of open-source remote sensing imagery made available within the ESA Copernicus program, coupled with GIS tools application, was considered as an easy and low-cost solution to the problem of information updating. The integration of this information into a GIS allowed localisation of vegetation and water surfaces bodies in relation to airport 'Obstacle Limitation Surfaces' (OLS), 'Rete Natura 2000' (SIC/ZSC and ZPS) areas, and the 'Important Bird Areas' (IBA) that play a key role in birdlife protection. The case study was related to the 13-km territorial area surrounding the airport of Catania, Italy. The monitoring of these attractive sources for wildlife, in different seasons of the year made it possible to obtain information about the periods in which it is most useful to reduce the risk. In detail, the vegetation coverage was found to increase to about 40% of the total investigated area in winter.

Further geostatistical analyses of kernel density performed by using GIS tools have defined the areas of greatest importance in relation to the weight of their suitability and proximity to the airport considered.

This approach has made it possible to analyse these areas both from the point of view of airport safety and to monitor ecological areas and corridors of high naturalistic value in order to protect them, providing a contribution for the sustainable management of the Wildlife Strike problem.



Blockchain technology for food supply chain traceability and authentication

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Keywords. Blockchain, traceability, cheese, meat, RFID.

Abstract.

Currently, companies adopt traceability systems scarcely shared among the players of the supply chain, uneven in terms of technology and tracked data structure. Generally, they are almost entirely aimed at complying the basic requirements of food safety regulations. Nowadays customers have access to product information through different channels that are largely deployed also in multi- or omni- channel marketing strategies (websites, mail, app, social media). Data analytics and Artificial Intelligence can then highly enhance marketing strategies. Furthermore, there is a high demand of proof of authenticity systems able to certify high-value food credential attributes. Thus, in this paper a blockchain-based system is proposed to manage and certify traceability information and, therefore, the authenticity of food products. Blockchain is a distributed ledger shared among a peer-to-peer network that allows to securely record transactions. Blockchain features of transparency, security, decentralization and data immutability make it a valid technology to share information between the numerous actors of agri-food supply chains.

In the context of the PININ project, the traceability of dairy and meat supply chains has been considered. A decentralized application (DApp) has been developed for the registration of the collected traceability data in a consortium blockchain, where a limited number of actors with shared responsibility can submit transactions and access data. The DApp also allows the publication of recorded data in a regional blockchain to render them publicly available. A mobile application, has been developed to connect the physical products with their digital twins. By means of a QR code printed on labels, blockchain certified data are then available to food supply chain public and private stakeholders.

An electronic collar equipped with GPS and Bluetooth systems has been also developed to georeferencing cattle in mountain pastures. The acquired data, recorded in the blockchain, allow competent authorities to securely verify the position of the animals for the correct disbursement of European funds to farmers, thus preventing frauds.



Natural fibers reinforcement for earthen building components: valorization of a low-quality sheep wool fiber

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Keywords. green building, natural fibers, sheep wool fiber, raw earth material.

Abstract. Worldwide, building sector is the leading cause of environmental degradation, global warming, and climate change with the 50% of carbon emissions, 20–50% of consumption of energy and natural resources, and 50% of total solid wastes production. Several studies were carried out by investigating eco-friendly materials that could be involved and integrated into building process with the aim of replacing traditional building materials, e.g., concrete, steel, plastic components. Totally in accordance with the circular economy statements, sustainable materials could be obtained by the reconversion of wastes, e.g., solid wastes coming from urbanized area and agricultural wastes. This research stems from the need to exploit wastes coming from livestock processes, i.e., sheep wool fibers (SWF), and their potential reuse as reinforcement for rammed earth building components. To this aim, experimental trials were performed to get useful information on the mechanical properties of SWF in wet environments like those present in lime mixes. Then, compressive and flexural tests have been performed on raw earth adobes by incorporating SWF. The obtained results encourage the use of sheep wool fiber as reinforcement for raw earth composite materials.