ΕΓΜΕ HelAgEng

EurAgEng

AgEng 2024

Agricultural University of Athens

1-4 July 2024
Athens-Greece

ageng2024.com

ABSTRACT BOOK

Table of Contents

OP01-1 | Mapping gas concentrations inside naturally ventilated dairy barns: Evaluating spatiotemporal dynamics and uncertainties

Harsh Sahu[1], Thomas Amon[1,2], Jürgen Zentek[3], David Janke[1]
[1]Department of Sensors and Modelling, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Max-Eyth-Allee 100, 14469, Potsdam, Germany, [2]Department of Veterinary Medicine, Institute of Animal and Environmental Hygiene, Freie University Berlin, Robert-von-Ostertag-Str. 7-13, 14163, Berlin, Germany, [3]Department of Veterinary Medicine, Institute of Animal Nutrition, Freie University Berlin, Königin-Luise-Str. 49, 14195, Berlin, Germany

In naturally ventilated dairy barns (NVDBs), emissions of carbon dioxide (CO2), methane (CH4), and ammonia (NH3) are influenced by varying meteorological conditions and microclimate. During emission measurements, a prevalent assumption poses the homogeneous distribution of gases within the barn. However, no evidence supporting this homogeneity exists in the existing literature. Therefore, the spatial and temporal dynamics of gas concentrations across the entire barn volume constitute the first objective of this investigation. To assess the uncertainty in gas measurements resulting from sensor placement strategy (number and position), we deployed a dense gas sampling network, comprising 50 sampling points (SPs), at a spatial sampling resolution of 90 m3 and a temporal resolution of 3 minutes. Gas concentrations were sequentially measured at each SP using two Cavity Ringdown Spectrometers (CRDS) and two Fourier Transform Infrared (FTIR) gas analyzers. The data collected at each SP were compared for significant differences and presented as relative percentage errors. The second objective involves an exploration of the influence of microclimatic factors (wind direction, speed, temperature, and relative humidity) and their impact on gas concentration distribution. Measurements are currently ongoing, and the significance of the study's outcomes regarding the optimization of recent measuring methods will be thoroughly addressed and comprehensively discussed. At the conference, we will share the outcomes derived from a dataset that has been consistently recorded across the barn throughout the span of 3 months.

Keywords
Open-Sided Dairy Barn; Emission Measurements; Microclimatic Factors; Gas Sensor Placement Strategy; Fourier Transform Infrared (FTIR) Spectrometer; Cavity Ringdown Spectrometer (CRDS); Ultrasonic Anemometer

OP01-2 | Evaluation of the cubicle hood sampler for monitoring methane production of dairy cows under barn conditions

Cécile Levrault[1], Peter Groot Koerkamp, Carel Peeters, Nico Ogink
[1]Wageningen University & Research, Wageningen, Netherlands

Over the past decades, the potent greenhouse gases emissions from cattle farming have kept rising, and alleviating the impact of the sector on the environment has become undeniably crucial. Whilst animal geneticists and nutritionist actively work on discovering lineages and rations that will allow to lower enteric methane emissions, the evaluation of the performance of these measures remains limited by the available assessment methods. Several devices have already been developed in an attempt to quantifying the individual methane production levels from dairy cows under barn conditions. Unfortunately, they often appear to be either inaccurate, laborious or expensive. In this study, we present a renewed design of the Cubicle Hood Sampler (CHS) as an alternative solution to this challenge.
Placed in the cubicles, the CHS collects and analyses the methane content of the air exhaled by cows when lying down. Due to the physiological rhythm of cattle and the location of the system, individual monitoring of up to 12 hours per day can be achieved. To investigate the ability of the CHS to 1) assess individual methane production rate (MPR), and 2) build a ranking index to select cows based on their methane production levels, the MPR of 28 dairy cows were measured by four CHS devices and compared to the levels measured by climate respiration chambers (CRC). A linear regression showed no strong correlation between the two sets of estimates ($r = 0.24$). Estimations made by the CHS appeared to be biased, which cannot be corrected for in the absence of a strong linear correlation. Using Bayesian modelling, information was borrowed across cows to simulate complete methane production curves in an attempt to improve the MPR estimation accuracy. However, the model could not compensate for biased observations, and accuracy levels did not improve. An under-recovery of the breath samples by the hood is suspected. These issues must be addressed. Nevertheless, the CHS ranked cows satisfactorily, with Kendall W values of 0.625 ($p = 0.201$) in the original dataset, and 0.659 ($p = 0.214$) after using the Hierarchical Methane Rate (HMR) model. Resolving the bias issue is expected to have a simultaneous positive effect on both ranking agreements. We advise to use the HMR model to borrow information across cows, and convert discrete measurements into methane production curves, as it will provide more realistic MPR estimations.

OP01-3 | Evaluation of intermittent sampling strategies for ammonia emissions from finishing pig houses

Marien Korevaar[1], Albert Winkel[1]
[1]Wageningen University And Research, Wageningen, Netherlands

The major part of anthropogenic ammonia emissions to the environment originate from livestock farming. Livestock houses with finishing pigs emit in the Netherlands annually 8.36 kilogram ammonia, which is 7.8% of the total emission from the agricultural sector. Determination of emissions require accurate measurement methods for gas concentrations and ventilation flows as well as an appropriate sampling strategy. In previous studies several sampling strategies with different sampling frequencies have been applied to determine the average emission from livestock houses. In order to determine an ideal sampling frequency based on costs and accuracy, more insight in the associated uncertainty with the sampling frequency is valuable.
In this study the ammonia emissions from 8 conventional finishing pig houses have been monitored continuously throughout a year. Based on these daily time series an analysis has been performed in which different frequencies of intermittent sampling strategies are evaluated. It is shown with theoretical 24-h samples that both the accuracy and precision increase with increasing sampling frequency. The uncertainty in the accuracy increased from 12-32 % for bimonthly sampling in the 8 livestock houses to 4-13 % for fortnightly sampling. The average uncertainty of the annual ammonia emission from a finishing pig house is smaller than 10 % if 13 24-h samples are taken with equal intervals. It is possible to determine average annual ammonia emissions accurately with the appropriate intermittent sampling strategy.

OP01-4 | Reducing ambient temperature to reduce NH3, N2O and CH4 emissions from a fattening piggery

Nadine Guingand[1], Yvonnick Rousseliere[1], Johan Thomas[1], Aurelien Collin[1]
[1]IFIP institut du Porc, Le Rheu, France

In France, most buildings that house growing-finishing pigs from 30 to 120 kg are operated in a dynamic mode with a set-temperature of 22-24°C throughout the fattening period. In contrast, certain northern European countries use a set-temperature of 18°C with the stated aim of maintaining zootechnical performance and reducing ammonia emissions from these buildings. The aim of this experiment was to study the influence of ambient temperature on zootechnical (ADG, FCR, %Muscle) and environmental (ammonia, nitrous oxide and methane emissions) performance by keeping temperatures cooler (16, 18 and 22°C) throughout the fattening period of pigs bred in a temperature-controlled unit (Climatotec). Performance of these of pigs were compared to those kept in a conventional room with a set-temperature of 22°C. Pigs were weighted at the entry, the day of the food transition and the day before departure for the slaughterhouse. The quantity of feed distributed to pigs per treatment were weighted daily. Analysis on feed random samples were achieved for each batch. Slurry samples were achieved three times per batch and per treatment in order to analyse its composition (dry matter, pH, total nitrogen and ammonium nitrogen). Gaseous concentrations (NH3, N2O and CH4) were semi-continuously measured by using a photoacoustic multi-gas monitor (Innova 1512). At the same time, the ventilation rate was continuously monitored by measuring the rotation speed of a full-size free-running impeller unit coupled with the exhaust fan of each room. Data validation was achieved by applying the mass balance method for nitrogen (N) and carbon © including the calculation of inputs (piglet carcases, feed intake) and outputs (fattening pig carcases, slurry composition, gaseous emissions). As a first step, pig performance and environmental parameters (gaseous emissions and slurry volume and composition) of the reference room were validated to be representative of commercial breeding units. Afterwards, the comparison with the other rooms was done. Zootechnical performance did not differ between the rooms at the lower set-temperatures and the reference room. However, the rooms at 16, 18 and 22°C emitted 42 %, 36 % and 39 % less ammonia, respectively, than the reference room and 57 %, 53 % and 27 % less methane, respectively. In contrast, no effect on nitrous oxide emissions was observed. Reducing of ambient temperature could be one way to investigate how existing buildings can decrease their environmental impacts.

OP01-5 | Emission measurements at NV dairy barns: Assessing individual barn measurability with the direct air flow rate method

Kobe Coorevits[1], Arnout Declerck[1], Loes Laanen[1], Eva Brusselman[1], Peter Demeyer[3], Tomas Norton[2]
[1]Technology and Food Science Unit, Flanders Research Institute For Agriculture, Fisheries And Food (ILVO), Merelbeke, Belgium, [2]M3-BIORES, Division of Animal and Human Health Engineering, KU Leuven, Leuven, Belgium, [3]Central Services, Flanders Research Institute For Agriculture, Fisheries And Food (ILVO), Merelbeke, Belgium

Measuring emissions in naturally ventilated (NV) dairy barns presents significant challenges. Currently two methods are employed: the indirect method, using tracer gases for estimating ventilation rates, and the direct method, utilizing ultrasonic anemometry.
Evaluating the measurability of a barn is crucial for accurate emission measurements, but is currently typically qualitatively assessed based on expert judgement. To address this issue, recent studies focused on refining the direct method, utilizing ultrasonic anemometers (UAs) to measure air velocities to determine airflow rates through barn openings. This allows, in theory, for achieving a closed mass balance between incoming and outgoing air flow on the barn level. Therefore, we introduced a 'ventilation balance check', a quantitative method for assessing the measurability of individual NV dairy barns for determining emissions using the direct method. This involves establishing a relationship between air in- and outflow rates of the barn, through orthogonal linear regression. These regressions are performed separately for the main air flow directions in the barn, and for the complete dataset, to assess differences under different flow regimes. Based on scaled experiments in a mock-up building, a maximum relative difference of 20 % between incoming and outgoing flow was proposed[1].
In this study, we present the results of a ventilation balance check of six NV dairy barns, with relative differences between in- and outgoing flow ranging from 5% up to more than 40%. We discuss the possible factors which influenced these results and give some suggestions to decrease differences by improving the measuring setup.

Keywords: ultrasonic anemometry, airflow dynamics, emissions

Acknowledgements: The Government of Flanders (Environmental Department) for their financial support. The technical team who meticulously implemented and maintained the experimental setup.

References:
[1] Van Overbeke, P., De Vogeleer, G., Mendes, L. B., Brusselman, E., Demeyer, P., & Pieters, J. G. (2016). Methodology for airflow rate measurements in a naturally ventilated mock-up animal building with side and ridge vents. Building and Environment, 105, 153-163.

OP02-1 | Analysis of the effect of reflective mulches on microclimate and production of a tomato crop in three multispan greenhouses with different natural ventilation capacities

Francisco Domingo Molina-Aiz[1], Mireille Nathalie Honoré[1], Diego Luis Valera Martinez[1]
[1]University Of Almería, Almería, Spain

The main objective of the proposed work is to study the effect produced by different natural ventilation surfaces combined with high reflection soil mulches on the microclimate inside greenhouses and on the growth and production of a tomato crop. The work was carried out during the autumn-winter cycle 2023-2024 in three multispan greenhouses located at the "Catedrático Eduardo Fernández" Experimental Station of the "UAL-ANECOOP Foundation" Center for Innovation and Technology Transfer in Almería (Spain). The 2/9/2023 a tomato crop (Solanum lycopersicum L.) was transplanted inside the three experimental greenhouses, that were divided into two similar sectors (East and West) by means of a plastic sheet. In the eastern sector (control treatment) of the three greenhouses, there was black polypropylene mulching. In the western sectors the soil was covered with reflective mulching, with a polyethylene plastic mulch (black on the inside) in one of the greenhouses (with two spans and 28.3% of ventilation surface) and with crushed gravel of white marble on the ground of the other two greenhouses (with three spans and ventilation surfaces of 18.1% and 25.3%). At the centre of each of the six study sectors there was measuring box which temperature, humidity and CO2 concentration sensors. In order to evaluate the development of the tomato crop, 3 lines of plants per sector and 8 plants per line was randomly selected. Every two weeks the total plant length, distance from apical meristem to last node, internode length, number of nodes, and stem diameter were measured. The marketable and total yield were measured in 13 yields carried out from 20/11/2023 to 23/02/2024. The marble mulching allowed net radiation (10-15%) and temperature to be reduced in hot periods (0.5-1ºC), while by controlling ventilation the same temperature could be maintained during the winter. The reflective mulching allowed to increase marketable tomato yield a 1-11% with the marble and 10% with the white plastic in comparison with sector with the black mulching. Tomato production was greater (6-7%) in the north part of both sectors of the greenhouse with the side vents free of obstacles in the north. In the greenhouse with only a side vent located in the south, marketable production was greater (2-7%) in this part of the greenhouse in both sectors (with marble and black mulching). The length of internodes of the tomato plants was reduced between 4 and 20% with the use of reflective mulches in the three greenhouses.

OP02-2 | Wind loads on two insect-proof tunnel nethouses: Full-scale and CFD analysis

Anastasios Giannoulis[1], Antonis Mistriotis[1], Demetres Briassoulis[1]
[1]Agricultural University Of Athens, Athens, Greece

The use of nethouses as a means of cultivation protection is steadily expanding over the last two decades. In mild climates, their permeable character enables efficient regulation of the microclimate within the nethouse through controlled natural ventilation. Depending on the net type they may offer protection against stressful climatic agents such as excessive sun radiation, rain, hail, strong wind, and also protection from insects and viruses.
Several studies in the international literature are related to the microclimatic conditions of nethouses with different types of net coverings. However, wind loading on such structures is poorly studied. Especially for the dense mesh insect-proof nethouses, wind forces can be significant and may affect their structural frame and elements stability.
Two single-span small-sized tunnel nethouses with different insect-proof net coverings (OptiNet 50 mesh, porosity: 53.4%; Biorete 50 Mesh AirPlus, porosity: 38.7%) were utilised for the full-scale experiment. The 50 mesh Airplus net allowed for increased ventilation through its thinner thread configuration. The nets were installed on two neighbouring tunnel nethouses. The corresponding wind loads were studied through experimental and CFD analysis means. Typical load measuring sensors (e.g. pressure taps, strain gauges) cannot be used on net coverings. A special setup was implemented using pressure differential sensors for the estimation of the wind pressures on the net covering. Wind direction perpendicular to the nethouses was considered and wind loads were measured at the mid-point of the windward and leeward sides of both nethouses. A reference anemometer at 10 m height was recording the free stream velocity.
The full-scale experiment was simulated through a 3D model in the ANSYS2022R1 software. The net coverings were simulated as porous domains with defined porosity and aerodynamic coefficients previously measured by wind tunnel experiments.
The recorded wind pressures were correlated to the free stream velocity. Results showed a quadratic relationship between the pressure and the free stream velocity ($P \sim V^2$), as expected. Windward pressures were lower for the nethouse covered with the 50 mesh Airplus net because of its advanced aerodynamic characteristics. However, the leeward pressures were higher for the same nethouse. This was attributed to the higher wind speeds at the 50 mesh Airplus nethouse interior and the airflow complexity that two neighbouring structures may impose. CFD wind pressures results showed very good agreement with the full-scale experiment and further numerical analysis provided the complete wind pressure distribution over the nethouse structures.

Nethouse, insect-proof, wind loads, Full-scale, CFD

OP02-3 | Evaluation of performances of the new vapour-permeable material as energy saving screens for greenhouse towards sustainable environmental controls

Takahiro Asai[1], Cecilia Stanghellini[1], David Katzin[1], Bram van Breugel[1], Vida Mohammadkhani[1], Silke Hemming[1]
[1]Wageningen University and Research, Wageningen, Netherlands

An energy saving screen plays a key role in improving heat insulation of a greenhouse and energy efficiency under heating. In general, screens are closed when a greenhouse is heated up in the winter. Transparent screens can be closed also during very cold daytime hours. However, by closing screens, vapour accumulates as well and finally high humidity and condensation will occur. In order to avoid these effects, a screen will be opened slightly for a short time or will have small holes or gaps on itself to discharge excessive vapour. Discharging vapour (latent heat) will in these cases come together with uncontrolled loss of sensible heat, thus energy-saving is decreased. In order to solve this problem, we evaluated the performances of new vapour-permeable film which can transmit vapour without air transport and considered decoupling latent heat release from sensible heat loss in greenhouse application. 6 types of transparent films, 2 vapour-permeable films with 80 µm (FJ80) and 130 µm (FJ130) of thickness, 3 perforated films with 20 cm x 20 cm (AC20), 15 cm x 15 cm (AC15), 10 cm x 10 cm (AC10) perforation holes of ca. 6 mm diameter, and 1 traditional weaved screen (LS), were compared with 2 repetitions. 12 boxes covered with the different films were set in the greenhouse as experimental plots. Environmental conditions inside every box and the greenhouse were measured. First, all of boxes were filled with high concentration CO_2 and the decay of CO_2 was measured to figure out the air permeability of each film. The permeabilities were FJ130 < FJ80 < AC20 < AC15 < AC10 < LS in the lower order, thus new vapour-permeable films can decrease not only CO_2 loss but also sensible heat loss. Second, the same number of potted plants were installed into every box as source of vapour and the effects of vapour transmission on each film were investigated. The level of both relative and absolute humidity of FJ130 was like AC20 as well as FJ80 was close to AC10. LS was the lowest humidity in all boxes. These results showed new vapour-permeable films (FJ130 and FJ80) indeed decouple sensible heat loss from vapour exchanges with at the same time retention of CO_2. There is a possibility to be able to improve energy efficiency under closing screens without problems of high humidity and condensation by installing the new films.
screen, humidity control, insulation, energy efficiency, greenhouse

OP02-4 | The shading created by different configurations of organic photovoltaic modules in a tunnel-type greenhouse

Helena Vitoshkin[1], Shay Ozer, Meir Teitel
[1]ARO, Volcani Center, Rishon-le'zion, Israel

The interest in dual land use for crop growth and electricity generation has recently increased. Yet, integrating photovoltaic (PV) panels/modules in the agricultural sector has been challenging. The main concern is the reduction of light incidence on the canopy due to the shading cast by the PV panels. This study uses a model to calculate the shading in a tunnel-type greenhouse (7.5 m x 17.5 m) due to the integration of 38 m2 strips of organic semi-transparent PV (OPV) modules inside the greenhouse. Several configurations of the placement/orientation of the modules were investigated; longitudinal, transverse, and checkerboard. The model uses the Fluent (Ansys, PA, USA) platform to calculate the daily integral shading. It takes into account the sun position, the day of the year, the geometry of both the greenhouse and the PV modules, and the position of the modules inside the greenhouse. In the first stage, the model was used to calculate the total visible and infra-red (IR) radiation absorbed on a very small plate at the top of the canopy (which simulated a Pyranometer sensor at a height of 3 m) in a greenhouse without any PV modules. A comparison between simulation and experimental results showed a good agreement. In the second stage, the OPV modules were introduced inside the greenhouse at a height of 3 m. Simulations were done to calculate the daily integral absorbed visible and IR radiation at ground level with modules placed in the different configurations. The results show that there are small differences among these configurations with regard to the absorbed radiation. Yet, it is clear that the modules in the transverse configuration result in the worst case with regard to spatial variability of radiation.

OP02-5 | Analysis of wall pressures and discharge rates in corrugated steel silos with centric and eccentric hoppers by discrete element models

Ana Grande Gutiérrez[1], JM Fuentes[1], E. Gallego[1], F. Ayuga[1]
[1]Universidad Politécnica de Madrid, Madrid, Spain

Corrugated steel silos are extensively used to store all types of agricultural and industrial materials, due to their excellent structural performance and resistance to buckling. Occasionally, commercial silos are designed with an eccentric hopper to facilitate the handling or flow of the stored bulk solid during the discharge process. However, this eccentricity can cause an asymmetry in the normal pressure distribution around the silo walls during discharge. Therefore, this study investigates the normal and tangential forces on the walls of a corrugated steel silo for storing biomass wood pellets with centred and off-centre hoppers by performing DEM simulations.

Numerical simulations were carried out using EDEM 2023 software, based on the Discrete Element Method (DEM), and a model silo with corrugated steel walls, a square cross section and different bottom configurations was designed to validate the DEM models. The vertical section of the silo consisted of two independent modules, each one having 0.75 m in height and 0.45 m width and length. Depth and wavelength of corrugations were 13 mm and 75 mm, respectively. Four different bottom configurations were used in the analysis (flat bottom with a centric square outlet with 0.06 m. and three hoppers with different outlet eccentricities (0%, 50% and 100%). Cylindrical wood pine pellets of 4 mm diameter and average length of 16 mm (±6 mm) were used as the granular material.

In this study, the walls pressures and the discharge rate during the emptying operation were investigated. The numerical results are compared with experimental values and with those predicted by the EN 1991-4. The DEM results during discharge indicate that the wall pressure was similar when the hopper was centred, but when it was eccentric the pressure on the far side of the eccentric discharge location was higher than on the nearest side. The DEM simulations, properly validated, can also be used to explore the effects of geometrical parameters, such as the corrugation dimensions, wall friction coefficient or particle size, amongst some others on pressures and material flow pattern.

Keywords: Silo, Discrete Element Method, Corrugated wall

OP03-1 | Agroview: Enhance satellite imagery using super-resolution and generative ai for precision management in specialty crops

Yiannis Ampatzidis[1], Christian Lacerda[1]
[1]University Of Florida, Gainesville, United States of America

Unmanned aerial vehicles (UAVs) and satellites are popular technologies for data acquisition in precision agriculture. However, both technologies have advantages and disadvantages. UAVs offer higher resolution but have a limited collection range, resulting in higher costs per acre. Satellite imaging is a cost-effective solution but has limitations of lower spatial resolution (> 0.5-10 m), which is not suitable for crop assessment in specialty crops. For example, our award-winning, cloud- and artificial intelligence (AI) based platform, Agroview, requires high-resolution images (~10-20 cm resolution) as inputs for accurate data analytics (aka., creation of plant inventory and fertility maps, plant canopy volume measurements, yield prediction, etc.). However, most available satellite images have much lower resolution (from 1-2 m up to 10 m). Several specialty crop growers and other stakeholders (e.g., crop insurance companies, crop consulting companies, etc.) expressed the need for developing a more cost-effective and less time-consuming data collection technology for precision crop management. The ideal solution would have near-UAV resolution levels with the cost and data collection advantage of satellites.
In this study, generative AI models, particularly generative adversarial networks (GANs), were used to address atmospheric interference and sensor limitations to upscale satellite images. These models were trained on large datasets of low (satellite images of 45 cm, 92 cm, and 180 cm resolution) and high (UAV images of 7 cm resolution) resolution images, learning to predict and recreate high-resolution details. The process of training a GAN to enhance satellite image resolution was conducted in a stepwise manner, starting with the 45 cm resolution with a 4x upscaling factor, and progressively decreasing it to 180 cm resolution with a 16x upscaling factor. This approach aimed to detect the points at which the GAN may encounter limitations in achieving the desired resolution of the original UAV ground truth images. This step-by-step analysis was essential for identifying specific stages in the training process where the GAN's performance may deteriorate, requiring adjustments or additional training to effectively enhance satellite image resolution. The proposed AI-enabled technology could be used as a digital twin of an agricultural field and as a climate-smart technology to help farmers rapidly calculate losses and better communicate recovery needs to ensure business viability and minimize interruption to the U.S. produce supply chain due to unexpected weather and climatic events.

OP03-2 | Artificial intelligence-based yield prediction in table grape production: A case study in the Vinalopó protected designation of origin

Ana María Codes Alcaraz[1], Carmen Rocamora Osorio[1], Herminia Puerto Molina[1]
[1]Universidad Miguel Hernandez, Alicante, España

Accurate yield prediction is crucial for effective harvest planning and manufacturing optimization in table grape production, especially given the labor-intensive nature of the process. This study introduces the outcomes of training a detection model Yolov5 to predict the yield of a table grape plot within the Protected Designation of Origin "Uva de mesa embolsada del Vinalopó" in Alicante (Spain). The main objective was to develop a fast and efficient methodology for cluster bag counting and grape production estimation. An unmanned aerial vehicle conducted a single flight over a commercial plot, capturing images parallel to the trellis rows at a height of 10 meters and a 35º angle.

A dataset comprising 55 labeled images, each containing an average of 150 cluster bags, was utilized for model training. Of these, 50 images were dedicated to training, while 5 were reserved for model validation. The results of the model training revealed a swift detection speed of 78.5 milliseconds, with a Precision of 80.38%, Recall of 85.63%, mean Average Precision of 86.40%, and an F1 rate of 83.13%. When applied to a different set of images, the AI model accurately counted 20,520 cluster bags. Notably, the production estimation using this methodology exhibited a mere 6.2% underestimation in comparison to the farmer's estimate, which experienced a considerably higher underestimation of 37.67%.

While these results showcase the potential of the proposed AI (artificial intelligence) based methodology for yield prediction, it is acknowledged that further refinement and updating the detection model to the new version of Yolov7 are essential. Expanding the dataset to include more plots or multiple campaigns will enhance the robustness of the methodology. This research signifies a substantial stride towards leveraging AI technologies in viticulture, promising improved accuracy and efficiency in the crucial task of yield prediction and allowing the analysis of spatial and temporal variability, ultimately contributing to the sustainable advancement of table grape production practices.

Keywords: Table Grape Production, Artificial Intelligence (AI), Yield Prediction, Unmanned Aerial Vehicle (UAV), Precision Agriculture

OP03-3 | Grape cluster and canopy volume estimation using smartphone-based 3D imaging in wine grapes

Priyanka Upadhyaya[1], Manoj Karkee[1]
[1]Washington State University, Prosser, United States of America

The accurate estimation of grape cluster and canopy volume is crucial in wine grapes for optimizing grapevine productivity. Canopy volume represents the overall vegetative growth, which informs vineyard management decisions, optimizing resources, and improving grape quality. Similarly, cluster volume serves as a crucial indicator of potential grape yield. Conventional methods for estimating canopy and cluster volume in viticulture rely on expensive and specialized equipment like 3D scanners or LiDAR systems, incurring high costs for acquisition, maintenance, and operation. In contrast, the ease and cost-effectiveness of utilizing cell phones for imaging vine canopies enable a diverse group of vineyard operators, including smaller-scale or resource-limited growers, to estimate and use cluster and canopy volume information in their farming operations. This research introduces a novel method for cluster and canopy volume estimation harnessing the iPhone 14 Pro's 3D imaging capabilities, complemented by a machine learning approach, specifically Gradient Boosting. The overall process included image acquisition and 3D point cloud extraction followed by accurate segmentation of vine canopies. To accurately estimate canopy volume, first, regions covered by trunks and background such as sky were first removed. Then a surface reconstruction technique was used to precisely estimate canopy volume. In addition, a Gradient Boosting Classifier was used to create 3D models of grape clusters, which was then used to estimate the cluster volume. The Gradient Boosting algorithm had a training accuracy of 0.99 and testing accuracy of 0.9. The results showed the potential of smartphone-based 3D imaging and machine learning in wine grapes, providing a cost-effective and efficient solution to help manage these crops effectively including yield estimation and nutrient need assessment.

OP03-4 | Advancements in coffee authenticity: A spectroscopic feature compression approach using explainable AI and vision transformer

Shanghua Liu[1], Majharulislam Babor[1], Leah Munyendo[2], Bernd Hitzmann[2], Barbara Sturm[1,3], Marina Höhne[1,4]

[1]Leibniz Institute For Agricultural Engineering And Bioeconomy (ATB), Potsdam, Germany, [2]Department of Process Analytics, University of Hohenheim, Stuttgart, Germany, [3]Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences, Humboldt-Universität zu Berlin, Berlin, Germany, [4]Department of Computer Science, University of Potsdam, Potsdam, Germany

Verifying the authenticity of food and its ingredients is crucial in food supply chains (FSC). This is particularly true for FSC that facilitate fair trade. Roasted arabica coffee, being one of the most extensively traded tropical commodities, demands stringent measures to trace its origin and prevent fraudulence. Variations in cup quality, aroma, and economic value tied to geographical origin pose challenges intensified by diverse species and roasting degrees. Verifying the authenticity of coffee using spectroscopic techniques with machine learning approaches can promote fair trade. Moreover, it is essential to ensure the reliability of such methods for their application in real-world scenarios. In this scope, a gap remains in understanding how these models effectively interpret redundant information within spectra. Employing only relevant spectral data via portable spectroscopy can reduce expenses. This reliability and cost-effectiveness will encourage traders to implement such approaches in real-world environments. In this study, we used near-infrared spectra to identify the geographical origin of arabica coffee from South America, Central America and Africa with varying degrees of roasting: light, medium, and dark. In addition to traditional machine learning methods such as Support Vector Machine (SVM) and Linear Discriminant Analysis (LDA), our study integrated the eXplainable AI (XAI) approach with the cutting-edge Vision Transformer (ViT) architecture. This integration discerns relevant spectral features crucial for authenticating origin. Adapting the ViT, originally designed for 2D images, to the unique characteristics of 1D spectra yields outstanding accuracy (99.8 %) in geographical origin determination. The robustness of our method was demonstrated through the utilization of standard dataset partitioning and 10-fold cross-validation using 1823 coffee spectral samples. Moreover, the application of XAI method GradCam++ provided insights into the decision-making process of the models, facilitating the elimination of less relevant features, thus enabling feature compression and pruning. Remarkably, reducing the feature space to 1.1 % (53 wavelengths) led to a varied performance among models, with ViT exhibiting the least drop in accuracy (86.4 %) compared to SVM (32.8 %) and LDA (65.7 %). Our study highlights the potential of advanced deep learning techniques and explainable AI in precise coffee authenticity determination, thereby ensuring fair value. Moreover, by illuminating feature redundancy within spectra, the findings offer practical solutions for real-time monitoring of coffee authenticity.

OP03-5 | Application of near-infrared spectroscopy for medicinal cannabis cultivar classification and cannabinoid and terpene concentration prediction

Matan Birenboim[1], Daniel Chalupowicz[3], Tarin Paz-Kagan[4], David Kengisbuch[3], Jakob A. Shimshoni[2]
[1]Department of Food Safety, Institute for Postharvest and Food Sciences, Agricultural Research Organization (ARO), Volcani Center, Rishon LeZion, Israel & The Hebrew University, Department of Plant Science, The Robert H Smith Faculty of Agriculture, Food and Environment, Rehovot, Israel, Rishon LeZion, Israel, [2]Department of Food Safety, Institute for Postharvest and Food Sciences, Agricultural Research Organization (ARO), Volcani Center, Rishon LeZion, Israel , Rishon LeZion, Israel, [3]Department of Food Quality, Institute for Postharvest and Food Sciences, ARO, Volcani Center, Rishon LeZion, Israel, Rishon LeZion, Israel, [4]French Associates Institute for Agriculture and Biotechnology of Dryland, The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus, Israel, Sede Boqer, Israel

Medicinal Cannabis inflorescence is widely used for various medicinal conditions, due to the beneficial pharmacological properties of its cannabinoids and terpenes. At the present, the quantitative chemical analysis of these active compounds is achieved by laborious, expensive, and time-consuming old-fashioned technologies such as high-pressure liquid-chromatography with photodiode arrays and mass spectrometer detectors (HPLC-PDA or MS), or gas chromatography-mass spectroscopy (GC-MS). Therefore, we aimed to develop simple, accurate, fast, and cheap analysis technique for the quantification of major cannabinoids (n = 10) and terpenes (n = 9) using near infra-red spectroscopy (NIRS) coupled with multivariate classification and regression models such as partial least square-discriminant analysis (PLS-DA) and partial least square regression (PLS-R) models. The PLS-DA classification model yielded an absolute major class separation (high THC, high CBD, hybrid and high CBG classes) and perfect class prediction using only three latent variables (LVs) while the cross-validation and prediction model errors indicate low probability of model overfitting to the data. Regarding the cannabinoid and terpene concentration prediction, the PLS-R models yielded 11 robust models with high predictive capabilities (R2CV and R2pred > 0.8, RPD > 2.5 and RPIQ > 3, RMSECV/RMSEC ratio < 1.2) and 15 models with suitable performances for initial screening purposes. Except for one model, all of the PLS-R models revealed model errors lower than 30%. Our results confirm that there is sufficient information in the NIRS spectral region to develop cannabinoid and terpene prediction models as well as major cultivar classification model.

Keywords: Cannabis sativa L., near-infrared spectroscopy, cannabinoids, terpene, partial least square.

OP04-1 | Assessing water and nitrogen stress in pepper plants (Capsicum annuum l.) using hyperspectral data: A comparative analysis of machine learning and vegetation indices

Maria Bempi[1], Aris Kyparissis[1]
[1]University of Thessaly, Volos, Greece

Early detection of plant stress is essential for optimizing crop yield and quality in precision agriculture. Analysis of reflectance data acquired through remote sensing technologies has significantly contributed to this area by enabling the identification and quantification of various physiological responses in crops under stress conditions. The emergence of machine learning algorithms can help analyze these complex datasets and identify subtle patterns that may be missed by traditional methods. This study presents two modeling approaches in assessing water and nitrogen stress in pepper (Capsicum annuum L.) plants using hyperspectral data. A controlled experiment was conducted with a 3 x 3 factorial design, evaluating three water stress levels and three nitrogen fertilizer application levels for a total of nine treatment groups. Hyperspectral data were collected from the plants using a spectroradiometer. The ecophysiological parameters measured include plant height, leaf surface area, number of leaves, chlorophyll content (a & b), carotenoid levels, leaf specific mass (LSM) and relative water content (RWC). Both modeling approaches compared the reflectance data with each ecophysiological parameter individually. The first modeling approach comprised linear regression models based on vegetation indices (NDVI, PRI, GNDVI, NDRE, NIRv). In the second approach, the reflectance data from the spectroradiometer were used as input parameters in four machine learning model algorithms, i.e., Random Forest (RF), K-Nearest Neighbors (KNN), Support Vector Machines (SVM) and Regularized Linear Regression (RLR). The results demonstrated that the ML-based approach outperformed the VI-based approach in most cases. Specifically, all four ML algorithms demonstrated a high performance with most of the ecophysiological parameters (chlorophylls: $R^2 > 0.83$ and $RMSE < 0.42$, carotenoids: $R^2 > 0.84$ and $RMSE < 0.39$, LSM: $R^2 > 0.65$ and $RMSE < 0.61$). The VI-based approach showed varying results between the five indices used. The NDRE and GNDVI models outperformed the other VI-based models (chlorophylls: $R^2 > 0.8$ and $RMSE < 0.42$, carotenoids: $R^2 > 0.75$ and $RMSE < 0.45$). The other three indices showed moderate to low performance with most of the ecophysiological parameters (chlorophylls: $R^2 < 0.52$ and $RMSE > 0.7$, carotenoids: $R^2 < 0.45$ and $RMSE > 0.71$, LSM: $R^2 < 0.5$ and $RMSE > 0.7$). These findings indicate the potential of ML algorithms to surpass conventional vegetation index-based methods for early detection and monitoring of plant stress using hyperspectral data in precision agriculture applications.

Keywords: Pepper, hyperspectral data, machine learning, vegetation indices, abiotic stress

OP04-2 | Early diagnosis of strawberry plants physiological responses to drought stress using chlorophyll fluorescence analysis

Myeongyong Kang[1], Niraj Tamrakar[2], Jung Hoo Kook[1], Dae Yong Kang[1], Elanchezhian Arulmozhi[2], Hyeon Tae Kim[2]
[1]Department of Smart Farm, Graduate School of Gyeongsang National University (Institute of Agric. & Life Sci.), Jinju, Republic of Korea, [2]Department of Bio-systems Engineering, Gyeongsang National University (Institute of Smart Farm), Jinju, Republic of Korea

Early diagnosis of crop growth conditions is essential for ensuring timely crop management resulting in high productivity. Recent advancements have focused on non-destructive monitoring techniques, with chlorophyll fluorescence analysis emerging as a promising method for assessing various physiological parameters. Drought stress significantly influences the physiological and biochemical processes in crops, leading to reduced gas exchange and impaired carbon assimilation due to stomatal closure. This study investigates the physiological responses of strawberry plants to varying levels of drought stress. Three groups of strawberry seedlings, each with three fully expanded leaves, were subjected to different daily watering treatments (200, 100, and 0 mL/day/plant) over the period of three days, then followed by a uniform watering regime (200 mL/day/plant) for another three days. Chlorophyll fluorescence data were collected daily using the chlorophyll fluorometer (OS-30p+, ADCBioScientific Ltd., UK) following 30 minutes of dark adaptation. The results obtained after measurement showed significant differences in OJIP parameters between the drought-stressed group (0 mL/day/plant) and the other groups (100 and 200 mL/day/plant) after three days of differential watering. Drought stress impacted the photosystem II efficiency, with notable variations in electron transport rates (ETo/RC and ETo/CS) and energy conversion efficiency (TRo/ABS). Based on our results, drought stress affected to low transfer of energy from light-harvesting complexes to photosystem Ⅱ rection centers and decrease in efficiency of QA reoxidation and inhibition in electron transport chain beyond QA. However, after reverting to the standard uniform watering regime, no significant differences were observed between the groups from second day. This study confirms the sensitivity of chlorophyll fluorescence analysis in detecting early physiological changes in strawberries due to drought stress. It suggests that this method can be used to analyze the impact of drought-stress in the crop, highlighting its potential for timely and effective crop management.

Keywords: Chlorophyll fluorescence, Crop monitoring, Drought stress, Strawberry plant, Photosystem Ⅱ

ACKNOWLEDGMENT

This work was supported by the National Research Council of Science & Technology (NST) grant by the Korea government (MSIT) (CRC23041-000)

OP04-3 | Detection of deficiency of iron, zinc and manganese in spinach plant under hydroponic cultivation conditions using digital image processing

Maryam Nadafzadeh[1], Ahmad Banakar[1], Saman Mehdizadeh Abdanan[2], Mohammadreza Zare Bavani[2], Saeid Minaei[1], Gerrit Hoogenboom[3], Abdul Mounem Mouazen[4]
[1]Tarbiat Modares University, Tehran, Islamic Republic of Iran, [2]Agricultural Sciences and Natural Resources University of Khuzestan, Ahvaz, Islamic Republic of Iran, [3]University of Florida, , USA, [4]Ghent University, Ghent, Belgium

Controlling the amount of nutrients needed in the spinach can reduce the consumption of chemical fertilizers, and also increase the production rate of this crop and preserve its quality. In fact, monitoring the growing conditions of products manually and traditionally has high costs and takes time, and sometimes lack of experience causes damage and quality reduction in products. Therefore, it is very important to provide a suitable and practical solution based on new and non-destructive technologies such as image processing that has the ability to recognize the needs of plants. These technologies have facilitated the monitoring of plant nutrient requirements, reducing reliance on human judgment and enhancing intuitive decision-making. The objective is to investigate deficiencies in three key nutrients - iron, zinc, and manganese - at five different levels of application of nutrients (ranging from none to 100% of the recommended amount). To achieve this, a comprehensive analysis was conducted, involving the extraction of color features (such as RGB, rgb, Lab, HSV, XYZ, I1I2I3, h*, and Chroma), morphological features (specifically Area), and various texture features obtained through the GLCM (Gray Level Co-occurrence Matrix) method (including Contrast, Energy, Entropy, Homogeneity, Correlation, and Prominence). After imaging of samples by a digital camera and data extraction, feature selection operation was carried out using the Sequential feature selection method in five distinct modes (SFS (Sequential Forward Search), SBS (Sequential Backward Search), SFFS (Sequential Floating Forward Search), SFBS (Sequential Floating Backward Search), and ReliefF), with the SFBS method demonstrating superior performance. Subsequently, five classification methods (ANN (Artificial Neural Network), Bayes, KNN (K-Nearest Neighbors), SVM (Support Vector Machine), and Random Forest) were evaluated using the selected features as input in a predetermined order based on the SFBS results. The classification accuracy rates were determined for varying numbers of input features through multiple iterations. The most effective features were identified after comparing the performance of different classification methods. The study revealed that the classification methods achieved the highest average detection accuracy when operating with two output classes (0.813). Acceptable accuracy rates were also observed for three output classes (0.609), while performance significantly declined when handling four or five output classes. In conclusion, the classification methods ranked in terms of effectiveness for detecting different levels of iron, zinc, and manganese deficiencies are as follows: ANN, KNN, SVM, Random Forest, and Bayes.

OP04-4 | Lightweight improved algorithm: YOLOv5s with ghostnetwork and CBAM

Niraj Tamrakar[1], Junghoo kook[1], Sijan Karki[1], Nibas Chandra Deb[1], Myeong Yong Kang[1], Hyeon Tae Kim[1]
[1]Gyeongsang National University, Jinju, Republic of Korea

Abstract
Lightweight vision algorithms play a crucial role in the effective implementation of strawberry harvesting robots in the real field. YOLO models are prevalently used for object localization and detection because of their characteristics, such as high accuracy, speed, and real-time detection. However, YOLO baseline architecture suffers from a large network size, higher computation operation requirements, and slow inference time. Therefore, the lightweight improved YOLOv5s-CGhostnet was proposed to enhance strawberry detection. The baseline YOLOv5s architecture was modified by replacing base modules CBS and C3 with Ghost modules GCBS and GC3, respectively, in the backbone and neck. Furthermore, the default GIOU bounding box regressor loss function was replaced by the SIOU loss function to improve localization. In addition, for feature enhancements, CBAM attention modules are added before SPPF in the backbone and between up sampling and down sampling feature fusion FPN+PAN network in the neck section. The proposed YOLOv5s-CGhostnet exhibited higher mAP@0.5 of 91.7% with a significant decrement in model size of 85.09% and a reduction in GFLOPs by 88.5% compared to the baseline model of YOLOv5. The model demonstrated an increment in mean average precision, a decrement in model size, and reduced computation overhead compared to the standard lightweight YOLO models.

Keywords— CBAM, Ghost module, Loss function, strawberry, YOLOv5

ACKNOWLEDGMENT
This work was supported by the Technology development Program (RS-2023-00281085) funded by the Ministry of SMEs and Startups (MSS, Korea).

OP04-5 | Training a new generation of farmers and agricultural entrepreneurs to implement the concept of circular economy in agriculture – the tango-circular Erasmus+ project

George Spyrou[1], Evangelos Dimitriou[1], George Papadakis[1], Piero Picuno[2], Vasco Fitas da Cruz[3], Lluis Martin Closas[4], Delphine Margout-Jantac[5], Christina Stamataki[6], Christina Stavropoulou[7], Camilla Tomao[8], Zoe Godosi[9], Anna Farus[10], Tomas Ribes[11], Teresa Baptista[12], Firmino Cordeiro[13]
[1]Agricultural University of Athens, Athens, Greece, [2]University of Basilicata, Basilicata, Italy, [3]Univesity of Evora, Evora, Portugal, [4]University of Lleida, Lleida, Spain, [5]University of Montpellier, Montpellier, France, [6]Eurotraining, Athens, Greece, [7]Inaso Paseges, Athens, Greece, [8]ENAPRA-Confagricoltura, Rome, Italy, [9]Unione delle Province d'Italia, Puglia, Italy, [10]Federació de Cooperatives Agràries de Catalunya, Catalunya, Spain, [11]Institució de Ponent per a la Conservació i l'Estudi de l'Entorn Natural, Lleida, Spain, [12]Comunidade Intermunicipal do Alentejo Central, Evora, Portugal, [13]Associação dos Jovens Agricultores de Portugal, Lisbon, Portugal

The volume of wastes produced by agricultural and livestock activities is constantly rising. This is a result of the continuous increase of crop and livestock production, in order to cover the nutritional needs of the accreting population of the planet. This enormous mass of wastes, coming straight from agriculture and animal husbandry as well, has a significant environmental impact. A very promising way to reduce the impact of agriculture on the environment, passes through the valorization of crop residues, agricultural by-products and other materials such as plastics, used for crop cultivation and animal production, currently considered as wastes. Hence, for a sustainable agriculture and under the perspective of circular economy, it is necessary to address the issue of properly managing such agricultural residues and by-products as also other materials considered as “waste”. By upgrading and spreading the valorization methods of agricultural residues, by-products and plastics, more than one advantage can be recognized. More specifically, the utilization of agricultural materials can contribute to strengthening the economic inputs of producers, ensuring a sustainable way of collecting, transporting and managing unused materials for the production of energy or new goods. Aim of this Project is the contribution to the development of regional ecosystems directly providing a valuable input to the economy, by integrating work-based learning thanks to a Quadruple-Helix approach involving actors from different sectors. Core of the Project will be the modelling, implementation and validation of the Project “Rural Labs” in which, under the coordination of some of the most important Universities of Mediterranean Europe, experts in agricultural waste management, the farmers and other relevant stakeholders will be trained. Two cycles of training activities have already been completed, while farmers and several stakeholders from the four participating countries (Italy, Greece, Spain, Portugal) have successfully attended the training courses at the Rural Labs implemented at national level. Education of farmers on such issues of circular economy is imperative for environment protection and economy enhancement.

OP05-1 | Unveiling citrus cargo temperature heterogeneity through digital twin simulations and field experiments

Elisabeth Tobler[1], Celine Verreydt[1], Thijs Defraeye[1]
[1]Empa (Swiss Federal Laboratories for Materials Science and Technology), St.Gallen, Switzerland

Refrigerated transport in trailers is one of the key unit operations in fresh fruit supply chains. Their design and operation should ensure uniform airflow, temperature, and humidity within the cargo in order to preserve the quality of such perishable products. Nevertheless, temperatures can rise locally due to improper precooled fruits, respiration, inadequate pallet loading, or equipment malfunctions. Hence, a significant amount of fruits and vegetables are still lost during refrigerated transport. To safeguard supply chains, in-transit monitoring is a common strategy. In commercial supply chains, the typical practice is to place only one temperature sensor in each transport, usually on top of the pallet closest to the door-end side of the trailer. However, relying on a single temperature sensor is insufficient to provide a comprehensive view of the hygrothermal conditions throughout the entire cargo, which is crucial for preventing localized high-temperature zones.

Taking a leap forward, we aim to combine gathered sensor data with physics-based 3D models of refrigerated trailers, a concept commonly referred to as digital twins. This enables the capability to precisely characterize airflow patterns and predict fruit temperatures and quality at every location within the loaded trailers and at every time during transportation. However, prior to integration into the supply chain, a critical evaluation of the accuracy and reliability of such aforementioned models is imperative. Therefore, we developed a physics-based 3D model of a refrigerated trailer with its cargo, according to an extensive field experiment. In that field experiment, more than 100 sensors were systematically distributed inside one trailer full of citrus fruit to monitor the temperature variability within the cargo during transport from Nafplion, Greece to Pratteln, Switzerland.

With the physics-based model, the airflow and the temperature distribution inside the trailer were analyzed, and the temperature was compared to the experimental dataset to evaluate the accuracy of the model. Furthermore, hot spots and their causes were identified, and the sensitivity of various model parameters was investigated. The model successfully reflected the temperature variability inside the trailer during transport and helped to understand the dynamics inside. Digital twins can be used by stakeholders along the supply chain to track and understand the development of fresh produce along their postharvest life and facilitate decision-making related to preservation and quality management. Furthermore, process optimization of refrigerated transport can be achieved more efficiently, leading to a reduction in the need for lengthy and extensive experiments.

Keywords: Refrigerated Transport, Supply-chain monitoring

OP05-2 | Visible and infrared spectroscopy as a tool to assess taste components in tomato fruit during postharvest shelf life

Sotirios Tasioulas[1], Pavlos Tsouvaltzis[1], Jessie Watson[1]
[1]Vegetable Horticulture, Horticultural Sciences Department, Southwest Florida Research & Education Center, University of Florida, Immokalee, United States

Tomato plants (cv. HM 1823) were grown during the Fall season in 2023 in Immokalee, FL following usual agricultural practices. Harvested fruit were sorted and only sound and uniform ones were left at 22oC in a room, simulating conventional conditions of the retail market. 1280 fruit were classified according to their ripening stage at harvest based on visual assessment; the mature green (MG), breaker (BR), orange (OR) and red (R). Four replications of 5 fruit in each of them were selected during storage for objective measurements, as well. The color was measured with a colorimeter, the reflectance data at 340-2500 nm was captured with a portable spectroradiometer, compression of the fruit (in millimeters) was measured with a portable deformation tester and puncture firmness was destructively measured with a suitable penetrometer equatorial zone of the fruit. After storage at -30oC for 2 weeks, the fruit were blended and filtered for pH, titratable acidity and soluble solids content measurements. Significant differences in compression and puncture firmness levels among the 4 ripening stages were found during shelf life period. Although similar differences were initially also observed in the color of the fruit, eventually all of them obtained the same red coloration at the end. However, the pH and the soluble solids content to titratable acidity ratio (SSC/TA) of the non-red harvested fruit were never equal to the ones harvested at the red ripening stage, implying that although all of the fruit became similar in terms of color, there were differences in the taste. A spectroscopy method at the visible and near infrared region of the electromagnetic spectrum combined with chemometrics was tested in terms of its performance to predict internal nutritional components that are only revealed upon lab analytical protocols. Partial least square regression analysis on reflectance data, preprocessing techniques with proper algorithms (SNV, detrend and mean centering) and coupled with random subset cross validation method was able to predict the pH, and SSC/TA components efficiently, with regression coefficients R= 0.86 and 0.85 and RMSE= 0.0716 and 0.839, respectively. The linear regressions between firmness/ color and pH or SSC/TA proved less valid, with a regression coefficient 0.74 (for color) and 0.84 (for compression) in the case of pH assessment and 0.71 and 0.80 for SSC/TA prediction. Apparently, portable spectroscopy is able to capture information that is transmitted from the fruit in the near infrared region more efficiently than any color or firmness test.

OP05-3 | Enhancing post-harvest quality prediction models: A synergistic approach integrating temporal boosting for improved performance with new season's datasets

Tamar Holder[1,2], Noam Koenigstein[1], Yael Salzer[2], Abiola Owoyemi[3,4], Ron Porat[3], Amnon Lichter[3]
[1]Department of Industrial Engineering, Tel Aviv University, Tel Aviv, Israel, [2]Institute of Agricultural Engineering, Agricultural Research Organization - Volcani Institute, Rishon LeZion, Israel, [3]Department of Postharvest Science of Fresh Produce, ARO - Volcani Institute, Rishon LeZion, Israel, [4]Faculty of Agricultural, Food and Environmental Sciences, Hebrew University of Jerusalem, Jerusalem, Israel

Approximately $162 billion worth of food goes uneaten yearly. Almost 30% of food loss takes place during post-harvest, processing, packaging, and distribution stages. This significant loss highlights the urgent need for innovative solutions within the industry. The current industry practice employs a "First In, First Out" (FIFO) logistic management approach, which may not be optimal for perishable goods. Recognizing the limitations of FIFO, transitioning to a "First Expired, First Out" (FEFO) strategy to minimize food loss has been previously proposed. To address this, previous efforts utilized datasets from recent years to construct traditional machine learning models, aiming to predict the shelf life of produce. However, while the traditional models performed well when trained on randomly split data, gathered over the duration of one season, they did not perform well when making blind predictions for new unseen seasons. Our research embraces a more realistic scenario where the test set comprises the most recent chronological data points available. This is vital for addressing real-world challenges in predicting future outcomes based on historical data.

The present research strives to address the time-related constraint; Leveraging the power of boosting, where models sequentially learn and correct errors, Temporal Boosting introduces a temporal dimension. Each model aims to predict and refine the chronological errors of the previous model, leading to a progressively more accurate prediction over time.
These methods were applied to large-scale datasets acquired over two seasons of high-throughput phenotyping analysis of the effects of pre-harvest and postharvest features on the shelf-life quality of 'Valencia' and 'Rustenburg' oranges (2021: 400 datapoints, 2022: 163 datapoints), 'Orri' Mandarin (2022: 279 datapoints, 2023: 216 datapoints) and 'Scarlotta Seedless' grapes (2020: 672 datapoints, 2021: 1100 datapoints). Preliminary trials consisted of comparing a regular Linear Regression model to a Linear Regression with an implementation of Temporal Boosting. Results suggest that applying Temporal Boosting improved new unseen season prediction of Scarlotta with RMSE = 0.334 and R^2 = 0.901 (regular Linear Regression: RMSE = 0.74, R^2 = 0.632). However, no improvement was recorded for the citrus models. Ongoing efforts focus on refining this approach. We anticipate that combining the more tailored Neural Network models with the Temporal Boosting principle will contribute to improved performance. Focusing on enhancing the models' capacity to forecast future data points, we aim to contribute to developing more potent and applicable solutions for mitigating food loss in the industry.

OP05-4 | Transmission Raman spectroscopy for inner layers chemical analysis of fresh produce

Rani Arielly[1]
[1]Agricultural Research Organization, Volcani Center, Rishon Letsiyon, Israel

We show the development of transmission Raman spectroscopy system and analysis techniques for identification of chemical properties at the inner tissues of fresh produce. Successful chemical analysis of inner tissues would enable us to identify major issues plaguing the agriculture supply chain like off-flavors and core-rot, since these are caused or accompanied by known chemical elements. Contrary to IR and near IR non-destructive spectroscopic techniques that cannot penetrate very deep into the produce tissues, our method consists of locating an optimal spectral window by conducting optical attenuation measurements, and calculating the required LASER power in that range. Elimination of the competing fluorescence signal is also taken into account by calculating the optimal shifted-excitation Raman difference spectroscopy parameters. All of these culminate with our provided complete optical system design and optimal parameters. The lack of a chromatography step which hinders the chemical identifications is compensated by the use of a custom designed neural networks developed with the help of synthetic and measured spectroscopic datasets.

OP05-5 | Physics-based digital twin to monitor citrus fruit quality evolution during overseas transport in refrigerated containers

Celine Verreydt[1,3], Tarl Berry[2], Deniz Turan-Kunter[3], Thijs Defraeye[1,3]
[1]Empa, Swiss Federal Laboratories for Materials Science and Technology, Laboratory for Biomimetic Membranes and Textiles, 9014 St. Gallen, Switzerland, [2]Citrus Research International, Department of Horticultural Science, University of Stellenbosch, South Africa, Stellenbosch 7602, South Africa, [3]Food Quality and Design, Wageningen University & Research, 6700 AA Wageningen, The Netherlands

We investigate the challenges of exporting citrus fruit ('Valencia' oranges) from South Africa to international markets along the postharvest cold chain. Maintaining optimal conditions for air temperature and relative humidity during maritime transport is crucial to minimize postharvest losses and preserve fruit quality. However, due to variations in transportation duration and hygrothermal conditions, the quality of the fruit upon arrival can differ significantly between shipments. Moreover, the packaging type and the compact arrangement of pallets within the container can cause additional variations in fruit quality loss inside one container. Currently, there is limited knowledge regarding where, when, and how much quality is lost during each shipment. Conducting extensive experimental measurements of fruit quality after every transport is impractical for commercial shipments due to time constraints, expenses, and potential damage to the fruit.

Digital twins, or virtual representations of the fruit connected to real-world sensor data, can provide additional insights by converting sensor data into fruit quality indicators. In our study, we developed a digital twin model to simulate a refrigerated container loaded with oranges, tracing its journey from South Africa to destinations in Europe and Asia. This model uses sensor data from real shipments to predict the quality evolution of each fruit within the container. The examined quality attributes include respiration-driven shelf life, moisture loss, chilling injury, and pest mortality. This approach enabled us to quantify expected variations in quality evolution within and between different shipments, thereby identifying potential quality issues, discussing trade-offs, and improving product handling upon arrival. Additionally, the insights gained from this study will allow for proactive measures to be taken to minimize quality losses and optimize fresh produce transport for the citrus industry. The digital twin developed in this research serves as an initial step towards real-time monitoring of fresh produce shipments.

OP06-1 | Measuring NMVOC and ammonia emissions from a naturally ventilated dairy housing: Comparison of different diets

Sabine Schrade[1], Michael Zaehner[1], David Steger[2], Giovanni Lazzari[3], Kerstin Zeyer[2], Joachim Mohn[2], Frigga Dohme-Meier[3]
[1]Agroscope, Ruminant Nutrition and Emissions, Ettenhausen, Switzerland, [2]Empa, Laboratory for Air Pollution / Environmental Technology, Duebendorf, Switzerland, [3]Agroscope, Ruminant Nutrition and Emissions, Posieux, Switzerland

In addition to ammonia (NH3) and methane emissions, cattle farming is a relevant source of non-methane volatile organic compounds (NMVOC) emissions. Together with nitrogen oxides, NMVOCs lead to the formation of ground-level ozone, which is both an air pollutant and a strong greenhouse gas. A large proportion of NMVOC emissions in cattle farming originate from feeding, mainly from silage. Available studies were often conducted on a laboratory scale, mostly focused on individual NMVOC compounds and often only concentration values were determined.
In order to improve the data basis on NMVOC emissions from dairy farming, Agroscope and Empa carried out a study on four different diets. The experimental dairy housing for emission measurements allowed comparative measurements of two diet variants on one compartment with 20 lactating cows, each. The effect of diets on NH3 emissions was also studied. The variants "silage-free diet" and "mixed silage diet" were investigated in 2018 and the variants "grass silage diets" and "sainfoin silage diet" in 2020. A dual tracer ratio method was used to quantify emissions under natural ventilation. Concentrations of about 30 different NMVOC compounds were analysed quasi-continuously by GC-FID, the tracer gases by GC-ECD and NH3 by CRDS. In order to cover different climatic conditions, the measurements were carried out in three seasons.
NH3 emissions in summer, with medians per variant ranging from 30 to 52 g LU-1 per day, were in the range of values measured previously on Swiss farms in summer. NH3 emissions showed typical daily patterns with higher values in the warmer afternoon hours. NH3 emissions were significantly affected by temperature, wind speed in the housing, and diet, and showed a positive relation with milk urea content, across all variants of each year including all seasons. The NMVOC emissions of all silage diets were significantly higher compared to the silage-free diet. Daily patterns of NMVOC emissions showed maxima, particularly in the silage-based diets, during feed distribution and main feeding times. In summer ethanol accounted for the highest proportion (by mass) of NMVOC compounds in the mixed silage and grass silage diets, with at least 80%, and in the silage-free diet, with at least 40%. In the case of the sainfoin silage diet, the methanol emissions with about 50% were slightly higher than the ethanol emissions.
These measurements of NMVOC emissions from different diets on a practical scale have substantially improved the database.

NMVOC, ammonia, emission, diet, dairy cow

OP06-2 | Development and deployment of a decision support tool for gas emissions at the dairy farm level: Analysis of two case studies for dairy farms

Evangelos Alexandropoulos[1], Vasileios Anestis[1], Thomas Bartzanas[1]
[1]Agricultural University of Athens, Athens, Greece

To meet national and global air quality and climate change policies, it is essential to equip the agricultural sector with farm-level decision support systems (DSS) for gaseous emissions. Developing these tools presents a significant challenge, as their reliability must be ensured through the incorporation of the latest methodologies and calibration using precise case study data. To address this issue, the authors updated a previous version of a DSS designed to estimate greenhouse gas emissions, ammonia emissions, the nitrogen cycle, the carbon cycle, energy use, milk production, and weight. This resulted in the development of a Prototype Livestock Farm-scale Gas Emission-based Decision Support Tool (PDST). The tool's modification includes integrating the most up-to-date estimation methodologies, such as IPCC, EMEP/EEA, UNECE, and ASAE. To assess the efficacy of the updated DSS, both versions were used for two case-study commercial farms in Greece and Poland. Both case studies refer to intensive livestock production systems with no-grazing practices, dunghill manure storage, and deep litter housing. It is important to note that in the Greek case study, the livestock farmer does not cultivate feed crops, while in the Polish case study, the opposite is true. This study specifically examines on-farm emissions related to livestock processes. To demonstrate the differences between the previous and updated versions, two scenarios were defined for each case study farm. The first scenario includes the previous version with the already available agroecological zone data, while the second scenario incorporates climate data from Greece and Poland. A comparison between the two scenarios was then conducted. The updated version of the tool demonstrated a reduction in annual emissions per kg of raw milk produced, ranging from 15% to 25%, when compared to the previous version. The reason for this was the modifications made to the methodologies used to estimate gas emissions. These included changes to the estimation of volatile solids, to various emission factors (EFs), such as the ammonia EF for housing and external manure storage, the nitrous oxide EF in external manure storage, the methane conversion factor, as well as adjustments to other parameter values, such as feedstuff, livestock breeds, and external manure storage types. The updated tool seems promising for providing improved gas emission estimations for livestock farms that are in agreement with the most updated methods.

OP06-3 | Towards a computational fluid dynamics analysis of ammonia emission from a poultry litter bed in a small lab chamber

Kasidit Phanpa[1], S.M.E.(Sayed) Derakhshani[1], J.D.(Hans) Stigter[2], P.J.A.(Peter) van Heijster[2], P.W.G.(Peter) Groot Koerkamp[1]
[1]Agricultural Biosystems Engineering, Wageningen University and Research, Wageningen, Netherlands, [2]Biometris, Wageningen University and Research, Wageningen, Netherlands
Ammonia (NH3) emission from poultry houses is a significant concern due to its adverse impacts on animal and human health, as well as the environment. Determining this emission is crucial for implementing effective mitigation strategies. Traditionally, NH3 emission has been measured experimentally, but this approach has limitations. It is a time-consuming process, lacks detailed information, and is subject to instrumental constraints. In contrast, numerical simulations using computational fluid dynamics (CFD), offer numerous advantages for analyzing pollutant emissions. CFD reduces the dependency on measurements and experiments, is cost-effective, and provides detailed insights into the emission process. Therefore, developing a reliable and accurate numerical simulation model is essential for understanding and minimizing NH3 emissions from poultry litter.

This study designed and developed a CFD model for simulating NH3 emission on a laboratory scale. The following steps were implemented: 1) Identifying the sensitivities of NH3 emission to variations in model parameters, and 2) Designing and developing of a CFD model for simulating emission.

Initially, airflow patterns within a chamber were studied using CFD-Ansys Fluent software. It was observed that the airflow inside the chamber did not directly interact with the poultry litter. This airflow pattern was validated using a cavity, a standard benchmark for CFD airflow simulations. Furthermore, heat transfer through the litter layer was investigated by heating the floor. Validation of heat transfer simulations was conducted using simple materials (wood, ash, and air) to compare temperature gradients and heat flux with Fourier's law of heat conduction. The results demonstrated a close match with an error of approximately 0.24%, confirming the validity of CFD for heat transfer simulations.

These findings prove the effectiveness of CFD in investigating parameters that are challenging to assess experimentally. Moreover, CFD holds promise for future research on heat transfer through specific materials (such as poultry litter), water penetration, and NH3 emissions. We anticipate that the results will be further validated in subsequent stages through measurements obtained in laboratory settings.

Keywords : Computational Fluid Dynamics, Poultry Litter, Ammonia Emission, Thermal Balance

OP06-4 | Effects of bedding material on performance, welfare and ammonia emissions of broiler chickens

Shutong Dong[1], Ing Jan van Harn[1], Kris De Baere[2], Ine Kempen[2], Albert Winkel[1]
[1]Wageningen Livestock Research, Wageningen, Netherlands, [2]Proefbedrijf Pluimveehouderij (Experimental Poultry Centre), Geel, Belgium

Peat is a bedding material used in Dutch broiler farms. It has a relatively low pH due to humid compounds/acids produced by soil bacteria under low oxygen levels, which may have the potential to reduce ammonia emissions. A study was conducted in experimental broiler houses with fast-growing broilers (Ross 308) with the following objectives: (1) to determine the potential of peat bedding in reducing ammonia emissions in broiler production compared with wood shavings, the mixture of wood shavings and peat, and straw pellets bedding, with attention to litter characteristics, animal production and animal welfare (footpad lesions and hock dermatitis); (2) to compare ammonia concentration measurement methods including Fourier Transform Infrared Spectroscopy (FTIR), Dräger sensor and wet chemical method; (3) to compare ventilation rates measured by the carbon dioxide mass balance method and by fan anemometers. Measurements were done with 42800 broilers during two rounds from September 2022 to February 2023. Results showed that peat had an ammonia emission of 13.450 (g animal place^{-1} year^{-1}), which was significantly ($P < 0.001$) higher than wood shaving (5.663 g animal place^{-1} year^{-1}) and the mixture of wood shaving and peat (7.389 g animal place^{-1} year^{-1}). The bedding material had no influence on the production performance (body weight, growth rate, feed conversion ratio, mortality) of broilers and the final litter composition (total N, ammonium N, P, K, ash, dry matter content, pH). However, broilers on peat bedding had fewer footpad lesions and hock dermatitis than broilers on wood shavings. With the wet chemical method as a reference method, Dräger had a better estimation of ammonia concentration ($y = 0.27 + 1.01*x$, $R^2 = 94.9\%$) than FTIR ($y = 0.04 + 0.91*x$, $R^2 = 95.6\%$). Ventilation rates calculated by the CO_2 mass balance method were 14% higher than measured directly by the fan anemometers ($P < 0.001$). The ammonia emissions in this study were lower than common broiler houses, which may be due to poor litter quality (friability and wetness). For both Dräger and FTIR sensors, periodical recalibrations are essential. More insight is needed to investigate how the litter variables interact with each other and how they influence ammonia emissions. Furthermore, validating the CO_2 mass balance method for today's broilers is recommended.

Keywords: broiler, peat, wood shaving, ammonia emission, CO_2 mass balance method

OP06-5 | Lab assessment of the suitability of low-cost ammonia sensors for emission monitoring systems in livestock housing

An Verfaillie[1], Eva Brusselman[1], Loes Laanen[1], Chari Vandenbussche[1]
[1]Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Merelbeke, Belgium

Ammonia (NH3) is one of the most important gaseous pollutants originating from livestock housing, as it lowers the air quality, it contributes to the formation of secondary particulate matter and causes eutrophication upon deposition. Ammonia emission factors represent a value quantifying the average amount of ammonia released to the atmosphere per animal within a specific type of livestock housing during one year. These emission factors are used to develop (inter)national inventories regarding air quality. Based on these inventories, (legislative) decisions concerning air quality management and -control strategies can be made. However, as these factors are averages based on limited data of discrete measuring days distributed over production cycles and seasons, the assumption being representative for each individual farm is questionable. Moreover, the temporal variability in emissions is not captured by a yearly average.

To capture this temporal and individual variability, emissions should be measured continuously in all livestock houses. Different low-cost sensors that continuously measure NH3 concentration are available on the market. However, most of these sensors are designed as warning systems for industry to alert when NH3 levels cross a certain safety threshold. It is therefore important to test the capabilities and limitations of these NH3 sensors regarding emission monitoring in livestock housing.

In this study, a first step assessment regarding the capabilities and limitations of low-cost sensors was performed by conducting different laboratory tests. A range of NH3-concentrations (0-33 ppm) in different gas mixtures (humidified air with or without mixtures of CO2 and/or N2O and CH4) was offered to eight different sensors, each in duplicate (sensor A and sensor B). Based on these tests, the performance specifications including response time and trueness of the sensor, the repeatability of the sensors based on simultaneous measurements of sensor A and sensor B and the interference with other gases could be quantified.

Acknowledgements: Flanders Government (Environmental Department) for their financial support. The technical team including Lorenzo Plant, Willem Grauls and Stan Roelens for the practical implementation of the experiment.

OP06-6 | An automatic pig toilet as solution for animal welfare and environmental friendly pig production

Fei Xie[1,2], Zhenpeng Hu[1,2], Marc Bracke[1], Peter Groot Koerkamp[1], André Aarnink[1]
[1]Wageningen University and Research, Wageningen, Netherlands, [2]China Agricultural University, Beijing, China

In various parts of the world pig production has intensified and new housing systems, for example with slatted floors and automated feeding systems, have been introduced to increase herd size and farm productivity. This process has, without doubt, improved farmers' living standards. However, there are some major drawbacks; the main ones being environmental pollution and impaired animal welfare. Both problems could be tackled with a 'pig toilet', which is defined as a relatively small area inside a pen where most excretions are deposited. Pigs are hygienic animals by nature and are especially moving away from their resting area for excretion. The main problem, in general, is that the motivation of pigs to excrete at a certain location is not very strong. This makes it difficult to create an area where most of the excretions are deposited.
To reinforce the desired behaviour a reward could be given immediately following excretion in the toilet; training with dogs and children have shown to be successful. The objective of this study was to develop a robust pig toilet where >95% of the excretions will be deposited. Studies were done to answer the following questions: - Should the toilet be an open or a closed system? - what is the learning curve of the pigs? – How can urination and defecation be rewarded consistently and automatically?
From the results it can be concluded that a higher number of excretions were achieved in an open toilet, but this system had the disadvantage of more displacement inside the toilet. Results until now do not show a steady learning curve and there was a large variation in the use of the toilet by the pigs. Image recognition using/on infrared thermal images and RGB images was applied to detect urination and defecation behaviour using three deep learning models which were EfficientB0, ResNet50 and VGG19 model. The results showed that the accuracy of these three models to recognize pig defecation and urination in thermal images was 90.3% for EfficientNetB0, 87.6% for ResNet50, and 81.8% for VGG19. In RGB images the accuracy was 79.1%, 76.4%, and 74.0%, respectively. Results from these studies will be compiled together to make an optimal design of an automatic pig toilet and this design will be validated on an organic pig farm with sows.

OP07-1 | Integrating agrivoltaics and other climate-smart technologies for diversified and urban farming systems in Kansas

Cary Rivard[1], Eleni Pliakoni[1], Tricia Jenkins[1]
[1]Kansas State University, Olathe, United States

Small-scale and diversified farming operations in the Central United States are extremely aware of the impacts of climate change upon the long-term sustainability of their operations. Many growers in the region are looking to adopt technologies that are practical, economical, and environmentally-sustainable. The adoption of passive-thermal greenhouses, often called high tunnels, has rapidly spread over the last decade as a way to protect crops from an erratic climate and extend the growing season without the use of energy inputs. Similarly, growers in the region have quickly adopted CoolBot™ technology, which enables small air conditioning units to be used for postharvest cooling and storage. In 2022, we developed and implemented a 6-kilowatt solar power plant at the KSU Olathe Horticulture Center, which energizes the irrigation system that is utilized for vegetable and high tunnel production. When it is not being used for irrigation, the system is utilized for powering/charging electric equipment and produce cooling. We are also implementing several research studies to investigate the use of agrivoltaics for vegetable production in Kansas. Agrivoltaics includes the use of land for both agriculture and solar photovoltaic energy production. Preliminary trials with vertical (90°) racking systems as well as traditional 30° ground mount systems will be discussed. The integration of climate-smart technologies will be essential in all scales of agriculture in order to make a significant impact. As opportunities arise for new technologies, it will be essential to integrate them into small-scale and diversified farming operations in urban and rural areas.
Keywords: solar, photovoltaics, hoophouses, microclimate modification, agrovoltaics

OP07-2 | Effect of solar panels on fruit quality for agricultural photovoltaic greenhouses

Pablo Gonzalez-Planells[1], Coral Ortiz[1], Francisco Rovira-Más[1], Elena Chaveli Lopez[3], Carmina Reig[3], Víctor Añón[2]
[1]Agricultural Robotics Laboratory, Universitat Politècnica de València, Valencia, Spain, [2]INDEREN, Ingeniería y Desarrollos Renovables, Silla, Spain, [3]Mediterranean Agroforestry Research Institute, Universitat Politècnica de València, Valencia, Spain

Agricultural photovoltaic systems (APV) integrate crop production with energy production from photovoltaic technology. However, the effect of reducing solar radiation on fruit quality under the panels is still uncertain. This study investigates the impact of solar panels on fruit quality in an experimental agrivoltaic greenhouse located in Spain.
The experimental design incorporates two high-value crops, dragon fruit and fig crop, under different support configurations, with three varieties of dragon fruit and one of figs. The fruits were harvested at their commercial harvesting stage, weighed, colour-evaluated, and analysed for mechanical firmness and soluble solid content. The results for dragon fruit showed a significant effect of the variety and significant lower sugar content and R-B colour components for fruits collected from the areas without solar panels. These outcomes suggest a potentially advantageous impact of solar panel coverage on dragon fruit quality. On the other hand, the results for fig crop showed that high-density coverage of solar panels significantly reduced fruit weight and productivity, whereas half-density coverage in a chessboard pattern resulted in a moderate reduction of weight without altering sugar content but reducing firmness. These results are promising for efficiently combining solar panels and agricultural production in greenhouses.

OP07-3 | Indoor cultivation of leafy greens under different led spectra powered by photovoltaics: A step towards sustainable vertical farming

Stavros Martinakos[1], Ioanna Chatzigeorgiou[1], Maria Ravani[1], Georgios Ntinas[1]
[1]Hellenic Agricultural Organisation-Dimitra, Thermi, Greece

With vertical farming becoming a very prevalent way of cultivation, containers are gaining ground in indoor farming of leafy greens and vegetables. However, it is important to consider how much energy efficient, such an indoor cultivation can be. In this study, findings of a hydroponically grown baby leaf rocket in a vertical arrangement under different spectrum LED lights, using photovoltaics (PVs) with public grid as back up, are presented. For the experimental design, 4 different light spectra were set up, maintaining 200 μmolm-2s-1 on canopy level and a 14h photoperiod for each treatment (Red, White, Red/Blue and Blue), under which, rocket was cultivated for 21 days during winter period in a floating hydroponic system. Six 570 W panels were installed on the roof of a 15 m2 container and connected to an Off Grid 5kW Solar Inverter and 2 lithium batteries 5kW each for the purpose of this study. For each treatment, morphological as well as physiological measurements have been performed (yield, leaf length, leaf width and stem length, photosynthetic rate, transpiration rate and stomatal conductance). Moreover, during the entire growth cycle the energy consumption of the experimental growth room was monitored. Leaf length, leaf width and stem length under red light, seems to have had statistically significant differences with all other light treatments. The results highlight the importance of Red light in the growth of baby rocket as the aforementioned quality traits were significantly bigger in size. With regards to yield, it was observed that the harvest under Red light, was 23% higher than the White light, and 22% higher than the Red/Blue and Blue, with the latter treatments consuming 20% and 28% less power respectively than the Red, overall. The overall energy consumption of the experimental container was on average 13.5 kWhday-1 deriving 77% from the PVs and 23% from the public grid. Further research must be conducted to determine the effect of different light treatments on various traits of leafy greens, with energy consumption being an integral part of indoor cultivation systems and maintaining the focus of future research, while trying to render such systems energy efficient and cost effective.

Keywords: Growth room; LEDs; leafy greens; renewable energy; photovoltaics; lithium batteries

OP07-4 | Skyscraper crop factory: A potential solution to meet rising urban food demand and light up urban agriculture

Xiao Yang[1], Li Zhang[1], Jie Peng[1], Qichang Yang[1]
[1]Institute Of Urban Agriculture, Chinese Academy Of Agricultural Sciences (IUA-CAAS), Chengdu National Agricultural Science and Technology Center, Chengdu, China

More than 56% of the world’s population lived in urban areas by the end of 2022 owing to rapid urbanization, and this will reach 67% by 2050, with a total population of 9.7 billion. In this context, traditional crop production and supply chains face unprecedented challenges in the tension between increasing food demand due to population boom and agricultural resource scarcity in urban and peri-urban areas. Therefore, a sustainable food supply system is needed at present. Vertical farming system, such as sky farm, is a potential agricultural system for stable and effective food production. Here, we highlight the potential of sky farm for crop production, as well as it potential for leisure and recreational activities, namely skyscraper crop factory (SCF). SCF is a potential crop production system that aims to increase the effective arable area for crops by building a high-rise structure with multiple levels on the same land footprint to continuously provide safe, nutritional, sustainable, and sufficient food. In addition, with the application of plant factory technology, green and sustainable technology, and energy-saving technology, SCFs can enable year-round, high-efficient, and environmentally friendly cultivation of crops. Moreover, the SCF offers non-food products and various functionalities in addition to its contribution to secure food supply, such as social activity (e.g. popularization of horticultural knowledge), and cultural activity (e.g. recreation and amenities). As a result, the SCF represents an ideal crop production system for increasing the effective arable area for crops, ensuring food security in case of unpredictable crises that give a shock to global trade, reducing greenhouse gas emissions, providing food in urban areas to meet the demands for increased health, taste, and safe production of crops by producers and consumers, and serving a variety of functions in urban horticulture such as social and cultural activity. SCF could be a sustainable addition to conventional agricultural crop production in urban agriculture.

OP07-5 | Behaviour of strawberry cultivars under artificial light as the sole source of lighting

Aikaterini Kouloumprouka Zacharaki[1,2], Jim M. Monaghan[1], Jennifer R. Bromley[2], Laura H. Vickers[1]
[1]Harper Adams University, Edgmond, United Kingdom , [2]Vertical Future Limited, London, United Kingdom

Introduction: There is limited literature around total controlled environment production (TCEA) of fruit crops, in particular of strawberries. Worldwide interest in growing in these systems due to the opportunity they present for year-round production for temperate countries. Three experiments were conducted with short-day (SD) and long-day (LD) strawberry plants grown indoors in soil-less vertical farming systems using broad (white) spectra artificial lighting (LED). Experiment 1 (Exp1) investigated the effect of three light intensities over a 18h light photoperiod on four short day (SD) strawberry cultivars; LI1, LI2 and LI3 (115, 125, 300 µmol m^2 s^1 respectively). Experiment (Exp2) used the best performing light intensity from Exp1 and compared three photoperiods of light P1, P2 and P3 (10, 11 and 12h respectively). Both experiments used SD cultivars; Malling Centenary (MC), Malling Allure, Elsanta and Sonata. The third experiment (Exp3) compared three temperature day/night schedules of T_High (24/22°C), T_Medium (22/16°C) and T_Low (22/09°C), to identify the ideal environmental conditions for Malling Centenary and Malling Ace.
Results: In Exp1, strawberries grown under higher light intensities showed higher yields (g) per plant, as expected, than those grown under lower light intensities. Malling Centenary had the highest yield (g) per plant compared to the other cultivars. Malling Centenary and Malling Allure showed the highest number of leaves and longer petiole lengths during the initial vegetative growth. Brix levels increased for Malling Allure 11.8, 12.1 and 12.5 (°Brix) as the light intensity increased (115, 125, 300 µmol m^2 s^1 respectively). However, Malling Centenary did not follow this trend.
The results of Exp2 showed that no significant difference between the photoperiodic treatments. These findings suggest the more diverse photoperiods should be used to detect a statistical difference between the treatments. Exp3 suggested that T_High had a significantly lower yield and fruit quality, with higher % of deformities due to pollination compared to T_Medium and T_Low, while the % of marketable yield was significantly higher at the T_Low treatment.
Conclusion: The results suggest that strawberry plants perform better under higher intensities of artificial lighting, but plant growth, yield and fruit quality vary between cultivars. Further experiments will be conducted to confirm cultivar responses and identify possible interactions between intensity and photoperiod. High night temperatures have detrimental effect on yield, fruit quality and increase the intensity and accuracy of pest and disease outbreaks.
Keywords: Fragaria × ananassa, short-day (SD), artificial lighting, Total Controlled Environment Agriculture (TCEA), Vertical Farming (VF)

OP07-6 | Enhancing alkaloid production in Catharanthus roseus through synergistic effects of LED lights and mycorrhizae-based biostimulant in a vertical farming system

Alberto Barbaresi[1], Alessandro Quadri[1], Mattia Trenta[1], Bianca Sambuco[1], Daniele Torreggiani[1], Federico Puliga[1], Alessandra Zambonelli[1], Laura Mercolini[1], Michele Protti[1], Patrizia Tassinari[1]
[1]University Of Bologna, Bologna, Italy

Catharanthus roseus, a plant rich in terpenoid indole alkaloids (TIAs) with important pharmaceutical properties, offers immense potential for drug discovery and development. The biosynthesis of these alkaloids is intricately regulated by abiotic and biotic factors, with light quality and arbuscular mycorrhizal fungi (AFM)-based biostimulants emerging as crucial influencers. Light, particularly its spectral composition, has been recognized as a key regulator of plant growth and secondary metabolites production. Specifically, in C.roseus light significantly promotes plant biomass and the biosynthesis of some TIAs (such as vindoline, vinblastine, vincristine, ajmalicine and serpentine), as well as plastid development and peroxidase activities. Similarly, biostimulants stimulate the growth and productivity of the plant by improving the absorption and assimilation efficiency of nutrients, tolerance to abiotic stresses and/or quality of the product regardless of their nutrient content. In general, these products can act on the primary metabolism by increasing photosynthetic activity and derived compounds or they can stimulate the secondary metabolism by activating specific biosynthetic pathways. AMF have been reported to improve the nutritional uptake, the general health of the plant and the accumulation of secondary metabolites in medicinal plants. In particular, some studies have demonstrated that AMF inoculation influences the synthesis and accumulation of some TIAs, such as vinblastine, vincristine, ajmalicine and catharanthine.
However, the collective influence of LED light and AFM-based biostimulants on TIAs in C. roseus have never been explored.
Hence, our study aimed to investigate the synergistic effect of LED light and an AFM-based biostimulant on the production of TIAs in C. roseus. Eight experimental treatments were administered in a vertical farming setup, using distinct LED light spectra (W as control, R, B, RB) either alone or supplemented with an AFM -based biostimulant.
Our results reveal nuanced responses in alkaloid production across the experimental treatments. The diverse LED light spectra, both individually and in conjunction with mycorrhizal fungi-based biostimulants, exerted differential impacts on alkaloid biosynthesis in C. roseus. While specific outcomes varied, a trend towards enhanced alkaloid production was observed in treatments supplemented with AFM-based biostimulants, suggesting potential synergistic effects with specific LED light spectra.
In conclusion, our study emphasizes the significance of tailored stimuli in optimizing alkaloid production in C. roseus within vertical farming systems. While specific details warrant further elaboration, the broader implications highlight the potential for strategic integration of LED light spectra and AFM-based biostimulants to enhance pharmaceutical activity in C. roseus.

OP08-1 | Mush-track: An automatic mask R-CNN based tool for the annotation of oyster mushroom instances

Christos Charisis[1], Dimitrios Argyropoulos[1]
[1]University College Dublin, Dublin, Ireland

Recent developments in the field of sensors and computer vision have promoted the application of crop detection systems, leading to their increasing use in agricultural task automation. Existing deep convolutional neural networks (CNNs) have achieved impressive performance in object detection and semantic image segmentation. While commercially cultivated oyster mushrooms are primarily grown in controlled environments, the spatial variability of clusters within the farm introduces complexities that challenge the adaptivity of computer vision systems to real-world farming conditions. Digital images represent important data sources that could provide precise, region-specific information and address a variety of agricultural problems. However, raw and annotated image datasets for oyster mushrooms do not exist. The aim of this study, therefore, was to develop a robust DL-based system to support detection, localization and tracking of mushrooms in a farm environment. Towards this objective, a comprehensive image dataset from a commercial oyster mushroom farm under real production conditions was developed. The proposed solution was based on the segmentation of single mushrooms in a cluster from RGB images using deep convolutional neural networks (Mask R-CNN model). A comprehensive dataset of 200 original RGB images captured over 3,944 instances of mushrooms, which were accurately labelled covering various different sizes, shapes and distribution densities. Each image has a dimension of 4032x3024 pixels and serves as the basis for the specific oyster mushroom detection and segmentation. The dataset was split into training, validation and test set, with 150, 20 and 30 images, respectively. Manual annotation was performed using an open-source image and video annotation tool (CVAT: Computer Vision Annotation Tool), creating the labels required for model training, testing and validation and the results were saved in Common Objects in Context (COCO) segmentation format. This process resulted in a collection of user-defined masks for each mushroom that was considered as an instance of interest for the segmentation. A Mask R-CNN based tool was developed capable of detecting, localizing and accelerating the annotation process of single mushrooms in the images, producing well defined individual mushroom masks (mAP = 68.5%; recall = 73.1%; F1-score = 70.7%). Mush-track is the first-of-its-kind automatic deep learning-based tool for the annotation of oyster mushroom images in a heterogenous farm environment.

OP08-2 | Computer vision-based early detection of Phytophthora spp. in orange grove

Diego José Gallardo Romero[1], Gregorio Egea-Cegarra[1], Manuel Pérez-Ruiz[1]
[1]University Of Seville, Seville, Spain

Over 150,000 hectares of orange trees are cultivated in Spain, representing 10.7% of the European Union’s orange cultivation area and 35.2% of the EU's total orange production. These figures position Spain as the sixth-largest orange producer globally, underscoring the crop’s economic and cultural importance in the country. Despite its prominence, the orange sector faces significant challenges, particularly concerning pathogens, with Phytophthora spp. being a noteworthy threat.
Phytophthora root or collar rot is a fungal disease that affects the roots and the base of the stem or trunk of orange trees, hindering the plant's ability to absorb nutrients and water. This pathogen can lead to wilting, defoliation, and even the tree's death. The primary issue lies in the difficulty of early detection of Phytophthora spp. in orange grove. The lack of evident symptoms in the initial stages of infection makes timely identification challenging, allowing the disease to spread quietly and cause considerable damage before being detected by humans.
In response to this challenge, the ongoing research aims to enhance the early detection of Phytophthora spp. using advanced technologies such as computer vision and multispectral imagery captured with drones equipped with RTK technology. Using the Mavic 3 Multispectral, 444 images were obtained in the Green, Red, Red Edge, NIR and RGB bands from 74 sampling zones in a 2-year-old Navelina orange grove. Creating the final dataset involves preprocessing, labeling, and data splitting. This split was done randomly, allocating 80% of the data for training, 15% for validation, and 5% for testing.
Data processing involved implementing the YOLOv8m-segmentation deep learning model and adjusting its hyperparameters. The results demonstrated precision values of 94.3%, recall of 87.1%, and mAP50 of 68.6% for segmentation and classification and, consequently, for identifying healthy and Phytophthora spp. infected orange tree seedlings. These results serve as fundamental basis for a critical first step in a systematic approach to fully automated individual plant care.

Keywords: Plant pathology, unmanned aerial vehicles, multispectral images, deep learning, segmentation models

OP08-3 | Synthetic spectral image generation of bruised 'conference' pears as additional training data for DL-systems for non-destructive bruise detection

Wout Vierbergen[1,2], Jonathan Van Beek[1], Wouter Saeys[2]
[1]Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Merelbeke, Belgium, [2]KU Leuven, Leuven, Belgium

Precise sorting of pome fruit post-harvest remains a prominent challenge in the post-harvest industry, given their vulnerability to surface, subsurface, and internal damages. Precision in grading and sorting is essential to align with consumer expectations for quality and uphold the market value of these products. To this end, spectral imaging technology has shown to be a promising technology to detect subsurface defects in pome fruit. Simultaneously, deep learning (DL) techniques have shown the capabilities to improve upon classical methods to analyse the image data in a quick and accurate way to meet requirements in post-harvest product grading.

However, one drawback of DL is the necessity to possess a large amount of data to train the neural network to perform robustly. To address this challenge, the exploration of synthetic data as an alternative data source has gained traction in various fields. This study presents a novel approach to generate physically representative synthetic spectral images. More specifically, synthetic images are generated to train a neural network for the detection of bruises in 'Conference' pears. To demonstrate the representativeness of the generated data, pears of the cultivar 'Conference' were first imaged with spectral imaging sensors, after which digital replicas of these pears were modelled with the proposed methodology.

Our methodology involves two main steps: model parameterisation and rendering. First, 3D models of the pear samples were constructed using a handheld 3D scanner. Next, double integrating sphere (DIS) measurements were combined with the inverse adding double (IAD) method to quantify the BOP of the pear tissues: skin, sound flesh and bruised flesh. Afterwards, the acquired BOP data and 3D information were inserted in a spectral computer graphics renderer (i.e. Mitsuba) to generate spectral images that can be used for training deep learning models for bruise detection.

To evaluate the generated synthetic images, the real captured spectral images and the modelled digital replicas were compared in both a qualitative and quantitative way.

With this work, we demonstrate the efficacy and potential of a spectral renderer in producing physically based synthetic hyperspectral images for post-harvest applications. The possibility to generate representative synthetic spectral image data offers the potential of reducing the threshold of the need for real data by leveraging synthetic data as an additional data source for model training. This potential will be explored in future work.

OP08-4 | Physics informed neural networks applied to controlled environment agriculture

Fernando Rojano[1]
[1]West Virginia State University, Institute, United States

Computational modelling of climate by means of artificial intelligence is foreseen as a promising tool to overcome challenges often found in computational fluid dynamics (CFD). In particular, the use of deep learning in the success to reproduce patterns using partial differential equations. The use of physics informed neural networks (PINNs) becomes an alternative, since it can address hyper-dimensionality and can also identify the set of parameters associated to singular problems, taking into account specifications of the domain, boundary and initial conditions. Furthermore, PINNs are suggested to cope the various challenges still observed in CFD models associated to turbulence and heat and mass transfer. With the current progress, it is foreseen that exemplary cases using PINNs will eventually become the cutting-edge engineering tool to design and operate controlled environment agriculture (CEA) following the fundamentals of momentum and heat and mass transfer. It is then here introduced a review of the state of the art about the potential use of PINNs in CEA, providing a summary of available methods and techniques and code as well as the benefits and advantages.

OP08-5 | GreenLight-Gym: A reinforcement learning benchmark environment for greenhouse crop production control

Bart Van Laatum[1], Sjoerd Boersma[2], Eldert van Henten[1]
[1]Agricultural Biosystems Engineering, Wageningen University & Research, , The Netherlands,
[2]Biometris, Wageningen University & Research, , The Netherlands

Greenhouse horticulture enables cultivating large quantities of food within controlled environments, offering resilience against unpredictable weather events. However, managing the climate for crop production remains a significant challenge, characterised by high energy consumption and a complex interplay between crop health, economic factors, and indoor and outdoor climates. Traditional control techniques, which rely on dynamical models to simulate system dynamics, encounter limitations when addressing model complexity and optimising strategies over the extended horizons inherent in systems like greenhouse crop production. Reinforcement Learning (RL) presents a promising framework for addressing sequential decision-making problems, allowing for more detailed model dynamics and better recognition of long-term dependencies. RL requires extensive data collection through system interactions to develop effective control strategies. Yet, within the context of greenhouse production systems, real-world experimentation is costly, prone to failure, and often results in scarce data availability. Therefore, we propose extending the GreenLight model, an established simulation tool for greenhouse crop production, to address these challenges. Our work has a three-fold contribution: first, we introduce GreenLight-Gym, a benchmark environment designed for the training and testing RL-based controllers within a state-of-the-art model of greenhouse crop production. This environment facilitates controllers to operate an array of high-tech climatic actuators to regulate the indoor climate of greenhouses, thereby enhancing their operational efficiency. Second, our research proposes an RL-based algorithm tailored explicitly for the autonomous management of indoor greenhouse climates. This algorithm prioritises economic objectives while adhering to system constraints, employing a standardised set for testing and evaluation to benchmark control performance across various controllers. Lastly, we have integrated additive penalty functions into the reward function to ensure that the greenhouse system operates within climatic boundaries where the model accurately describes the impact on crop processes. Our experiments reveal that GreenLight-Gym accurately captures the dynamics of the GreenLight model and significantly reduces execution time. Moreover, our analyses indicate that our RL-based control algorithm exhibits minimal sensitivity to the coefficients of the additive penalty functions and surpasses the efficacy of traditional static rule-based controllers by learning the non-linear relationships between crops and climate. In conclusion, our findings underscore the viability of learning-based control systems in addressing autonomous greenhouse control challenges. By providing a benchmark environment for the swift development, training, and evaluation of RL algorithms in this domain, we open new avenues for research and application in precision agriculture.

Keywords: autonomous greenhouse control, deep reinforcement learning, precision agriculture

OP08-6 | Application of artificial neural network to identify the closest variety to ogbomoso mango fruits

Michael Odewole[1], Toluwani Adegbite[1]
[1]University of Ilorin, Ilorin, Nigeria

Several varieties of mango fruits have different physical properties, differentiating them from one another. Some of these physical properties may be similar, but not the same. This situation may lead to wrong produce identification by unsuspecting potential end users. Therefore, the objective of this study was to use existing selected physical properties (major, minor, intermediate, geometric mean diameters, surface area and sphericity) of four (4) varieties of mangoes (Julie, Ogbomoso, Saigon, and John Bull) with the aid of Artificial Neural Network (ANN) to identify the closest variety of mango to Ogbomoso mango fruit. The aforementioned physical properties of fifty (50) samples of each variety of mango were subjected to four (4) ANN models. The ANN software was tasked to specifically identify Ogbomoso mango among the four (4) varieties. The model had six (6) inputs, one (1) hidden layer and four (4) outputs. Six (6) data of Ogbomoso (sample, major, minor and intermediate diameters, geometric mean diameter and surface area) were used as input while sphericity of all the four (4) varieties were used as an output. The ANN analysis was done using four (4) transfer functions, TanhAxon, SigmoidAxon, BiasAxon and Axon. Results showed that TanhAxon predicted (identified) best out of the four (4) transfer functions used, with 87.5% for Ogbomoso mango, 80% for Saigon, 0% for Julie and 40% for John Bull, with mean square error of 0.02374. Also, from the results, Saigon had the closest prediction value of 80% (most similar) to Ogbomoso mango (87.5%). This implied that, Saigon is the variety usually misidentified as Ogbomoso mango fruits by unsuspecting potential end users. The outcome of this study can be used to develop efficient and effective mango sorting systems.

OP09-1 | Precision crop protection in viticulture using a variable rate air blast sprayer: Challenges and issues

Daniele Sarri[1], Andrea Pagliai[1], Carolina Perna[1], Rafael Pinheiro Amantea[1], Marco Vieri[1], Salvatore Filippo Di Gennaro[2], Simone kartsiotis[3], Niccolò Bartoloni[3], Niccolò Rimbotti[1], Riccardo Lisci[1]
[1]University of Florence DAGRI – Department of Agriculture Environment Food and Forestry Biosystem Engineering division, Piazzale delle Cascine 15, 50144 Florence, Italy, [2]Institute of Biometeorology (IBIMET), National Research Council (CNR), Via Caproni 8, 50145 Florence, Italy, [3]Agrobit srl, Via Fiume 11 50123 Florence, Italy

The pursuit of the objectives of the European Green Deal requires an essential change in the approach to agricultural practices. Reducing at least 50% of pesticide use in crop protection represents an ambitious goal for 2030. Variable rate sprayers can optimize crop protection stages based on spraying maps among the commercially available solutions. These can be carried out starting from the study of the spatial variability of the vegetative vigour of the vineyard or the analysis of the digital biometric characteristics of the plants. The general objective of this research work was the assessment of a variable rate sprayer for crop protection in viticulture. Analysis of vigour variability through biometric and physiological characteristics using terrestrial LiDAR and photogrammetric techniques from UAVs and Smartphones was used to set a variable spraying rate. The study was conducted in 2023 in a commercial vineyard during the phases BBCH 15-19 (T1), BBCH 71-75 (T2), and BBCH 83-85 (T3). Specifically, two management zones (MZ) have been identified at stage T1 and three MZ at stages T2 and T3. The tests compared deposit and coverage analyses of variable rate application volumes of tartrazine mixture with uniform application rate. Specifically, each treatment's mean volume application rate and MzZ were extracted. A Nobili brand Antis axial sprayer equipped with a variable rate application kit from the Arag company was used for the tests. The results showed at T1 UA 113.76 l ha-1 Vs 54.57 l ha-1 in VRA mode, at T2 UA 238 l ha -1 Vs 176 l ha-1 in VRA mode and T3 UA 313.80 l ha-1 Vs 275.78 l ha-1 in VRA, i.e. in terms of savings in variable rate were 52.03% Q1, 26.05% Q2, 12.12% Q3. In terms of coverage, coverage above the dripping limit and high deposits are highlighted in the UA condition, while in VRA and specifically the three T-1-2-3 phases, there was a trend of reaching optimal coverage thresholds (30%) and deposits medium-high. The results highlight a progressive reduction in the recovery of applied volume, which varies according to the plot's spatial variability and the canopy's progressive growth. The present study achieved exciting savings in the volume application rates for variable-rate treatments in viticulture. The techniques used for the digital target characterization and the variable rate spraying have demonstrated their potential in spraying optimization. Therefore, biological efficacy maintaining tests of reduced doses shall be validated in different scenarios.

OP09-2 | Creation of an ISOBUS-compliant prescription map for variable rate spraying in vineyards based on canopy 3D reconstruction

Björn Poss[1], Nikos Tsoulias[1], Galibjon M. Sharipov[1,2], Andreas Heiß[1], Dimitrios S. Paraforos[1]
[1]Hochschule Geisenheim University, Geisenheim, Germany, [2]Universität Hohenheim, Stuttgart, Germany

Compared to arable farming, ISOBUS-compliant sprayers are not yet widely used in viticulture. Only in recent years tractor manufacturers started to offer ISOBUS connectivity for narrow-tracked tractors. This opens up new possibilities in the connection of implements for the cultivation of vineyards, in particular for plant protection. It is desirable to use pesticides precisely and demand-oriented, not only for economic reasons but also for ecological reasons such as environmental protection. Developing prescription maps for variable rate application (VRA) and carrying out the application with the ISOBUS-compliant sprayer has significant potential in saving plant protection products. To achieve that, this work aims to develop a methodology to create an ISOBUS compliant prescription map based on the leaf area derived from a 3D point cloud of grapevine rows by means of light detection and range (LiDAR) systems.
During the growing season from 39 to 109 days after bud break (DABB) in 2023, a phenotyping platform with a LiDAR, an IMU and an RTK-GNSS was mounted on a tractor to acquire georeferenced 3D point clouds of the vineyard. The tractor was driven at 0.5 km h-1 along the rows, while the LiDAR mounted parallel to the vines. In parallel, manual measurements were carried out by means of defoliation over the growing stages (n = 20) to estimate the leaf area (LA_Manual) in vines. The LiDAR's reflectance and the geometric features of point clouds were utilised to segment the woody parts from the total number of points per vine (PPV). Thus, a linear regression model was built to express the relationship between manually obtained leaf area data and remaining PPV, separately for each growth stage. The leaf area was then divided into vertical sections in the direction of travel and the leaf area for each section and the corresponding dose rate for left and right side of the sprayer were calculated.
The leaf area that was obtained by using the above-mentioned phenotyping platform showed agreement with the manual measurements LA_Manual. Based on these results, the dose rates to be applied for both sides of the sprayer were determined and a VRA ISO-XML prescription map was created successfully. Future work includes the validation of the actual dose rates compared to the prescribed ones by using a prototype ISOBUS sprayer for vineyards, on the test facilities of Geisenheim University that are utilized for commercial spraying machine certification.

Keywords: Vineyard, LiDAR, Precision Viticulture, ISOBUS, Prescription Map

OP09-3 | Enhanced detection of vine diseases by 3D multispectral point clouds

Lorenzo Comba[1], Simonpaolo Kartsiotis[2], Alessandro Biglia[1], Alessandro Sopegno[1], Davide Ricauda Aimonino[1], Paolo Gay[1]
[1]DiSAFA - University of Turin, Grugliasco, Italy, [2]Computer Science Department - University of Turin, Turin, Italy

For precision agriculture applications, the knowledge of the crop status within parcels and plots is essential, and the monitoring should be extensive, reliable, and on time. In this framework, high and ultra-high resolution maps of the crops play a crucial role, enabling the extraction of valuable information on crops through computations of vegetation and morphological indices. The availability of such detailed datasets is now possible due to advanced and lightweight sensors, such as multispectral cameras, which can be mounted on low-altitude uncrewed aerial systems (UASs). Recently, 3D models of crops, represented as point clouds or triangulated meshes, are boosting remote sensing. Such dataset can be directly derived by 3D sensors or, by structure from motion techniques, which use standard imagery.
In this work, a new disease detection and mapping method, based on crop 3D multispectral point clouds, is presented. In particular, the activity focused on the detection of Flavescence dorée (FD) and Esca disease (ED) in vineyards. To this aim, two case studies were selected in Agliano Terme (AT), Italy, with 2 hectares surface and cultivated with Barbera variety. In July and August 2023, two acquisition campaigns were performed, involving a set of surveys using a Micasense Altum PT five bands multispectral camera, airborne on a DJI Matrice 300 RTK. Acquired images were processed with Agisoft Metashape software to build 3D models of the parcels, in which each vine is represented by about 2000 points on average, with each point characterised by 3 spatial coordinates and 5 digital numbers related to the reflectance of the target. As a reference, in-field mapping of diseased vines were performed close to each flight, which led to the accurate recording of more the 200 diseased plants positions using a Stonex DGNSS system. The potential of a combination of vegetation indices was investigated, analysing their spatial and frequency distribution at single plant level, considering both healthy and diseased vines. Finally, a Linear Discriminant Analysis Classifier, based on NDRGVI, NDVI and ARI spectral indices, was selected as most performing detection method, achieving an overall accuracy higher than 90%, using the K-Fold Cross-Validation method (k=10).
Finally, the proposed method was compared to standard 2D multispectral maps analysis, on the same vineyards. It resulted that 3D multispectral crop models-based method improves the accuracy of more than 20%, proving thus enhanced information content on crop status.

Keywords
Prevision Viticulture, 3D Point Clouds, Multispectral Sensing, Uncrewed Aerial Vehicle, Precision Agriculture.

OP09-4 | Early detection of Esca disease in grapevines using in-field hyperspectral proximal sensing

Ainara López Maestresalas[1], Jon Ruiz de Gauna[1], Carmen Jarén[1], Sara León-Ecay[1], Silvia Arazuri[1]
[1]Public University of Navarre, Pamplona, Spain

Esca is a grapevine trunk disease (GTD) considered one of the most destructive vine diseases in the world. GTDs cause significant economic losses, mainly due to reduced grape yield and quality. Currently, the approved methods of controlling this disease include preventive methods such as the use of fungicides on plant wounds, the use of planting systems that do not require intensive pruning, or the purchase of healthy plant material from nurseries. It is therefore advisable to monitor the crop in order to identify those vines that are susceptible to the disease. For this reason, in this study a proximal hyperspectral camera was use for early detection of Esca disease in asymptomatic grapevine leaves of cultivar Tempranillo.
Images of 11 vines of the Tempranillo variety grown in the town of Etxauri (Navarre) were used. All the vines were selected from plots with a history of esca incidence. Hyperspectral images were acquired using a Specim IQ snapshot camera, mounted on a tripod, working in the range of 400–1000 nm with a spectral resolution of 7 nm (204 bands), and an image resolution of 512 × 512 pixel including an RGB camera (5 Mpix). The images were taken under natural ambient light conditions on 21 August 2023. From the 11 vines selected, 9 showed visual symptoms of esca and the remaining 2 were asymptomatic to the naked eye. An image was taken of each vine, taking care to ensure that the entire front of the vine was captured in relation to the camera. All individual images were imported into MATLAB and handled with HYPER-Tools 3.0. A total of 200 pixels were randomly selected from the entire image dataset, 100 corresponding to asymptomatic leaves of asymptomatic vines (class 1) and 100 corresponding to asymptomatic leaves of symptomatic vines susceptible to developing the disease (class 2). Partial Least Square Discriminant Analysis (PLSDA) was performed to classify the leaves into the two classes mentioned above. Classification rates of 97% were achieved in the cross-validation dataset. The PLSDA models were externally validated at the pixel level using 2 images, one corresponding to an asymptomatic vine and another to a symptomatic vine. The visualisation of the images confirmed the correct classification of the pixels into the two classes according to their symptomatology, indicating that by using proximal hyperspectral sensing an early identification of the disease was possible.

Keywords: HSI, GTD, PLSDA, pixel, symptomatology

OP09-5 | Performance of the pronofrut system for crop growth and yield estimation in commercial fruit and wine orchards

Dvoralai Wulfsohn[1], Ines Zamora[1], Jonathan E. Gardi[1]
[1]Geco Enterprises Centro de I+D, San Vicente de Tagua Tagua, Chile

Pronofrut is a crop monitoring service developed for the fruit, viticulture and horticultural industries which incorporates an efficient manual stereological sampling methodology supported by Information technologies to optimise sampling, data collection and processing. The Pronofrut methodology has been applied for more than a dozen different crop species over 15 years, demonstrating that it is feasible to obtain accurate yield forecasts (typically within 10% absolute error) with low cost in human resources and time.

Following a general presentation of the Pronofrut methodology and tools – stereological concepts, sampling design, error model, the Sampler mobile app, applications-- we present a summary of the performance (errors, person-hour workloads) of surveys conducted in commercial grape and cherry orchards of different sizes and training systems.

We will use several real examples of Pronofrut surveys to illustrate how estimation and forecast errors are primarily related to crop spatial-temporal variability. We will also discuss future research needs for improved yield forecasting.

OP09-6 | AI-based method for testing weeding quality in field as a potential standard

Oliver Schmittmann[1], Patrick Zimmer[1]
[1]Institute of Agricultural Engineering University of Bonn, Bonn, Germany

Technical innovations are in big demand to reduce the use or the amount of herbicides. The scope of herbicide trials or testing of the efficiency of new technologies is limited due to labor-intensive screening. Common methods are based on plant counting in randomly distributed estimation frames and estimation of weed coverage by person. In addition, there is a lack of standardized precise methods for testing modern techniques for weed control, such as sensor hoes, hoeing robots, or spot sprayers, to evaluate their working quality and agronomic effects.
The approach to close this gap is described by the example of testing a spot sprayer and a sensor guided hoe: High resolution UAV imagery is captured from sugar beet field trials before and after weed control measures. A state-of-the-art instance based semantic segmentation model was trained to observe the field from crop emergence to row closure.
Our pipeline yields georeferenced plant locations as well as species and size for each detected instance. Weed population composition, density, and coverage are derived therefrom and agronomically evaluated using weed damage thresholds. Information on crop density and sugar beet development is determined as a 'by-product'. All data can be processed, displayed, and archived in GIS.
We evaluated our proposed testing method in field trials: a spot sprayer was tested with different setups in comparison to conventional broadcast spraying as reference. Additionally, a hoe was equipped with different tools as well as sensors for row-following, and was likewise compared in various configurations and working speeds. Hit rate determination using dyes in the spray broth was further used as a complementary method that evaluates the interaction of plant identification, determination, and targeted application technology. The estimation frame method was applied as a reference for all trials.
Our method proved to be precise and meaningful for technology evaluation. The conditions of a test standard like comparability, independence, reproducibility, and repeatability with clear and practically relevant key figures are fulfilled.
The presented method can also be used in conventional herbicide trials, thus increasing their scope. By using the technique test as a standard, the possibility arises - similar to the well-known IIRB or DLG seed drill tests - to compare different methods and equipment of various manufacturers.

OP10-1 | Comparison of non destructive techniques in assessing shelf life storage of tomato fruit

Pavlos Tsouvaltzis[1], Sotirios Tasioulas[1], Nikolaos Tziolas[2], Jessie Watson[1]
[1]Vegetable Horticulture, Horticultural Sciences Department, Southwest Florida Research & Education Center, University of Florida, Immokalee, United States of America, [2]Artificial Intelligence in Soil Science, Department of Soil, Water, and Ecosystem Sciences, Southwest Florida Research & Education Center, University of Florida, Immokalee, United States of America

Tomato as a climacteric fruit, is able to ripen postharvest even when collected when it is still green and firm and later becomes red and soft, suitable for human consumption. Although color changes are easily perceived, other changes also occur in the fruit that are not always related to the color and are therefore not detected in time. The scope of this study was to compare the efficiency of several non destructive methods, such as the external color measurements, the near infrared spectroscopy beyond the visible part of the spectrum (at 900-1700 nm) and the compression at the equatorial zone of each fruit in assessing storage of tomato fruit. Harvested fruit from tomato plants (cv. HM 1823) that were grown during the Fall season in 2023 in Immokalee, FL were sorted and the sound and uniform ones were left at 22oC in a room, simulating conventional retail market conditions. 1280 fruit were classified into 4 ripening stages based on visual assessment; mature green (MG), breaker (BR), orange (OR) and red (R). During storage for 2 weeks, all the non destructive measurements described above were taken and several regression analyses were performed in order to test their correlation to the postharvest storage period within each ripening stage of fruit at harvest. The linear regressions between color or deformation tests and shelf life days were strong at the mature green ripe harvested fruit (Rcv= 0.890 for color and 0.796 for firmness), but the regression coefficients decreased when both methods were tested in more ripen fruit. In particular, the Rcv between color measurements (hue angle parameter) and storage days was 0.778, 0.634 and 0.389 for the BR, OR and Red fruit, respectively and even lower when the compression firmness was tested. However, the partial least square regression analysis on reflectance data captured from 2 portable NIR spectroradiometers (one of high precision and the other one as an evaluation module), that were suitably preprocessed and coupled with random subset cross validation method were able to predict shelf life efficiently with regression coefficients R= 0.80 to 0.85 for the MG harvested fruit, 0.707-0.791 for the BR, 0.578-0.734 for the OR and 0.456-0.575 for the red ones. The spectral signatures of the 2 NIR instruments were compared with the spectral angle mapper and a value of 0.16 was generated, suggesting a moderate degree of similarity between the compared spectroradiometers.

Keywords: infrared spectroscopy; chemometrics; storage; postharvest

OP10-2 | Dragon fruit quality assessment using a grading machine prototype based on image analysis

Pablo González-Planells[1], Francisco Rovira-Más[1], Coral Ortiz[1], Vicente Alegre[2]
[1]Rural and Agrifood Engineering Department, Polytechnic University of Valencia (Universitat Politècnica de València), Valencia, Spain, [2]Greenvision, Benifayó , Spain

Dragon fruit or pitahaya is a tropical product which demand has recently increased Europe. The Mediterranean are of Valencia (Spain) is obtaining promising results for pitahaya production. The dragon fruit quality is crucial to assure and increase consumers acceptance of this new and high price product. Size, colour and sugar content are important parameters to define fruit quality. Nowadays, the assessment of fruit quality is addressed at the packing houses using image analysis sorting machines. In the present study the objective was to assess product quality using a prototype image analysis device. In the experiment 177 dragon fruits (144 from the variety Nevada y 33 from the variety Purple) were measured non destructively with the image analysis system. Whole fruit external RGB colour coordinates, maximum and minimum diameters, external estimated perimeter and estimated area were measured, two repetitions were developed per fruit. After the non-destructive image analysis, weight (g), destructive mechanical firmness (N/mm) with and without skin, soluble solid content (° Brix) and titratable acidity were measured. Besides, internal flesh colour parameters were also measured after cutting the fruit in two halves. Promising results were found, a multiple regression analysis could explain sugar content and weight based on the image analysis parameters (R2 of 95.33 % and 89.25 % for weight in Nevada y Purple; 52.40 % and 87.95 % for soluble solid content in Nevada y Purple, respectively). These preliminary results, suggest the possibility of assessing dragon fruit quality using image analysis during grading.

OP10-3 | Study of physicochemical changes in loquat fruit during cold storage using non-destructive spectroscopy

Marina Lopez-Chulia[1], Salvador Castillo-Girones[1], Pau Talens[2], Jose Blasco[1]
[1]Instituto Valenciano De Investigaciones Agrarias (IVIA), Valencia, Spain, [2]Food Technology Department, Universitat Politècnica de València (UPV), Valencia, Spain

Non-destructive monitoring of physicochemical changes in fruits during cold storage is one of the most significant challenges in postharvest technology. Spectral sensors are a promising technology that can enhance and automate the monitoring operations. This study assessed the potential of Vis/NIR spectroscopy for monitoring physicochemical changes in loquats during cold storage.

A total of 540 loquats from two cultivars ('Algerie' and 'Xirlero') were harvested at commercial maturity. Initial characterisation of 120 fruits (60 per cultivar) was carried out upon arrival at the laboratory. The remaining fruit was split and stored at 1 °C and 3 °C. Weekly evaluations were done for four weeks. Each week, 60 fruits were removed from the cold chamber, of which 30 fruits were analysed and the other 30 after five days at 20°C, simulating commercial conditions. The analyses consisted of the non-destructive measurement reflectance spectra of each fruit, acquired by a multi-channel spectrometer covering the visible range and near-infrared (450-1700 nm) range. Destructive analyses were later performed to obtain soluble solid content (SSC) and titratable acidity (TA) used as reference values.

Predictive models were developed using partial least squares (PLS) to set correlations between the measured spectra and the reference values. Spectral pre-processing was performed using multiple scatter correction, standard normal variate and first derivative.

Storage at 1 °C resulted in lower acidity loss than 3 °C in 'Algerie'. For 'Xirlero', no differences were observed under cold storage, but after 5 days at 20°C, more acidity loss was observed in the fruit stored at 3°C. These results show the importance of monitoring changes during the evolution of loquats under cold and commercialisation storage conditions. Preliminary results for predictive models showed R2 values between 0.70 and 0.80 for both cultivars in predicting SSC and TA. This work points out the potential of this technology as a tool for monitoring the postharvest quality of the loquat during storage, offering a non-destructive alternative to conventional analyses.

Keywords: Chemometrics, Near-infrared (NIR) spectroscopy, Postharvest, Storage temperatures

Acknowledgements: This work was partially funded by ERDF funds of the GVA 2021-2027 and projects GVA-IVIA 52204B and GVA-PROMETEO CIPROM/2021/014.

OP10-4 | Color image evaluation of fruits of grape in consideration of postharvest process

Yuki Iwase[1], Ken-ichiro Suehara[1], Kazuhiko Kawamura[2], Atsushi Hashimoto[1]
[1]Mie University, Tsu, Japan, [2]Chubu Electric Power Co., Inc., Nagoya, Japan

For data-driven agriculture as a subsystem in smart food system, which aims to sustainably produce high-quality agricultural products, technological development of a simple, easy, rapid, and non-chemical measurement method for biological information and on-site agricultural use to acquire the bioinformation of target crops is desirable. Such techniques should be applied to pre- and post-harvest processes, as the quality of agricultural products typically changes before and after harvesting. We then focused on our attention on the surface color appearances of grape fruits and analyzed the relationship between the color information and inner quality information.
Grapes (Vitis vinifera ‘Shine Muscat’) grown in Makinohara City, Japan, in 2022 and 2023 were used as the sample agricultural products. An exemplary farmer visually inspected the bunches at different ripeness levels and sampled them. The ripeness was categorized into groups A (unripe) to D (overripe) in four levels by the farmer, with group C representing optimal ripeness. After harvesting, the grape bunches were stored in a constant temperature chamber set at 25℃ (room temperature). Color images of the fruits and the infrared spectra of the squeezed juices were obtained using a handmade standard color imaging system composed of a digital camera, two fluorescent lights and a diffuser, and a Fourier transform infrared spectrometer (ALPHA, Bruker Optics) equipped with an attenuated total reflection sampling accessory with a diamond internal reflection element, respectively.
At the time of harvesting, the surface color parameters of the fruits were different among the ripeness levels, with significant differences observed in the H (Hue) values. The sweetness values of the juices were calculated based on the predicted glucose, fructose and sucrose contents derived from the infrared spectral information, and these values increased as the fruits ripened. The relationship between them showed good linearity for the grapes cultivated in 2022 and 2023, indicating experimentally that the sweetness of the fruits at harvesting could be quantitatively determined by evaluating the H values of the surface color. Additionally, the sweetness values increased over time during storage, and was well-fitted by a logistic function. Consequently, these results suggest that it is possible to non-destructively predict the sweetness of the fruits based on the information taken at harvesting, taking into account of the postharvest process.

OP10-5 | Laser spectroscopy for monitoring oxygen dynamics in pome fruit

Wouter Saeys[1], Manju Joseph[1], Hui Xiao[1], Annelies Postelmans[1], Maarten Hertog[1], Pieter Verboven[1], Bart Nicolaï[1,2]
[1]KU Leuven Department of Biosystems, MeBioS, Leuven, Belgium, [2]VCBT Flanders Centre of Postharvest Technology, Leuven, Belgium

The intercellular O2 concentration in a fruit results from the interplay between gas consumption through respiration and gas transport through diffusion. It has a strong impact on the respiration activity and thus on the postharvest evolution of its quality. Therefore, there is a strong interest in postharvest research to monitor the intercellular O2 concentration in fruit. Conventional sensing approaches for O2 in fruit are invasive and prone to measurement artefacts, limiting their application for pre- and post-harvest monitoring of the oxygen dynamics.

The aim of this study was to investigate the potential of pathlength calibrated gas in scattering media absorption spectroscopy (GASMAS) in diffuse transmittance mode for non-destructive and quantitative determination of the O2 concentration in intact pome fruit. Furthermore, we explored the application of GASMAS to determine the gas exchange and respiration dynamics properties of pome fruit.

Fruit from two apple cultivars (Malus x domestica Borkh.'Jonagold' and 'Nicoter') and one pear cultivar (Pyrus communis 'Conference') were considered in this study. A custom built pathlength-calibrated GASMAS O2 sensor was used to quantify the intercellular O2 concentration in an intact fruit during dynamic experiments. Next, the measured O2 profiles were fitted with a lumped respiration-diffusion model to estimate the effective mass transfer coefficient, maximum respiration rate and Michaelis Menten constant of intact fruit.

The average O2 level in intact apples and pears under ambient conditions at room temperature was found to be considerably lower than the ambient O2 concentration with clear differences among the studied cultivars. After optimization of the model parameters the simulated O2 profiles matched well with the measured O2 profiles and the uncertainty on the estimates for the gas exchange and respiration parameters was low. This demonstrates the potential of GASMAS in transmission mode for non-destructive monitoring of the intercellular O2 concentration in intact fruit and estimating the gas exchange and respiration properties of porous fruit more efficiently. This has high potential for improving postharvest storage of porous fruit.

Keywords:
GASMAS, O2, pathlength calibration, pome fruit, respiration, diffusion

OP10-6 | Assessing grapevine bunch compactness with digital twin models

Lorenzo Guerrini[1], Alessandro Zanchin[1], Francesco Marinello[1], Nicola Belfiore[2], Diego Tomasi[3]
[1]Università di Padova, Legnaro, Italy, [2]Research Centre for Viticulture and Enology, Council for Agricultural Research and Economics (CREA-VE), Conegliano (TV), Italy, [3]Consorzio di Tutela del Conegliano Valdobbiadene Prosecco DOCG, Pieve di Soligo (TV), Italy

The assessment of grapevine (Vitis vinifera) bunch compactness poses challenges due to its subjective nature in morphology evaluation. Unlike quantifiable descriptors such as berry count, height, and width, compactness lacks an objective evaluation method. Typically, trained personnel visually classify bunches following the Organisation Internationale de la Vigne et du Vin standard, criticized for its subjectivity and lack of sensitivity. Recent research has explored alternative methods for compactness evaluation.
This study presents findings from three experimental trials focusing on morphological analysis of grapevine bunches using digital twin technology. Digital twins, generated through photogrammetry, enabled a comprehensive three-dimensional analysis of bunch shape. Results were compared with objective variables linked to the bunch's shape and compactness.
In each study, we identified key three-dimensional indices for compactness classification. Utilizing CouldCompare, 28 measures and 36 three-dimensional features were retrieved, followed by feature selection through analysis of variance. The most significant features across the three experimental trials were estimated, namely empty volume, vertical section size, and sizes of the top and bottom horizontal sections. First, the morphology of bunches from seven Vitis vinifera varieties were assessed according to the standard methodology and the three-dimensional approach. The features selection was performed through a clustering analysis. In the second study, we utilized these indexes to assess the susceptibility to Botrytis cinerea of 17 Pinot Gris and 6 Pinot Noir clones. Specifically, the in-field bunch rot infections were correlated with the three-dimensional indices. The bunch rot disease is strictly linked to the bunch compactness. Hence, an infection risk model was built based on the Pinot Gris and Pinot Noir morphology. Finally, 3D photogrammetry monitored Moscato Giallo bunch morphology during drying performance for Passito wine production. The obtained information aids in assessing the risk of mold development during grape drying and can be used to choose the most appropriate Moscato Giallo variety or fix the environmental conditions (i.e., temperature, humidity, and air speed) in the drying room based on the bunches' features.
Further comparative analysis in diverse contexts may validate the efficacy of this technique. By leveraging digital twins and advanced analytical methods, this research offers a promising avenue for objective assessment of grapevine bunch compactness, addressing the limitations of traditional visual classification methods.

OP11-1 | RES4LIVE – Progress on pilot systems for energy smart livestock farming towards zero fossil fuel consumption

Dimitrios Tyris[1], Thomas Amon[2], Stefano Benni[3], Jarissa Maselyne[4], Petros Demissie Tegenaw[4], Manon Everaert[4], Thomas Bartzanas[1], Dimitris Manolakos[1]
[1]Agricultural University Of Athens, Athens, Greece, [2]Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Potsdam, Germany, [3]University of Bologna, Bologna, Italy, [4]Flanders Research Institute for Agricultural, Fisheries and Food (ILVO), Merelbeke, Belgium

The utilization of fossil fuels in agriculture has elevated its status as a significant contributor to Greenhouse Gas (GHG) emissions, thereby impacting global climate change and posing a potential threat to food security. A major contributor to these emissions is intensive livestock farming, a highly energy-consuming sub-sector heavily dependent on fossil fuels. This practice requires a diverse range of energy sources, including electricity and thermal energy for heating and cooling indoor livestock facilities, equipment operation, lighting, and ventilation. The European Union (EU) recognizes the urgent need for sustainable livestock production and fossil-free husbandry facilities.

The H2020 RES4LIVE project aims to eliminate fossil fuel consumption in certain areas of industrial livestock farming by introducing cost-effective Renewable Energy Sources (RES) technologies. The focus is on advanced, economically attractive solutions with low maintenance, operational flexibility, and enhanced thermal comfort for animals. Decreasing costs and improved reliability of RES technologies provide an opportunity for farmers to achieve energy self-sufficiency and transition away from fossil fuels. The project showcases and evaluates various innovative RES technologies on four European pilot farms with swine, dairy cattle, and laying hens. These interventions aim to demonstrate the feasibility of achieving fossil-free energy farming sustainably.

The study presents the installation process of the most distinctive integrated systems in the four pilot farms and provides performance results obtained after the first months of their operation. Specifically, the systems highlighted include the (i) PVT/heat pump of the EV ILVO swine farm in Belgium, (ii) PVT/geothermal storage/heat pump of the GOLINELLI swine farm in Italy, (iii) PV/heat pump in the laying hens AUA farm in Greece, and (iv) biogas upgrading to biomethane, and the retrofitted tractor designed for biomethane utilization in the LVAT dairy farm in Germany. The results add to the existing knowledge on incorporating RES into livestock systems and provide valuable perspectives on the adaptability of the studied systems for use in commercial facilities.

Keywords: Renewable Energy Sources, Intensive livestock farming, Livestock farming de-fossilization, Climate resilience

OP11-2 | Verifying the reliability of CFD domain decomposition technique on modelling the airflow field inside naturally ventilated cattle barn

Guoxing Chen[1], Guoqiang Zhang[1], Li Rong[1]
[1]Aarhus University, Aarhus C, Denmark

Computational fluid dynamics (CFD) has been widely applied to simulate airflow fields inside naturally ventilated livestock buildings. The whole domain, including domains of indoors and outdoors, technique is conventionally employed under atmospheric boundary layer. Presences of surrounding buildings, indoor facilities and animals, make the required computational power unexpectedly large when the entire computational domain is modeled, especially for large scale cattle barn. The domain decomposition technique, dividing simulations into two separate steps, is expected to provide sufficient accuracy with less computational effort. The objective of this study was to verify the reliability of domain decomposition technique on modelling the flow field inside naturally ventilated cattle barns with varying sidewall opening ratios based on wind tunnel measurements. The outdoor airflow field around an opened barn was first simulated to obtain the boundary conditions (velocity components, turbulence kinetic energy and turbulence dissipation rate) at the sidewall opening with whole computational domain but using relatively coarse mesh resolution inside barns. The indoor airflow field was subsequently simulated with the aforementioned boundary conditions with indoor computational domain and refined mesh resolution. The indoor airflow fields obtained by domain decomposition technique were in good agreement with those achieved from whole domain technique and wind tunnel measurements. The results suggested that domain decomposition technique provides an alternative for CFD application in naturally ventilated large scale cattle barns.

OP11-3 | Small scale bio-CNG farm filling fuel production from biogas: Hybrid compression and hollow fibre permeation for technically and economically feasible biofuel production

Lukas Wannasek[1]
[1]Leibniz Institute of Agricultural Engineering and Bio-economy e.V. – ATB, Potsdam, Germany

The reduction of fossil fuels is an important task in the efforts to counteract climate change. As one type of biogenic form of energy, anaerobic digestion of manure, feed residues, and agricultural by-products to produce biogas is a well-established technology. Small-scale biogas plants that use this technology are used especially on livestock farms, offering an effective manure management and renewable energy solution onsite. While the biogas thus produced on-farm is commonly used for electricity and heat generation, its further processing to fuel-grade biomethane is rare, mainly because the technology for small-scale plants is not readily available and the practice is not economically attractive.

As several studies have shown, agricultural residues can produce the total fuel requirement for the agricultural sector as non-fossil fuels. The possibility of producing compressed natural gas (CNG) fuels from livestock manure independently of the natural gas grid is a basic prerequisite for tractor markets to establish CNG as an alternative fuel on a relevant scale and thus make a significant contribution to the de-fossilisation of agriculture. Challenges that could be solved largely with the realized pilot plant within this study were the economic feasibility of very small bio-CNG production plants from 10m3 raw biogas/h and the achievement of fuel quality >97% CH4. The economic feasibility with industrial quality standards in the ranges from 10 m3 was achieved with a new type of hybrid compression.

The study shows the results from the operation of the two pilot plants (i) the one with 10 m3/h of raw biogas at the Leibniz Innovation Farm near Potsdam, Germany, and (ii) the other with 35 m3/h of raw biogas in Utzenaich, Austria. The pilot plant in Potsdam has operated since January 2024 and supplies the farm's fuel for CNG-powered tractors. The study describes the measured key performance indicators of the two pilot plants, such as bio-CNG quality, specific energy consumption, and manufacturing costs of market-ready plants. With the results from the monitoring of the two realized pilot plants, the study also determines the expected unit costs per plant as well as specific costs of €/kg Bio-CNG fuel for further plant sizes of 65 m3/h and 100 m3/h raw biogas. The expected cost degression is seen between the system sizes. The development of the small-scale Bio-CNG farm filling station is proving to be technically and economically feasible based on initial pilot plant data and thus offers enormous multiplication potential for livestock farms.

OP11-4 | Renewable sources and energy retrofitting solutions for microclimatic control in pig barns

Stefano Benni[1], Carlos Alejandro Perez Garcia[1], Marco Bovo[1], Alberto Barbaresi[1], Francesco Tinti[2], Patrizia Tassinari[1], Daniele Torreggiani[1]
[1]University of Bologna, Dept. of Agricultural and Food Sciences, Bologna, Italy, [2]University of Bologna, Dept. of Civil, Chemical, Environmental and Materials Engineering, Bologna, Italy

Livestock farming, a key and energy-intensive sector of agriculture, currently plays a significant role in greenhouse gas (GHG) emissions. Acknowledging the need to shift from fossil fuels to Renewable Energy Sources (RES), the scientific community is actively exploring retrofitting approaches for existing farms. These approaches aim to develop innovative RES-based equipment for various farming activities. In swine farming, ensuring optimal environmental conditions in nursery barns is crucial for the health and proper growth of weaners. However, maintaining ideal temperature and humidity levels is challenging in both hot and cold seasons, especially in old facilities characterized by poorly performing building envelopes. Generally, proper microclimatic control requires energy-intensive HVAC systems that rely on fossil fuels and contribute to notable GHG emissions.
This research focuses on devising sustainable heating systems and energy retrofitting for livestock barns, as alternatives to existing fossil-fuel-based systems. The study centers on a pilot case, a swine farm in northern Italy, which houses 500 sows and 2500 weaners. The research involves designing and testing an integrated RES system, incorporating a photovoltaic-thermal plant, a geothermal heat storage unit, and a modular heat pump. The retrofitting issue was addressed by analyzing the case of a hog barn poorly performing both in winter and in summer: an energy efficient solution based on smart opening and ventilation systems was designed, installed and tested in the pilot farm. A sophisticated control system was developed and implemented to monitor energy usage and environmental conditions. The results emphasize that a customized combination of RES can be effectively implemented for a specific livestock farm, utilizing the renewable resources present in farming environments. Additionally, energy retrofitting proved capable of improving the thermo-hygrometric conditions of existing pig barns, reducing the energy demand of the farm. In both cases, monitoring outdoor and indoor environmental parameters proved crucial for collecting time histories, evaluating system effectiveness, and enabling remote control of the equipment.

Acknowledgments
This research was funded by the European Commission, within the Horizon 2020 program for the Innovation Action project RES4LIVE “Energy Smart Livestock Farming towards Zero Fossil Fuel Consumption”, running in the period 2020-2024, Grant agreement ID: 101000785, DOI 10.3030/101000785.

OP11-5 | Smart control strategies for optimal environmental conditions and minimum energy requirements in livestock facilities

Stelios Kalogridis[3], Michael Moraitis[1], Athanasios Balafoutis[1], Bas Paris[1,2], Nikolaos Ipiotis[3], Michail Savvakis[3], Dimitris Manolakos[2], Dimitrios Tyris[2]
[1]Institute of Bio-Economy & Agri-Technology, Centre of Research & Technology Hellas, Volos, Greece, [2]Department of Natural Resources Development and Agricultural Engineering, Agricultural University of Athens, Athens, Greece, [3]Plegma Labs S.A., Athens, Greece

In recent years the demand for animal products has increased considerably with a direct impact on increased energy consumption of livestock facilities. This problem can be managed by adopting energy efficient equipment and optimal planning of energy use picks but also by switching to and adopting Renewable Energy Sources (RES). By interconnecting these technologies using the Internet of Things (IoT) and controlling them with smart control systems based on artificial intelligence combined with the breeding and fattening cycles of the livestock, it is possible to optimize energy production and consumption and their respective emissions, with simultaneous improvement of the animals' well-being due to optimized microclimate. This paper presents the current state of the art of the different smart control technologies and practices, combined with a review of data analytics techniques that can be used to enhance the traditional control methods to meet the optimal indoor environmental needs of the main livestock species (poultry, cattle and swine). Additionally, a review of the main RES technologies for livestock facilities is conducted. Based on these reviews, the paper primarily showcases the research opportunities, technical and financial challenges as well as the knowledge gaps for precision environmental control of livestock buildings and then introduces a smart livestock building control system prototype utilizing a novel topology to enable: (i) remote monitoring of environmental factors such as temperature, humidity, toxic gasses etc., (ii) optimal penetration of different RES units, and (iii) energy consumption reduction by retrofitting or replacing legacy equipment, coupled with livestock performance in relation to the indoor environmental conditions and the energy consumed.

OP11-6 | Thermal and electrical performance evaluation of a hybrid solar system for a livestock farm in Belgium

Petros Demissie Tegenaw[1], Manon Everaert[1,2], Iván P. Acosta-Pazmiño[3], Alexander Loris[3], Steven Lecompte[2], Jarissa Maselyne[1]
[1]ILVO, Merelbeke, Belgium, [2]UGent, Gent, Belgium, [3]MG Sustainable Engineering AB, Oppsala, Sweden

On-farm energy use for livestock farming is a major contributor to CO2 emissions. The integration of renewable energy sources (RES) is an important step to mitigate these emissions. RES4LIVE is an EU Horizon 2020 project focused on reducing fossil fuel usage in livestock farms. During the project, a hybrid solar thermal system was installed on a typical pig farm under Belgian weather conditions. This hybrid system converts solar radiation into both electrical and thermal energy. The electrical energy is directly used by the barn's feeding pumps and ventilation system, whereas the thermal energy is stored in an 800 liter buffer tank used as a heat source for a 60 kW heat pump installation. The hybrid solar system consists of 24 photovoltaic thermal (PVT) flat plate collectors installed in four groups of six panels with a total aperture area of 45.12 m². The PVT system has an installed electrical and thermal capacity of 8.40 kWelecrtical and 32.8 kWthermal. A standardized and commercially available PVT collector was installed to reduce the engineering resources needed during the design, installation, and commissioning phases. The heat transfer fluid (HTF) consists of 35 % propylene glycol and its flow in the system is dynamically controlled by a modular solar central control unit. The electrical and thermal performance parameters of the system are recorded every minute, including the temperature of the HTF, its flow rate and the incoming solar radiation.
The data collected from the hybrid solar system is continuously being analyzed to evaluate the thermal and electrical performance. During an average summer day of 2023, the HTF has gained a maximum temperature rise of about 30 °C relative to the ambient temperature. During the six months of data collection, July 2023 to January 2024, it was possible to generate 3 MWh of electricity in total for an average solar radiation of 654 W/m². The performance evaluation has shown the capability of such hybrid solar system to reduce carbon emissions and effectively replace fossil fuel consumption in the livestock sector in real working conditions.
Keywords: livestock, pig farm, renewable energy, hybrid solar thermal, photovoltaic thermal panels

OP12-1 | Energy use and indoor climate in livestock buildings for pigs in North America and Europe - a literature review

Therese Malm[1], Knut-Håkan Jeppsson[1], Dennis Johansson[2], Vahid Nik[2], Jenny Yngvesson[1], Marie-Claude Dubois[1,2]
[1]Department of Biosystems and Technology, Swedish University of Agricultural Sciences, Alnarp, Sweden, [2]Department of Building and Environmental Technology, Lund University, Lund, Sweden

Climate change is expected to raise average temperatures and humidity, leading to more extreme weather conditions. This intensifies the need for studies on indoor climate and energy use in livestock buildings as it will affect animal welfare and economy. This review was based on a keyword search on the theme "energy use and indoor climate of livestock buildings for pigs, including passive and active adaptation measures". This review aimed to identify knowledge gaps and the need for further research in this area. In total 32 articles was reviewed, published between 2000-2023, from North America and Europe.
We examined information on building properties, pig and energy data, as well as outdoor and indoor climate conditions. One key finding was that the performed studies have different aims and approaches in scope and presentation of results.
Nearly all studies provided data on building area, as well as age, size, and number of pigs, while only a few articles covered building properties. The energy use was described as energy consumption, energy balance, energy demand, or energy saving potential and the result was presented in various units. Most of the articles included energy data from at least one year, whereas some studies only included part of the year, particularly from the winter. However, many of the studies did not report any outdoor climate data and were partly incomplete when reported. Indoor climate conditions were also reported in different ways, e.g., temperature or humidity during a given day or period, cooling capacity, or using various definitions of heat stress. No information on indoor climate conditions was provided in more than ten studies. Some studies included production traits as measures of conditions for the pigs. However, sustained production is not a single measure of good animal welfare.
Our review revealed that the variety of scope, periods and type of results make it difficult to compare studies or generalise research results within different production systems. Studies are needed on energy performance related to building and housing systems, outdoor climate conditions, and fulfilment of indoor climate requirements depending on the pigs' thermal neutral zone, expressed in well-defined key figures. Furthermore, more research is needed to understand the effect of climate change and the potential of adaptation measures in terms of energy-efficiency, cost-effectiveness, improved indoor climate, and animal welfare in livestock buildings for pigs.

Keywords: ventilation; heat stress; energy; indoor climate; livestock;

OP12-2 | Modelling of energy usage on dairy farms using ANN "Case study in Canterbury province, New Zealand"

Majeed Safa[1], Hafiz Mohammad Abrar Ilyas[2]
[1]Lincoln University New Zealand, Christchurch, New Zealand, [2]Sustainable Minerals Institute, The University of Queensland,, Brisbane, Australia

This study was conducted pastoral (PDFs) and barn (BDFs) dairy farming systems in New Zealand. Total energy consumption was estimated for pastoral and barn systems 50538 MJ/ha and 55833 MJ/ha, respectively. On average, electricity and fertiliser were used more than other energy sources. In this study, several direct and indirect factors have been identified to create an artificial neural networks (NN) model to predict energy use in milk production in different conditions. The final model can predict energy consumption based on farm conditions (size of crop area), farmers' social considerations (level of education), and energy inputs (electricity, N and P use and irrigation frequency), and it predicts energy use in New Zealand Dairy farms.
Keywords: Modelling, Energy Consumption, Neural Networks, Dairy farming, New Zealand

OP12-3 | Optimizing the performance of a seawater reverse osmosis membrane under variable operating conditions: A comprehensive experimental study

Vangelis Dimitriou[1], Jorge Camacho - Espino[2], George Papadakis[1]
[1]Agricultural University of Athens, Department of Natural Resources & Agricultural Engineering, Athens, Greece, [2]University of La Laguna, Higher Polytechnic School of Engineering, Santa Cruz de Tenerife, Spain

The integration of Reverse Osmosis (RO) desalination systems with Renewable Energy (RE) technologies offers a sustainable approach to water production, especially in remote and insular regions. However, the inherent variability of RE sources, along with seasonal shifts in seawater temperature, present significant challenges to the effectiveness of RO membrane elements. Consequently, there is a critical need for research to examine the impacts of such variations on membrane performance. This study investigates the performance of a small-scale Seawater RO (SWRO) unit under variable operational conditions, including non-stable feed flow rate and pressure, across three different feed water temperatures (10, 25, and 35 °C). Utilizing a simulated power produced by photovoltaics (PV) on a hypothetical cloudy day for the operation of the SWRO unit, this research aims to address the challenges posed by the intermittent and variable nature of RE sources and the environmental and economic drawbacks of battery usage. The focus of this research is to assess how these operational variations affect key performance indicators such as water flux, water permeability, salt rejection, and membrane fouling and scaling. The results reveal that abrupt variations in applied pressure and flow rate can adversely affect the membrane performance, particularly at feed water temperatures below and above 25 °C. Specially, a decrease in water flux by approximately 0.5×10-6 m/s and a 12% reduction of the water permeability coefficient are observed at 10 °C. Furthermore, extremely high values of membrane recovery (up to 40%) were noted during the unit's operation, which can be attributed to sudden pressure fluctuations. In addition, sharp pressure variations, especially at low feed water temperatures (10 °C), results in significantly high specific energy consumption (SEC) values. These findings underscore the need for careful consideration of operation control strategies in RO desalination units powered by RE to ensure high efficiency and membrane longevity.

Keywords: Seawater reverse osmosis desalination; Renewable energy; Variable operation; Membrane performance.

OP12-4 | Wood vinegar: A renewable product for a sustainable agriculture

Carolina Fabbri[1], Roberto Mussi[1], Lorenzo Pezzola[1], Valerio Magalotti[1]
[1]Yanmar R&D Europe, Florence, Italy

The management of crops prunings has become, after the new-CAP, an important challenge for agriculture, due to burning ban in support of environmental policies. In this contest, Yanmar R&D Europe (YRE), the European research branch of the Japanese Yanmar Company Ltd, developed a farm circular solution. The idea was to develop a small-scale gasifier adapted for farms use, that process woody prunings to generate principally heat and energy, but also biochar and wood vinegar (WV). The last two products have become in the last years particularly interesting in the agricultural sector. Biochar is widely used as a soil amendment and soil remediator, while WV is mainly used as an insect repellent and biostimulant for crops. In particular, WV is a pyroligneous acid derived from the condensation of gasses during the gasification process, possible to contain lots of organic components that vary based on process and feedstock. In the YRE gasifier, WV was generated from using crop prunings burned at 700°C. The gas line is then composed by a dual stage catalytic filter for condensable tar conversion, packed bed filter for organic compounds absorption on high porous media and drain separators. WV derived from this process was tested in the field as insects' repellent. In particular, the product was tested against Bractocera oleae: a trial insect damaging olives production at global scale. The product was applied over two growing season (2022/2023), in two farms (one in the hinterland of Tuscany region and one in the coast) and two rates (1:200 and 1:100) in comparison to control (no treated plot). Wood vinegar was applied over the field from kernel hardening to harvesting, every two weeks. Olive fly traps were positioned strategically in the field and monitored. Olives samples were harvested periodically and analyzed to detect the degree of attack. The results showed a deterrent activity of WV, able to lower the insect number in the traps and olives degree of attack in the field. Over the two years treatment, 1:200 showed significant deterrent activity with total 60% lower olive flies in the traps than control and 70% lower number of olives attacked. The potential use of these low-cost, organic and easy to use products has to be further studied to understand if the repellent activity is due to the acre odour of the product or the composition. In the last case, the standardization of the product in the process will be optimized.

OP12-5 | Empirical determination of the compression behaviour of Miscanthus round bales

Niklas Bargen-Herzog[1], Johannes Knapp[1], Marcus Geimer[1]
[1]Karlsruhe Institute of Technology, Institute of Mobile Machines, Karlsruhe, Germany

Miscanthus x giganteus (Miscanthus) is a renewable raw material and a climate-friendly alternative to fossil fuels for energy production. However, to utilise the energy crop economically, technical prerequisites are required to cultivate, harvest and transport Miscanthus in large quantities. As there is little knowledge about the material behaviour of Miscanthus, tests were carried out on Miscanthus round bales. The test results provide information about the compression behaviour of Miscanthus and thus form the basis for optimising large-scale processing of Miscanthus.
During the tests, conventional round bales of Miscanthus were compressed in a customised compression box by a descending hydraulic compression plunger. In each of five test series, a round bale of Miscanthus was first compressed up to a pressing force of 2000 kN and then up to a pressing force of 4000 kN. For each pressing process, the pressing force was recorded over the travel path of the plunger.
The pressing force increases linearly to the density of the bale at the beginning of the pressing process. The gradient of the force hereby depends on the initial density of the bale. The gradient is approximately proportional to the reciprocal of the root of the initial density.
The linear increase in force is transitioning into a non-linear compaction behaviour as soon as the bale has reached the density of the previous maximum compaction. The measuring points of all test series in this range can be described by a single trend line, which can be approximated by an exponential function.
When the plunger is lifted, the bale is relieved and its density decreases. The decompression of the bale corresponds to the linear curves that describe the compression behaviour at the start of the subsequent pressing process. In this case, the gradient of the measured forces are proportional to the reciprocal of the root of the density that is achieved after relaxation.
In summary, three key characteristics of the pressing process were identified from the pressing tests: The initial linear increase of the pressing force, the subsequent exponential progression and the relaxation behaviour. The approximated curves for describing these three findings describe the measurement results with a normalised absolute deviation of 10.7 % and make a schematical description of the pressing process possible.

Keywords: Bioenergy; Renewable raw material; Miscanthus; Material properties; Compression tests

OP12-6 | Assessing the environmental benefits of switching to renewable energy sources in cheese production: A case study from Western Macedonia, Greece

Anna Vatsanidou[1], Styliani Konstantinidi[1], Vasileios Anestis[2]
[1]Department Agricultural Development, Agri-Food & Management of Natural Resources, National and Kapodistrian University of Athens, 34400, Psachna, Evia, Greece, , , [2]Laboratory of Farm Structures, Department of Natural resources and Agricultural Engineering, Agricultural University of Athens, 11855, Athens, Greece,

This study presents an environmental Life Cycle Analysis of the PDO 'Kasseri – kefali' cheese which was produced in a dairy industry in Western Macedonia, Greece. The main objective was to evaluate the environmental benefits of installing photovoltaic panels to supply the energy needs of the production process at the dairy. The Environmental Footprint 3.1 method was used to align with the PEFCR rules and standardize the environmental impact assessment. A comparative approach was followed, considering two scenarios: cheese production with the current reliance on the conventional energy grid versus a theoretical scenario, where the dairy's energy needs are met exclusively by the installed photovoltaic solar panels. The comparison was made for 1 kg of packaged and ready-to-consume 'Kaseri Kefali PDO' cheese, at the gate of the dairy unit. The study revealed that switching to photovoltaic energy resulted in a 6.2% reduction of the carbon footprint of the cheese for the entire cradle-to-dairy-unit supply chain. Specifically, the study focused on energy inputs, and found an 82.3% reduction in the carbon footprint associated solely with energy inputs. This study highlights the potential environmental sustainability advantages of switching to green energy in the cheese production industry. The substantial decrease in the overall carbon footprint and its remarkable improvement resulting from energy inputs, underscore the crucial role of renewable energy sources, particularly solar energy, in enhancing the environmental profile of dairy production processes.

Key words: Life Cycle Assessment, Carbon Footprint, Green Energy, PEFCR, Cheese Production, Greece

OP13-1 | Prediction of the indoor temperature in vertical farm using neuralprophet model

Carlos Alejandro Perez Garcia[1], Dafni Despoina Avgoustaki[2], Marco Bovo[1], Daniele Torreggiani[1], Thomas Bartzanas[2], Patrizia Tassinari[1]
[1]University Of Bologna, Bologna , Italy, [2]Agricultural University of Athens, Athens, Greece

The integration of artificial intelligence techniques into data analysis and formulation of predictive models is a widespread paradigm in agricultural engineering and aims to increase the production efficiency of farms in a sustainable way. Among the new agricultural exploitation practices, vertical farming systems are emerging as a potential solution to address the imperative of ensuring food security for the continuously growing global population, surpassing the capabilities of traditional agricultural systems. However, there are significant challenges to the adoption of this farming technology on a large scale, with high energy demand being a major hurdle. This paper presents a predictive model designed to predict the indoor temperature in a vertical farm using the NeuralProphet forecasting framework. The development of this predictive model was conducted as part of an experiment involving hydroponic lettuce production in a pilot vertical farming facility. The experiment included the recording of internal temperature measurements, considered as the target variable, along with exogenous variables for model training: ambient temperature, relative humidity, solar radiation variables obtained from a local weather station located outside the facility, as also the electricity consumed by the ventilation system. Analysis of the results revealed significant autocorrelation of the target variable with its previous lag, highlighting the temporal dependencies inherent in the system. The predictive model showed a high level of accuracy, as evidenced by a coefficient of determination (R^2) of 0.95 and Mean Absolute Error (MAE) of 0.4 °C. This framework represents an important intermediate step in the establishment of model-based environmental control systems for vertical farming. The use of such systems holds immense potential for reducing the energy demand of ventilation systems without compromising the essential comfort parameters necessary to ensure the efficiency and sustainability in indoor food production.

OP13-2 | Deep learning algorithm based on RGB-D images for obstacle avoidance systems in agricultural environments

Pierluigi Rossi[1], Leonardo Assettati[1], Leonardo Vita[2], Davide Gattamelata[2], Leonardo Marrazzini[3], Martina Olivieri[3], Luca Landi[4], Luca Burattini[4], Danilo Monarca[1], Maurizio Cutini[5]
[1]Department Of Agriculture And Forest Sciences (DAFNE) - University Of Tuscia, Viterbo, Italy, [2]Department of technological innovations and safety of plants, products and anthropic settlements - Italian National Institute for Insurance against Accidents at Work (INAIL) , Rome, Italy, [3]Department of Civil and Industrial Engineering - University of Pisa, Pisa, Italy, [4]Department of Engineering - University of Perugia , Perugia, Italy, [5]CREA Consiglio per la Ricerca in Agricoltura e L'analisi Dell'economia Agraria (Research Centre for Engineering and Agro-Food Processing), Treviglio, Italy

Run-over accidents represent one of the most common occupational hazards related to agricultural machinery and obstacle detection systems can represent a major step forward in workers' safety. The object of this study, funded by the Italian National Institute for Insurance against Accidents at Work (INAIL), is to introduce an approach that integrates image analysis from RGB and depth cameras into a novel risk assessment method based on a real-time locating system (RTLS) that provides the position of static obstacles and dynamic obstacles in relation to the expected vehicle's position in time. To do so, a real-time stream of images has been captured by an RGB-D camera that provides both colour (RGB) and depth (D) frames at the same pixel resolution and rate. Colour frames with a resolution of 1280x720 pixels have been analysed through a deep-learning algorithm at 30 frames per second, using a Tensorflow-lite object classification model which has been pre-trained on Common Objects in Context (COCO) image database enriched with images from agricultural contexts, which has been run on a Raspberry Pi 4 coupled with a Google Coral AI accelerator. Information regarding obstacles gathered from RGB frames has been transposed in the depth frames to map them by computing their distance in horizontal and vertical axes from the vehicle, eventually providing acoustic and visual alerts on a display to the driver when obstacles were detected.
Tests have been run with clear illumination conditions and detection data has finally been compared to the georeferenced data of obstacles obtained with Real Time Kinematics (RTK). Results showed an average error of 0.5 metres in the range of the RGBD camera limit, which is 16 metres. The low-cost hardware solution tested in this research, together with an ad-hoc object detection algorithm, proved to be fast enough to detect obstacles and notify the driver in less than one second. Results also showed that obstacle detection was more affected by dimension and direction of the obstacle's shadow than illumination conditions since it can reduce both RGB detection rates and depth assessment.

OP13-3 | Data-driven approach to classifying the nitrogen nutritional status of ryegrass-based forages

Luís Silva[1,2,3], Luís Alcino Conceição[2,3,4], Sofia Barbosa[1], Carla Barreto[2,3], Fernando Cebola Lidon[1], José Santos-Silva[5]
[1]Earth Sciences Department, NOVA School of Science & Technology, Campus of Caparica, NOVA University Lisbon, 2829-516 Caparica, Portugal, [2]Polytechnic Institute of Portalegre, 7300-110 Portalegre, Portugal, [3]Research Center for Endogenous Resource Valorization, Polytechnic Institute of Portalegre, 7300-110 Portalegre, Portugal, [4]InovTechAgro—National Skills Center for Technological Innovation in the Agroforestry Sector, 7300-110 Portalegre, Portugal, [5]INIAV—National Institute of Agricultural and Veterinary Research, I.P., 2005-048 Vale de Santarém, Portugal

The management of crop nitrogen (N) fertilization needs an understanding of the optimal N concentration (%Nc) and the monitoring of N dilution in plant tissues. Critical N dilution curves (CNDC) are essential and vary due to factors such as the year, crop, and cultural practices, and they are subject to scrutiny owing to uncertainty. A Bayesian model, superior to sequential models, offers a single-step estimation of critical N parameters, revealing inconsistency in N sufficiency levels. This research highlights the need for sophisticated models to improve N fertilization accuracy and promote sustainable agricultural practices and concentrates on N dilution in plant tissues during the growth of crops. The primary objective of this study is to analyze the implementation of a hierarchical model using a relatively small dataset of Plant Dry Matter (PDM) and Plant Nitrogen Content (PNC) from forage crops, to estimate CNDC parameters and assess their uncertainty. The study conducted experimental trials on ryegrass and ryegrass-clover mix during the 2022-2023 season at the INIAV - Elvas Innovation Centre, Portugal (38°53'38.52"N; 7°3'19.01"W). The experimental design addresses a randomized block split-plot model with variations in N topdressing doses (0, 120, and 200 kg of fertilizer with 27% N) and water management scenarios (rainfed and irrigated). PDM and PNC data were collected at two critical crop stages—ryegrass tillering and stem elongation. In total, there are 96 data pairs reflecting variations in PDM and PNC. Notably, PDM ranges from 0.34 to 1.99 t ha-1 at the first sampling moment and 0.98 to 5.02 t ha-1 at the second moment. Meanwhile, PNC varies between 1.21-2.70% and 1.15-2.29% at the respective sampling moments. To estimate CNDC parameters, the study employs a Bayesian hierarchical model. The resulting CNDC for ryegrass-based forage crops under no-till management and semiarid conditions indicates an average A1 value of 2.18 [%CI=(2.00;2.36)] and A2 equal to 0.23 [%CI=(0.15;0.31)]. These values demonstrate lower A1 and higher A2 values compared to other forage crops. The N Nutritional Index (NNI) is calculated, revealing variations between 0.66 and 1.57 with the three applied fertilization doses. The paper showcases the potential of open-source software for data processing and the application of a hierarchical model, serving as a foundation for ongoing crop nutritional monitoring, the integration and education of optical sensors for remote monitoring of nutritional status, and tailored N site-specific fertilization plans. This approach aims to mitigate over-fertilization risks and enhance the sustainability of agricultural systems.

OP13-4 | Automated insect monitoring: A comparative analysis of deep learning strategies

Laura Carolina Martinez Esmeral[1], Bart de Ketelaere[1], Ioannis Kalfas[1], Wouter Saeys[1]
[1]KU Leuven, Leuven, Belgium

Agricultural productivity faces a substantial challenge with pest insects contributing to an annual reduction of 40% in global crop yields and an economic loss of at least $70 billion due to invasive species, according to the Food and Agriculture Organization (FAO). While using more pesticides might seem a logical solution, the coexistence of harmful and beneficial insect species complicates this approach. Beneficial insects contribute to crucial ecological functions such as pollination, pest predation, and soil health maintenance.

To optimize pesticide application and ensure targeted interventions during critical situations, precise insect population monitoring becomes a necessity in agricultural fields. Traditionally, entomologists employed manual methods, such as sticky plate traps, for insect population surveillance. However, recent advancements in Computer Vision and Deep Learning have introduced automated, image-based alternatives. These, while promising, are data-greedy, requiring numerous target insect images to train models. In practice, such large datasets are typically not readily-available, and collecting them for every new invasive insect impedes the rapid development of detection models. To quickly address practical needs, investigating how prior knowledge from similar applications can effectively train models for new insect species becomes fundamental.

Our study centers on the efficient training of Convolutional Neural Networks (CNNs), specifically the EfficientNetV2 architecture—a well-established and adaptable framework. We present a comparison between training a CNN from scratch and scenarios leveraging prior knowledge, incorporated as pretrained models. Particularly, two pretraining types are explored: a generic approach based on ImageNet and a domain-specific one relying on the iNaturalist dataset—a collection of citizen-contributed observations of various species, including insects. Additionally, we examine not only the impact of model pretraining but also its relationship with architecture, training dataset size and the application of data augmentation techniques.

In our first experiments using an EfficientNetV2 (version “M”), we compared three training approaches—traineding from scratch, pretraineding on ImageNet, and pretraineding on iNaturalist—across varying training set sizes from 1,000 to ~30,000 images. Without augmentations, pretrained models consistently outperformed models trained from scratch, especially for smaller datasets. Despite augmentations leading to improvements for all cases, a noticeable performance gap persisted between pretrained models and those trained from scratch.

These preliminary findings offer valuable insights into optimizing a CNN model design and training for insect population monitoring. Leveraging prior knowledge, whether drawing on generic ImageNet or domain-specific iNaturalist data, proves vital for strengthening agricultural defenses against pest-induced yield losses.

OP13-5 | Advanced forest digitization with collaborative multi spectral drone and quadruped robot actors: ML advanced soil moisture prediction, forest density and species

Charalampos-Rafail Medentzidis[1], Theocharis Tsenis[1], Vassilios Kappatos[1]
[1]CERTH/HIT, Thessaloniki, Greece

Forest digitization offers numerous advantages, including improved forest health monitoring, enhanced resource management, and informed decision-making for sustainable practices. This paper presents an innovative approach to harness these benefits through a collaborative system of multi-spectral drones and quadruped robots. The drones, equipped with advanced multispectral camera, capturing high-resolution images enabling machine learning-powered prediction of soil moisture content, crucial for forest health and resource management, and forest density estimation for biomass assessment. Meanwhile, quadruped robots complement the drones by gathering ground-level data, like species identification through close-up imagery and sensor readings, and augmenting drone-captured information. This collaborative and machine learning-powered approach has the potential to significantly improve the accuracy and efficiency of forest data collection, providing deeper insights into forest health, density, and species composition, ultimately supporting sustainable forest management practices.

Keywords: Forest digitization, Multi-spectral drone, Machine learning, Soil moisture prediction, Sustainable forest management

OP13-6 | Estimating air temperature using Modis LST aiming to feed daily evapotranspiration models - Case study for the plain of Arta Greece

Chris Koliopanos[1], Ioannis Tsirogiannis[1]
[1]Department of Agriculture, University of Ioannina, Arta, Greece

Air temperature data are fundamental for agricultural practice including irrigation water management decisions. While agro-meteorological stations offer precise measurements, the challenge lies in the requirement for a dense and costly network in order to acquire micro-climatic variations. In contrast, satellite data can offer land surface temperature measurements at high spatial resolutions. However, its availability may be intermittent due to factors such as orbital dynamics and cloud coverage.
This study aims to propose a methodology for estimation of air temperature (Tair) values in agricultural areas by leveraging satellite-derived Land Surface Temperature (LST) data from the MODIS instrument. The study Focus area is the plain of Arta, Greece, an area that is characterized by Mediterranean-type climate and where an official network of 6 agro-meteorological stations operates. The proposed approach utilizes daily MODIS LST data extracted for the region's spatial grid of interest (ROI), considering ground data from an agro-meteorological station network as a reference.
The primary objective is to establish models to correlate LST measurements with various air temperature metrics, including Tmin, Tmax, and Tmean. For this reason, a linear regression model and also other machine learning algorithms are explored to predict Tair metrics. In the proposed methodology, Tair is considered as the target variable, with LST data and other features serving as independent variables.
The results are intended to serve as the basis for potential updates to ground-based measurement methods, as they could be used to relocate agro-meteorological stations, to detect measurement problems, to fill gaps in data series and to produce micro-climatic level information that could be used to calculate indices like reference evapotranspiration.

OP14-1 | Contactless-actuated drip emitters for variable rate irrigation

Raphael Linker[1], Shay Yulzary, Shai Rogel, Guy Ovadia, Zvi Shnider, Benny Almog, Ehud Katzenelson, Victor Alchanatis[2]
[1]Technion-Israel Institute of Technology, Haifa, Israel, [2]ARO-Volcani Institute, , Israel

Thanks to technological developments in the domain of proximal and remote sensing it is nowadays possible to estimate accurately the water status of soil and crop canopy at high spatial and temporal resolutions. Numerous works that implemented such monitoring techniques have shown that applying irrigation uniformly in a field or orchard results in significant spatial variability in soil and crop water status. These observations led to the concept of variable rate irrigation (VRI) according to which the amount of water delivered should be location-dependent in order to avoid over- or under-watering in certain areas. However, to date VRI can be implemented only in open field agriculture via moving irrigation systems, either linear booms or pivots. The present work was dedicated to developing a drip emitter whose flow rate could be adjusted via contactless actuation. Ultimately, our vision consists of a tractor (or any other suitable ground-based platform) that travels along the drip lines and adjusts the status of each drip emitter (e.g. open, half-way open, closed) on-the-go according to GPS location and a water prescription map that has been computed ahead of time. Toward this goal we have designed, produced and tested two types of contactless-actuated drip emitters. The first type relies on passive, magnetic actuation and the second type relies on radio-frequency (RF) energy harvesting. The presentation will provide an overview of these designs and discuss their respective advantages and limitations. The performance of the emitters observed during field deployment will be presented as well.

OP14-2 | Subsoil compaction amelioration using a novel soil drilling machine in fodder maize

Muhammad Ali[1], Ajit Borundia[1], Muhammad Qaswar[1], Muhammad Ali[1]
[1]Department of Environment, Faculty of Bioscience Engineering, Ghent University , 9000, Ghent, Belgium

Soil compaction negatively impacts crop yield and soil health, posing a serious threat to the environment and sustainability of agricultural industry. The amelioration of subsoil compaction mainly by subsoiling remains a costly and labor-intensive task, requiring intelligent automation solutions. In this study, a novel soil drilling machine was employed to mitigate subsoil compaction by creating vertical hollow cylinders (40 mm diameter) by means of mechanical spiral auguring with high pressure air injection. Twelve treatments with three replicates were tested in plots of 9*9m2, which were randomly distributed across a field with fodder maize. These treatments differ in depth (D) and hole-to-hole spacing (S), including options with and without air injections, along with one control. Treatments with air injection (at 10 bar pressure) consist of T1 (50 cm D by 50 cm S); T2 (50D by 75S); T3 (50D by 100S); T4 (90D by 50S); T5 (90D by 75S); T6 (90D by 100S), whereas without air injection include T7 (50D by 50S); T8 (50Dx by 75S); T9 (50D by 100S); T10 (90D by 50S); T11 (90D by 75S); T12 (90D by 100S). The control treatment (T13) received no drilling or air injection. Results showed that treatments with air injection including T2, T5 and T6 increased crop yield by 1.4%, 3.8% and 7.2%, respectively compared to control treatment, whereas in T1, T3 and T4 yield was decreased by 0.1%, 5.8% and 6.4%, respectively. Treatments without air injection including T10, T11 and T12 showed 5.24%, 12.9% and 11.48% increase in yield and T7, T8 and T9 showed 2.78%, 5.1% and 4.6% decrease in the yield, respectively. These findings suggest that treatments with 50 cm depth penetration exhibited an overall negative impact on yield except for the T2 treatment, while all 90 cm depth treatments increased yield except T4, with 75cm and 100cm spacing showing the highest increase in yield. Further research is needed to determine the optimal depth and spacing for different crops.
Keywords: Subsoil compaction, auguring, air injection, maize, yield.

OP14-3 | Site-specific yield recording in grassland and forage production using sensor technology on the self-propelled forage harvester

Maria Schneider[1], Stefan Thurner
[1]Bavarian State Research Centre For Agriculture, Poing-Grub, Deutschland

Introduction

Site-specific yield recording can identify the yield potential of individual (sub-) sites, which can be used to implement efficient management. Grassland sites are very heterogeneous in terms of yield potential. With sensor-based yield recording using the self-propelled forage harvester, yields can be displayed on a (sub-) site-specific basis. As part of the DigiMilch experimental field, the sensor technology was first tested for accuracy and then its practical suitability for the farmer was evaluated.

Material and methods

The sensor technology, including the near-infrared spectroscopy (NIRS) sensor technology, on selected self-propelled forage harvesters from four manufacturers available on the market, were tested on several farms (n=9) in Bavaria. The fresh mass, dry matter (DM) content and nutritional attributes were determined in the harvested material using various reference methods over four years (2020–2023). Furthermore, the complete grassland harvest at different cutting dates and the silage maize harvest were weighed and representatively sampled on two farms to compare these values with the forage harvester data on a site-specific basis.

Results and discussion

Comparing the test data with the forage harvester data per load (n = 1,141) resulted in a high coefficient of determination of 68 % in grassland and forage harvest and 83 % in silage maize harvest. It could thus be concluded that the sensors were very accurate for determining both fresh mass and moisture. Due to the difficulty of determination with comparably high-water content and the limitation in the calibration curves, the estimation of the nutritional attributes achieved good results only in some cases. The examination of the site-specific yield recording showed that the recorded dry matter yields per site from the forage harvester had a median relative deviation of 9.26 % for grassland (n = 60) and -6.10 % for silage maize (n = 9) compared to the reference method. It should be noted that the comparatively high deviations were mainly due to differences in the area sizes.

Conclusion

Sensor-based yield recording offers the possibility of accurately and simply recording yields for specific sites. The annual dry matter yield calculated from this data helps farmers decide which optimisations in roughage production are feasible and can be implemented. There are nonetheless still possibilities for optimising the sensor technology, data processing and interpretation that need to be implemented before practical suitability can be confirmed without hesitation.

Keywords: dry matter content, fresh matter, near-infrared spectroscopy, nutritional attributes, yield potential

OP14-4 | Incorporation of soil N mineralization rate for optimizing precision N doses using N balance method: A DNDC simulation study

Farida Yasmin Ruma[1], Muhammad Abdul Munnaf[2], Stefaan De Neve[1], Abdul Mouazen[1]
[1]Ghent University, Ghent, Belgium, [2]Wageningen University & Research, Wageningen , Netherlands

The optimal dosage of nitrogen (N) fertilizer is crucial for maximum crop growth, reduced nitrate leaching, whereas the current practices of precision N fertilization (PNF) ignores soil N mineralization, a fundamental biogeochemical process regulating mineral N content largely. Therefore, this study aims to optimize precision N doses by explicitly including site-specific soil N mineralization rate (SNMR) and evaluate its agroecological performances for wheat yields and N leaching using a modeling approach. This study relies on delineated management zone (MZ) maps of five agricultural fields with soil pH, organic carbon, clay and SNMR data. Mineralized soil N (SMN) was estimated at both MZ and field scales. Five N application scenarios were developed including three PNF [Robin Hood-based (RHPN), Kings-based precision N (KPN), and innovative precision N (IPN)]— and two uniform rate applications [uniform rate N (URN) and innovative uniform rate N (IURN)]. URN relies on farmers' recommended N rate and IURN calculates N dose using the N balance method considering SMN at field scale. RHPN and KPN follow the principles of allocating less fertilizer to the richest and poorest fertile MZ, respectively, and vice-versa, adjusting URN dose by up to ±40 % depending on fertility level of MZ classes. Besides, IPN involves N dose calculation by using the N balance approach considering MZ-specific SMN. Wheat grain yield and N leaching were simulated using DeNitrification-DeComposition (DNDC) model and results were validated against measured N leaching at one field. RHPN and KPN are likely to consume unnecessarily high (233 Kg N ha-1) or low (80 Kg N ha-1) N doses, particularly for low and high fertile MZ classes, leading to increased N leaching or N stress. Consequently, a 2-10 days shorter grain growth period was often simulated for RHPN and KPN compared to URN, IURN and IPN approaches. Field-scale analysis reveals that, IURN and IPN to frequently reduce N leaching (16-32 Kg N ha-1) and increase/maintain the grain yields (8.02-10.52 t ha-1), compared to other applications (16-42 Kg N ha-1; 8.01-10.51 t ha-1). A linear curve fitting reveals a strong positive correlation between measured and simulated N leaching (R2 = 0.89), validating the current simulations at least to some extent. Therefore, N recommendation using the N balance method incorporating SMNR data — specifically IURN and IPN— are likely agroecologically friendly practices, with IPN being particularly sustainable N management practice.

Keywords:
Agroecosystems; DeNitrification-DeComposition; Soil nitrogen mineralization; Precision fertilization; Soil-water environment.

OP14-5 | Optimizing of online nutrient measurement by fertilization with liquid manure: Implementing a quality management system for mobile NIRS systems "NIRS-QS"

Diana Andrade[1], Michael Kutzob, Michael Hanrieder, Susanne Höcherl
[1]Bavarian State Research Center for Agriculture LfL, Freising, Germany

Keywords: NIRS, fertilization, digital farming, manure

Motivation

To efficiently work towards achieving climate goals both nationally and internationally, it is imperative to utilize liquid fertilizer in a responsible manner to mitigate any negative impacts on groundwater, water sources, soil life, and emissions. The incorporation of digital solutions like NIRS allows for real-time monitoring of nutrient levels in liquid fertilizers before or during application. Farmers are increasingly interested in using NIR spectroscopy to track nutrient concentrations during manure application, however, there is currently a lack of standard procedures for validating NIRS devices for this purpose.

Goals

The NIRS-QS initiative aims to establish guidelines for quality assurance, develop and test process steps, and provide practical training tools to ensure accurate documentation of nutrient levels in manure and biogas fermentation residues.

Methods and Experimental Procedure

To develop a quality assurance system for mobile NIRS devices, we adapted quality planning, control, and testing functions. We focused on technical reviews with manufacturers, determining tolerable deviations during online measurements, and ensuring reproducibility and accuracy. The LfL NIRS measuring station provides ideal conditions for testing matrix homogeneity, temperature monitoring, and data reproducibility.

Results and Conclusions

16 mobile NIR sensors from three manufacturers were tested at the measuring station. All sensors, manufacturer-specific, were identical in construction or the technical components of the sensor were the same for all units, and also have the same calibration model certified by DLG.

In the comparative measurements, variations were found based on manufacturers and nutrients. Ammonium and nitrogen were selected as examples due to their strict regulation. Sensor A showed larger deviations in ammonium levels (up to 12% of the mean) compared to sensor B (up to 5%). The nitrogen measurements showed lower deviations for sensor A (below 4% of the mean) and higher for sensor B (up to 35%). Overall, no significant differences were found in the analysis of variance for manufacturer, matrix, or nutrient content.

The reproducibility and repeatability of the measurement data in the sensor to gold sensor comparison were verified and confirmed during implementation in the LfL NIRS measuring station. The measurement data from the sensors was confirmed to be reproducible and repeatable, with deviations of less than 6% in all 120 measurements. This validation ensures the accuracy of the sensors when compared to the gold standard measurement at the LfL NIRS measuring station.

OP14-6 | The challenges of developing a decision support system for niche agricultural communities: A case study of date palm growers

Noy Saraf[1], Yuval Cohen[1], Tal Oron-Gilad[2], Noah Morris[3], Maia Nosinov[3], Avi Sadowsky, Tamir Tichochinsky[3], Yael Salzer[1]
[1]Agricultural Research Organization - Volcani Center, Rishon Lezion, Israel, [2]Ben-Gurion University of the Negev, Be'er Sheva, Israel, [3]Southern Arava R&D, Eilot Regional Council , Israel

Characterisation of a decision support system (DSS) tailored for a small, specialized interest group lies in understanding and addressing its members' needs. Moreover, developing a DSS for niche communities, requires strong justification, such as significant economic incentives. We examine the case of Israeli date palm growers, a group consisting of only a limited number of individuals, including 12 based in the Southern Arava region, yet ranking among the leading global Mejhool (Majhūl) date exporters. Despite their small number, their combined turnover is substantial, reaching 35,000 tonnes of dates, valued at an estimated 600 million USD as of 2022. Fruit pricing is greatly influenced by factors like fruit size and quality, which depend on effective management practices and timely fruitlet thinning. Currently, fruitlet thinning protocols are determined based on individual expertise, horticultural knowledge, environmental factors, and estimates of date market capitalization. Despite their significant role in the industry, Mejhool date growers lack a DSS to assist them. In this study, we utilized a mixed-method approach, including interviews, data presentations and in-field data collection, to understand the future DSS requirements and potential impact on thinning practices. We hypothesized that frequent protocol changes between seasons might impact the precision with which workers carry out the grower's directives. Initially, semi-structured interviews were conducted with eight experienced date growers. Participants ranked the contribution and importance of predetermined factors for their thinning strategy. The researchers independently reviewed the interview transcripts, comparing their evaluations with the growers' perspectives to determine the perceived importance of each factor. On the following year, novel format interfaces connecting past thinning protocols with yield and fruit size were presented. Additionally, over a three-year period (2021-2023), six growers had their thinning protocols documented, and trees subjected to thinning were sampled for fruitlet counts. Despite differing approaches, growers shared a common goal of maximizing profit, emphasizing desired fruit size and yield. Fruit quality was considered of minimal importance, as the growers believed that fruitlet thinning had a limited impact on quality. Growers disagreed on the significance of historical records, as they lacked the means to associate them with fruit size or quality. Key information influencing decision-making and preferred display mode was revealed. Greater consistency in the grower's thinning approach resulted in smaller gaps between the protocol and actual counts. The results indicate that while DSS offers the advantage of informed decision-making, there may be a trade-off in terms of reduced accuracy in field operations.

OP15-1 | Multivariable and multiobjective optimization of convective drying for carrot slices

Joerg Schemminger[1,2,3], Sharvari Raut[2], Barbara Sturm[2,3], Thijs Defraeye[1,4]
[1]Empa, Swiss Federal Laboratories for Materials Science and Technology, Laboratory for Biomimetic Membranes and Textiles, CH-9014 St. Gallen, Switzerland, [2]Leibniz-Institut für Agrartechnik und Bioökonomie e.V. (ATB), Max-Eyth Allee 100, 14469 Potsdam, Germany, [3]Humboldt-Universität zu Berlin, Faculty of Life Sciences, Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences, Hinter der Reinhardtsstrasse 6–8, 10115 Berlin, Germany, [4]Food Quality and Design, Wageningen University & Research, P.O. Box 17, 6700 AA Wageningen, Netherlands

The optimization of convective tray drying for carrot slices presents a challenging task. Multiple process variables play a role, and several objectives must be met. Striking a balance between preserving quality-determining ingredients, optimizing throughput, and minimizing energy consumption necessitates a profound understanding of the underlying physical and chemical mechanisms in both the product and the processing technology. To quantify these tradeoffs, hybrid physics-based digital shadows emerge as a useful tool, offering insights and enabling the quantification of causal relationships. This study employs Monte Carlo simulations of physics-based models to comprehensively assess the entire population of carrot slices within the dryer and find the optimal drying conditions. Using these insights, the drying process is terminated once a water activity of <0.6 for 99 % of the carrot slice population is reached. The optimization focuses on reducing air heating energy demand, shortening drying time, and enhancing β-carotene retention. To achieve this, parameters such as drying air speed, porosity of the drying tray, carrot slice thickness, drying air temperature, and drying air humidity are varied in technically relevant ranges. Our findings reveal that reducing slice thickness from 5 mm to 2 mm can significantly shorten drying time by 272 minutes or 62 % compared to our base case: an increase of over 6 % in terms of mass throughput. Simultaneously, β-carotene retention improves by 37 %, and air heating energy demand per kilogram processed carrots decreases by 6 % when reducing slice thickness. Air velocity loses impact with increasing values, whereby the increase in porosity always shortens the drying time and thus saves energy and quality. Furthermore, increasing the drying air temperature from 65 °C to 80 °C can shorten the drying time by up to 23 % while saving energy for air heating by >5 % and improving carotene retention by >4 %. Two distinct use cases with different optimization targets and production line restrictions, offering valuable insights and discussions are explored. This work facilitates informed decision-making for optimizing dried fruit and vegetable production lines tailored to individual requirements. The presented method extends beyond carrot slices and tray drying processes, making it also applicable to a broader spectrum of industrial and research drying applications.

OP15-2 | The effects of combined hot-air, microwave and infrared sweet potato drying on colour and β-carotene

Khuthadzo Mugodo[1], Tilahun Seyoum Workneh, Sunette Laurie, Naushad Emmambux
[1]University of Kwazulu-Natal, Pietermaritzburg, South Africa

The purpose of this study was to investigate the drying kinetics of sweet potato (SP) and the effect of using a combination of drying techniques on SP quality. To ensure consistency, the study employed a Randomized Complete Block (RCBD) design, which included three blocks of experiments labelled as cultivar, drying methods, and pre-drying treatment factors. The drying techniques examined were convective hot-air drying (CH), infrared drying (IR) and microwave drying (MW) as well as in combination, all under predetermined conditions. The SP cultivars used included OFSP (Bophelo) and two cream-fleshed varieties (Blesbok and Ndou), with blanching as the pre-drying treatment technique. Results showed that the drying method significantly ($p \leq 0.05$) affected the drying time, while SP variety and blanching had no significant ($p > 0.05$) impact on this parameter. Additionally, the CH+MW+IR method dried SP faster than CH, CH+IR, and CH+MW. Moreover, it was evident that reducing the drying time by as much as 15 minutes, had a significant effect on product quality. The drying kinetics data was fitted to eight mathematical models and the Demir et al. and Jenas and Das were the best fit. Fresh Bophelo had the highest concentration of β-carotene (225 µg. g-1), while β-carotene was not detected in the Blesbok and Ndou varieties. Samples dried using the CH+MW+IR drying method maintained a fresh-like color and retained 67% of β-carotene. The total colour change (ΔE) was lower for combined CH+MW+IR drying methods and was in the order of CH+MW+IR< CH+IR < CH+MW< CH. To conclude, the study found that using combined drying methods, blanching pre-drying treatment and SP variety were effective in reducing SP drying time and preserving the quality characteristics.

OP15-3 | Sweet in a flash: Fiber-optic refractometer for rapid, accurate, and minimally invasive sugar content measurement

Mark A. Zentile[1], Xu. U. Zhang[1], Peter Offermans[1], BSc Najim El Harchioui[2], Lydia Meesters[2]
[1]Stichting imec Nederland within OnePlanet Research Center, Wageningen, Netherlands, [2]Food and Biobased Research, Wageningen University and Research, Wageningen, Netherlands

Sugar content is an important parameter to measure in agricultural industry. It is an essential indicator of taste and quality, particularly in products such as fruit and juice. Sugar content is commonly quantified in degrees Brix (°Bx) using a prism refractometer, which measures the refractive index and calculates the soluble-solid content based on the measured refractive index. This approach is affordable, portable and accurate. However, sample preparation is destructive, labour intensive and time consuming. Recently, approaches based on technologies such as millimetre-wave reflectometry and VNIR spectroscopy/hyperspectral imaging have been developed to assess fruit sugar content. In contrast to the prism refractometer, these technologies allow fast, non-invasive measurements. However, these methods require enormous effort on data collection with labour intensive labelling/reference measurements and model training. What's worse, the accuracy can drop dramatically for different cultivars and among produce of different seasons.

This abstract presents a novel needle refractometer enabled by optical fiber technology, which minimises sample preparation, is fast, minimally invasive and maintains the advantages of refractometry. A benchmarking experiment is performed on four fruit types (green grapes, red grapes, blue berries, and strawberries) using the fiber-optic needle refractometer, an NIR fruit sugar sensor with a custom model trained on fruits from the same batch, and an off-the-shelf NIR fruit sugar sensor with a pre-built model. Samples were also measured destructively using a standard prism refractometer as the reference measurement. The results obtained by the needle refractometer demonstrate good correlation and accuracy when compared to reference measurements. ($r2 = 0.71 – 0.96$; RMSE $= 0.46 – 1.1$ °Bx). The needle refractometer enabled by optical fiber technology outperforms the NIR sensor with a pre-built model ($r2 = 0 – 0.73$; RMSE $=$ $1.13 – 4.22$ °Bx) and performs for most types of fruit similar to the NIR sensor with a custom model trained on fruits from the same batch ($r2 = 0.68 – 0.95$; RMSE $= 0.43 – 1.02$ °Bx).

In addition, this study shows a unique feature of this technique, in that it allows highly localised measurements, which enables the measurement of sugar distributions within a single fruit.

OP15-4 | A Nitrogen-based brayton cryocooler prototype for foods quick-freezing

Alessandro Biglia[1], Matteo Bilardo[2], Chiara Messina[1], Lorenzo Comba[1], Marco Grella[1], Davide Ricauda Aimonino[1], Enrico Fabrizio[2], Paolo Gay[1]
[1]University of Turin, Grugliasco, Italy, [2]Politecnico of Turin, Torino, Italy

Reverse Brayton cryocoolers are an option for industrial applications requiring temperatures lower than -50 °C. One application where low temperatures are crucial for food preservation and shelf-life extension is freezing.
We designed an innovative quick-freezing plant based on a nitrogen Brayton cryocooler prototype, which performance was then tested. The prototype is innovative in both the cycle configuration and the thermodynamic parameters. Moreover, nitrogen is an eco-friendly gas. The prototype was tested at design operating conditions (maximum and minimum pressure of 18.5 and 8 bar respectively, and minimum temperature of -120 °C), obtaining a cooling effect of about 16 kW, and a performance coefficient equal to 0.29, which rises to 1.34 when 55 kW of waste heat, that can be recovered at a temperature lower than 100 °C, is considered. A sensitivity analysis was also done to test the prototype at different thermodynamic operating conditions in terms of minimum temperature and maximum pressure. The innovative quick-freezing plant was used to freeze food products. The physicochemical characteristics of frozen and thawed food products were evaluated to assess the effect of the low freezing temperature, the time-temperature profiles were also monitored during the freezing and thawing processes. A comparison with two other standard freezing methods was conducted, and unfrozen food products were used as a reference.
We discovered that the prototype performed better at higher maximum pressures, and that a minimum temperature of roughly -140 °C was attained. Our research showed that the tested prototype has a lot of potential for use in a variety of industrial settings where low temperatures are necessary. The trial campaign findings also demonstrated that the prototype plant could freeze at a rate of 50 °C/h, which is faster than normal plants, thus significantly decreasing the amount of the thawing losses of frozen food products.

OP15-5 | CO2 laser-labeling on fresh produce: Evaluating postharvest quality, microbial safety, and consumers' acceptability

Eleni Pliakoni[1], Graduate Durga Khadka[1], Martin Talavera[1], Logan Britton[1], Manreet Bhullar[1]
[1]Kansas State University, , United States

Fresh produce is traditionally labeled with plastic price lookup (PLU) stickers attached to the produce surface using edible glue. However, the stickers and glue are environmental contaminants, and the stickers can still easily detach from the produce surface during handling and disrupt traceability. A new method of labeling, the CO2 laser-labeling technology (LLT), has been gaining attention in recent years. However, engraving Quick Response (QR) code using LLT is novel, and the performance of this technology varies from produce to produce. Also, information on its effects on postharvest quality, microbial safety, and consumers acceptability is not reported. The objectives of this study were to investigate the effect of laser-labeling technology on 1) postharvest quality, 2) microbial safety of fresh produce, and 3) consumers' perception and acceptability. Three horticultural crops, 'Red delicious' apple (Malus pumila), green bell pepper (Capsicum annuum), and cucumber (Cucumis sativus) were procured from a local grocery store. They were engraved with a Quick Response (QR) code or 6-digit alphanumerical (text) code using the commercially available Trotec Speedy 300 CO2 laser engraver, followed by the application of edible wax. Consumers' perception and acceptability of laser-labeled produce were assessed by a consumer study (N=75) utilizing only the apples with three treatments: 1) Apple with QR-code, 2) Apple with PLU plastic sticker, and 3) non-labeled control. Fresh weight loss for laser-printed produce was higher than the nontreated control, but no difference in visual quality ratings was observed compared to the control. The laser-labeled produce was assessed for microbial contamination by artificially inoculating rifampicin-resistant Escherichia coli (E. coli) log10 6 CFU/mL to the labeled fruit. The result showed that the population of rifampicin-resistant E. coli was statistically higher in all three products labeled with text code compared to the non-treated control. The QR-coded treatments were similar to the control. The wax application did not affect the microbial attachment on the laser-labeled produce. Consumers ranked based on the apples' overall appearance and labeling methods before providing any information about the technology. Consumers ranked QR-code-labeled apples as the lowest group, followed by sticker-labeled and unlabeled apples. In contrast, after sharing information on the QR code technology, the ranking scores from the same consumers were statistically similar. The CO2 laser labeling technology has the potential for industrial application of specific produces and seems prominent to make this technology more successful if consumer education is provided.

OP15-6 | Mobile application for recording the empty packages of plant protection products

Dimitrios Kateris[1], Ioannis Menexes[1], Panagiotis Papazisis[1], Christina-Anastasia Kontogiorgi[1], Dionysis Bochtis[1]
[1]Institute for Bio-Economy and Agri-Technology (iBO), Centre for Research and Technology-Hellas (CERTH), 6th Km Charilaou-Thermi Rd., GR 57001 , Thessaloniki, Ελλάδα

In recent years, the use of plant protection substances has intensified. This results in an increase in the number of empty packages that are discarded after their contents are applied in the field. Unfortunately, farmers don't know how to manage these empty containers as well as the residual amounts of spray liquid left in their sprayers after spraying in the field. This results in many of the packages ending up, at best, either in the household waste, without rinsing the packaging, or being burned, causing air pollution and consequently respiratory problems for anyone near the point of combustion.
This work aims to present a new Android mobile application with the help of which the operators of the spraying machines are able to register in real time with the help of mobile phones both the plant protection products they use and the disposal points of their empty packages in order to continuously monitor them in order to their collection is organized. The digital application is part of a complete information system. The ecosystem in which this application was developed and developed includes the latest application and server development technologies. The collection of the data as well as their analysis is carried out initially on the mobile device (as well as in cloud services) and then in the information system for further analysis and organization of the results. The Android mobile application in collaboration with the external cloud services used, is the main factor of the system as it is the source of extraction and management of the data, where in this case, it is the formulations of fertilizers and agrochemicals. The developed mobile application was tested in real conditions giving promising results.

Keywords: Mobile application, plant protection products, empty packages, environmental pollution

Funding: This research was carried out as part of the project «EcoPPPs - Development of an Integrated Management and Monitoring System for Plant Protection Equipment» (Project code: KMP6-0287186) under the framework of the Action «Investment Plans of Innovation» of the Operational Program «Central Macedonia 2021-2027», that is co-funded by the European Regional Development Fund and Greece.

OP16-1 | The SUS3D project as link between animal welfare and sustainability for the dairy cow sector

Marco Bovo[1], Claudia Giannone[1], Enrica Santolini[1], Daniele Torreggiani[1], Patrizia Tassinari[1]
[1]Department of Agricultural and Food Sciences - University of Bologna, Bologna, Italia

The sustainable development of animal-derived products is one of the greatest challenges for next years, due to the increasing pressure on the livestock sector to meet the growing demand of a growing population, but at the same time reducing the resource requirements and the environmental impacts, safeguarding animal welfare. Therefore, the environmental, social, and economic sustainability of livestock farms are widely acknowledged in the European Green Deal where the transition to sustainable food production is recognised as a key element for the future development of the planet. Strong efforts are currently being made to convert livestock farms to more sustainable and technological management, but there is still a long way to go. In the procedures tools nowadays used to assess the sustainability of farms, animal health and welfare are usually neglected or not organically integrated despite the numerous validated protocols existing their assessment. Thus, innovative approaches should be developed with a "One Sustainability" perspective, therefore taking into account each ecosystem involved in animal production: the environment, the animals, and the humans. The main objective of the SUS3D project is to define and develop a tool, based on a big data approach, integrating the different assessments of the different ecosystems and dimensions (environmental, economic, social) of sustainability for dairy cow farms and for a prospective decision-making, which aims at a comprehensive optimization. In the con-text of SUS3D project will be shown the potentialities of PLF and data analysis tools and will be clarified as innovation and digitalization can improve the competitiveness, sustainability, animal welfare, health and productivity of farms.

OP16-2 | Wellness for chickens - development and prototype testing of dust bathing unit for laying hens

Bastiaan Vroegindeweij[1], Ellen van Weeghel[2], Bram Bos[2]
[1]Livestock Robotics, Ochten, Netherlands, [2]Wageningen Livestock Research, Wageningen, The Netherlands

Non-cage laying hen houses allow expression of natural behaviours by chicken like foraging and dust-bathing, and are regarded as better for animal welfare. An important drawback is their higher indoor concentrations as well as emissions of particulate matter (PM) and ammonia. The use of dried manure as a substrate for these natural behaviours is the main cause. For dust-bathing, the desirability of dried manure as a bathing substrate is questionable. Thus, an improved location for dust-bathing is desired, with lower emissions and conditions that better matches the birds' requirements.

For that, we present a dedicated dustbathing unit, designed with future integration in commercial aviary housing systems in mind. The design is centered around a 20 cm deep layer of sand, with raised platforms on the sides for easy and spacious access, but also inducing jumping and wing-flapping behaviour to leave the bathhouse in order to retain as much of the sand as possible. The bathing area itself is enclosed with walls and a roof and allows a broad entrance via transparent flaps to ensure an easily accessible and protected area with increased light levels.

A prototype was constructed for testing in a commercial laying hen house with extensive indoor foraging area. During a 15-month period with 6000 hens with access to it, the animals made extensive use of the bathhouse. Data from AI-interpreted video registrations is presented and complemented with human observations. Video registration showed that within minutes after obtaining access, the dustbathing unit was fully occupied by birds. Using the hens' most favourite dustbathing spot in the hen house as reference, it was found that the dustbathing unit had significantly more dustbathing animals per unit of space, as well as a longer duration of dust baths, indicating a more undisrupted and complete sequence of typical dust bathing behaviour. Despite its design, the extensive use of the dustbathing unit resulted in a significant decrease of sand layer, with only 5 cm remaining after several months. A slow but acceptable accumulation of poultry droppings over time was observed. A small but non-problematic number of floor eggs were found in the course of the testing period.

Based on these results, we consider the pilot with this dustbathing unit as successful. Only minor improvements are needed for the next generation, of which implementation and testing under commercial conditions is currently on-going, in combination with the 'Manure Shuffle' (Bos 2021).

OP16-3 | Technologies for monitoring pig and chicken welfare at the slaughterhouse – tracing back to farm, loading, transport and slaughter

Jarissa Maselyne[1], Slađana Blažević[2], Sandra Stojanović[2], Christian Manteuffel[3], Kristina Maschat[4], Konstantinos Perakis[5], Thomas Banhazi[6], Nicolas Galtier[7], Pol Llonch[8], Bas Rodenburg[9], Martijn Bouwknegt[10], Ronald Klont[10], Bart de Ruiter[10], Josep Reixach[11], Pauline Créach[12], Nemanja Kajari[13], Joanna Marchewka[14], Petra Thobe[15], Carsten Cruse[16], Jan Schulte-Landwehr[16], Christoph Bonk[16], Juliette Zamparini[17], Jorinde Mulder[17], Shanida Mullatahiri[1], Kenny van Langeveld[1], Noémie Van Noten[1], Anneleen Watteyn[1], Frank Tuyttens[1], Anneleen De Visscher[1]

[1]ILVO (Flanders Research Institute for Agriculture, Fisheries and Food), Merelbeke, Belgium, [2]Center for Innovation and Business Development, BioSense Institute, University of Novi Sad, Serbia, [3]Research Institute for Farm Animal Biology (FBN), Dummerstorf, Germany, [4]Center of Animal Nutrition and Welfare, University of Veterinary Medicine Vienna, Vienna, Austria, [5]UBITECH, Athens, Greece, [6]InnoTech Vision, Tjele, Denmark, [7]Wel2be, Rennes, France, [8]School of Veterinary Science, Autonomous University of Barcelona (UAB), Barcelona, Spain, [9]Faculty of Veterinary Medicine, Utrecht University, Utrecht, The Netherlands, [10]Vion Food, Boxtel, The Netherlands, [11]Selección Batallé, Riudarenes, Spain, [12]ITAVI, Paris, France, [13]Carnex DOO, Vrbas, Serbia, [14]Institute of Genetics and Animal Biotechnology, Polish Academy of Sciences, Magdalenka, Poland, [15]Thuenen Institute of Farm Economics, Braunschweig, Germany, [16]CLK GmbH, Altenberge, Germany, [17]Plukon Food Group, Wezep, The Netherlands

The aWISH project (HEurope, grant nr. 101060818) aims to perform large-scale automated monitoring of animal-based indicators at slaughterhouses in order to obtain information about animal welfare on farm, during transport and at slaughter of broiler chickens and grower/finisher pigs. The project is centered around six European pilots where technologies are developed, tested and validated. Each pilot consists of a slaughterhouse, in cooperation with a local research partner, associated farms and various technology providers. The pig pilots are located in Austria, the Netherlands, Serbia and Spain, while the broiler pilots are situated in France and Poland. Eighteen different technologies have been selected measuring a range of welfare indicators for pigs (ear lesions, skin lesions, tail length, tail lesions, blood parameters, stress vocalisation, tear staining, stunning effectiveness, environmental parameters, body weight, lung lesions, liver lesions, food consumption, meat quality) and broilers (hock burn, footpad lesions, catching damage, back scratches, stress vocalisations, activity, stunning effectiveness, environmental parameters, on-farm welfare assessment). These technologies are installed mainly in the slaughterhouse , but some are also installed on-farm, in the transport truck or depend on human observations. They include mostly vision and sound-based systems with a TRL (technology readiness level) from 2 to 9. Per phase of the production process (farm/transport/slaughter) an overview will be given of all the technologies, their exact installation location, the status of development and which animal welfare aspect they are measuring. Data collection has now started. The data collected in the pilots will be used to provide feedback to farmers, transporters, catching teams (for broilers) and slaughterhouse itself. A data platform and online user interface have been developed for this purpose with a clear view of individual indicators level as well as the aggregate welfare scores per stage of production (on-farm, depopulation, transportation, slaughter). Data will also be used further in aWISH to document animal welfare improvements, to investigate the socio-economic and environmental impact of welfare-improving initiatives and to create best practice guides. Therefore, this project will make a significant contribution to the objective assessment of animal welfare for pigs and broilers throughout Europe.

Keywords: animal welfare, automation, precision livestock farming, slaughterhouse

OP16-4 | Drinking and water-based cooling systems in animal buildings: A literature review about the identification of opportunistic plumbing pathogens with emphasis on occupational health risks

Stephane Godbout[1], Vicki Clouet-Côté[2], A. Dalila Larios-Martinez[1], Valérie Létourneau[3], Nyckie Albert[3], Caroline Duchaine[3], Émilie Bédard[4], Sébastien Fournel[2], Francois-Xavier Philippe[5], Martine Boulianne[6], Erika Yukari Nakanishi[1], Martine Denicourt[6], Stéphane Perron[7], Francis Pouliot[8], Bernardo Predicala[9]
[1]Agri-Food Engineering Division, Research and Development Institute for the Agri-Environment (IRDA), Quebec, QC., Canada, [2]Département des sols et de Génie Agroalimentaire, Faculté des Sciences de l'Agriculture et de l'Alimentation,Université Laval (ULAVAL), Quebec, QC., Canada, [3]Centre de Recherche de L'Institut Universitaire de Cardiologie et de Pneumologie de Québec (IUCPQ), Quebec, QC. , Canada, [4]Department of Civil Engineering, Polytechnique Montréal, , Montréal, QC, , Canada, [5]Veterinary Ecology and Ethology Unit, Department of Animal Productions, Bât. B43, Faculty of Veterinary Medicine, University of Liège, Liège, Belgium, [6]Faculté de médecine vétérinaire, Université de Montréal, , Canada, [7]Institut national de santé publique du Québec, Montréal, QC,, Canada, [8]Centre de développement du porc du Québec inc. (CDPQ), Quebec, QC., Canada, [9]Prairie Swine Centre Inc. (PSCI), Saskatchewan , Canada

Global warming is accelerating the implementation of water-cooling strategies inside Canadian animal confinement buildings. Heat-stressed animals are highly susceptible to reduce their feed intake to minimize the production of energy from their metabolism, which results in low weight gain, low reproductivity and sometimes deaths. If a generalized stress situation happens, it could bring significant economic losses. Water-based cooling strategies (e.g., high-pressure fogging, cooling pads) are implemented in new or existing buildings to overcome this problem, which may aerosolize waterborne human respiratory pathogens. Opportunistic plumbing pathogens (OPPPs), especially Legionella pneumophila (legionnaire's disease), can proliferate naturally in tap water used in drinking systems and to operate water-based cooling systems. They can multiply and be enriched in these systems. For example, the release of Legionella-contaminated air from water-based air filters has already been revealed in previous studies. The present paper aims to reveal the OPPPs identified in drinking and water-based cooling systems installed in livestock buildings as well as the associated risk to occupational health. Results from the literature review showed the presence of a great diversity of OPPPs in drinking and water-based cooling systems installed in animal buildings. Some identified microorganism included Legionella spp., Citrobacter, Enterobacter, Pseudomonas, Proteobacteria, Actinobacteria, Firmicutes, Bacteroidetes, Photobacterium, Salmonella, Cryseumonas, Deinicoccus-Thermus, Ochrobactrum, Pasteurella, Dermatophilus congolensis, Kluyvera, Buttiauxella. The presence, diversity and abundance of these microorganisms depend on the water sources, the characteristics of the water distribution systems as well as the maintenance and disinfection operations. The studies on the aerosolization of these microorganisms in the air and the associated risks are still scarce.

Keywords: drinking water, water-based cooling systems; animal buildings, opportunistic plumbing pathogens, occupational health risks.

OP16-5 | Design of a moist feeding system for poultry

Salma Rian[1], Peter Groot Koerkamp, Rene Kwakkel, Marjolein Derks
[1]Wageningen University and Research, Wageningen, Netherlands

Poultry production has become important throughout the World because of the increasing demand for animal proteins. Appropriate nutritional interventions, such as the use of moist feeding for poultry, have been found to improve both their meat and egg production and to ameliorate their welfare and feed conversion efficiency. The moist diet allows for a more sustainable feeding approach and therefore less feed-food competition, by introducing alternatives such as industry by-products and insect slurry.
Our research introduces the design process of a moist feeding system for poultry, which is based on the RIO (Reflexive Interactive Design) approach. This involves conducting a thorough system and actor analysis, designing new arrangements or sub-solutions and supporting niche developments. This iterative method involves the major stakeholders in the design itself, who are in this case poultry farmers, farm equipment companies, feed and by-products providers and formulation specialists. Our aim is to obtain a system ensuring an optimal and reliable storage, mixing and distribution of the moist diet, along with proper cleaning. Identified key challenges were contamination, lower shelf-life of the diet, the cost-effectiveness of the final product and higher storing and cleaning requirements. The poultry's feeding behaviour is an additional obstacle making the design more demanding. Moreover, the project involves the right use of the systems' waste streams for more circularity, the adaptation of the system to different size of farmers but also different contexts, and the full display of the birds' natural behaviour to avoid spoilage.
A series of sub-solutions were obtained and are to be tested in practice, such as 1) the conveyor belt, 2) the distribution trolleys, and 3) the single head feeders. This will allow to evaluate the distribution and cleaning frequencies needed for each system, along with lifespan of the moist diet in the barn conditions, which gives an idea on the efficiency and cost-effectiveness of the system.

OP16-6 | Mathematical model for the dynamics of nutrients in fish excretions under uncertainty

Daniel Reyes Lastiri[1], Jan-David Wacker[1], Simon van Mourik[1], Karel J. Keesman[1]
[1]Wageningen University, Wageningen, Netherlands

Waste streams from inland aquaculture contain nutrients that could be reused. Knowledge on the nutrient dynamics in fish excretions can help designing and operating technologies for nutrient recovery and reuse. Real-time in-situ monitoring is costly and uncommon in commercial applications. Mathematical models with data assimilation from experimental measurements can provide the required knowledge on nutrient dynamics. However, model identification is hindered by measurement uncertainties, common in aquaculture systems.

We investigated the dynamics in fish growth and nutrient excretions. For this purpose, we developed a mathematical model describing the nutrient balances in fish. The model followed a system dynamics, semi-physical approach, and it was analysed using an all-at-a-time (AAT) Sobol sensitivity analysis, and calibrated using a set-membership approach (suitable for calibration under uncertainties) considering multiple time scales. Uncertainty propagation was analysed using Monte Carlo simulations.

The model consisted of only three state variables and four parameters to facilitate calibration. The state variables were the masses of fish, solid excretions, and soluble excretions. The model parameters were the time constants for solid and soluble excretions, and the fractions of mass flows taken up by fish and excreted as solids.

The AAT Sobol sensitivity analysis revealed that the most relevant model parameters were the two time constants, and the fraction of mass taken up by fish. Furthermore, the initial conditions for the fish body mass and the soluble excretions were also found to be relevant for calibration.

The set-membership calibration revealed that the model is identifiable, as long as parameter bounds based on known experimental conditions are provided.

The uncertainty propagation based on Monte Carlo simulations revealed that the largest prediction uncertainties were in the soluble excretion of P, Ca, and Na. To decrease prediction uncertainty, future experimental measurements should focus on these nutrients.

Keywords: Mathematical model, nutrients, aquaculture, uncertainty

OP17-1 | Energy management in agriculture - potential for farmers and the region

Heinz Bernhardt[1], Jörn Stumpenhausen[2], Christopher Bader[1,2], Martin Höhendinger[1,2]
[1]Technical University Of Munich, Freising, Germany, [2]University of Applied Sciences Weihenstephan-Triesdorf, Freising, Germany

Effective energy management in dairy cowsheds is crucial for the sustainability and profitability of farms. The principles and effects of the CowEnergy concept will be presented here. It aims to make optimum use of energy resources in the dairy barn while minimizing the environmental impact. The structure and the experience gained in practical projects will be presented.
CowEnergy is divided into several areas. A central pillar of CowEnergy is the use of renewable energy sources on the farm. By installing photovoltaic systems on the barn roofs, recycling liquid manure and feed residues into biogas and integrating wind turbines on the farm premises, a large proportion of the energy required can be generated on site. This not only reduces dependence on external energy suppliers, but also helps to reduce greenhouse gas emissions.
In addition to generating electricity from renewable sources, the CowEnergy concept is supported by intelligent energy management in the barn. Energy consumption is optimized through the use of energy-efficient lighting and ventilation systems as well as modern milking and feeding technologies. The use of electric drives for farm vehicles such as wheel loaders or self-propelled feed mixers makes it possible to dispense with combustion fuels here too. Automated processes and sensor technologies help to analyze and adjust energy requirements in order to avoid overcapacity and use resources efficiently.
A storage system for the energy is also necessary to balance out the fluctuations in the generation of renewable energy systems. This can take various forms. In dairy farming, for example, ice water cooling for the milk is an option. For biogas, it can be an oversized gas storage tank. Electrical energy from PV systems can be stored in vehicle batteries or external batteries. In the future, hydrogen may also be available.
Another important aspect of CowEnergy is the regional energy supply. This involves the exchange of energy peaks and troughs in the region. This offers, for example, the possibility of centralized energy storage or the exchange of available energy between different users. This not only strengthens the regional economy, but also promotes independence from fossil fuels and helps to protect the environment. One current problem in Germany is the legal situation in energy trading.
By integrating regional and renewable energy sources and optimizing energy consumption, it not only increases the profitability of farms, but also makes an important contribution to environmental protection.

OP17-2 | Fuel consumption prediction based on GNSS recordings of agricultural machinery

Ying Chen[1,2], Liwei Pan[1,2], Xiaoqiang Zhang[1,2], Xiang Luo[1,2], Caicong Wu[1,2]
[1]College of Information and Electrical Engineering, China Agricultural University, Beijing, China, [2]Key Laboratory of Agricultural Machinery Monitoring and Big Data Application, Ministry of Agriculture and Rural Affairs, Beijing, China

With the rapid advancement of agricultural mechanization, fuel consumption in agriculture has witnessed an increase, particularly in agricultural machinery, leading to a high production cost. One way to reduce the fuel consumption of agricultural machinery is to select an operation plan with the minimal fuel consumption, while such selection requires fuel consumption access for operation plans. So, in this paper, we propose a novel approach which can automatically predict fuel flow in the plan. Specifically, the approach predicts fuel flow at each point in a GNSS trajectory provided by the plan. We initially characterize the motion features of each trajectory point by calculating its speed, acceleration, angular velocity, and angular acceleration. Subsequently, we normalize the trajectory motion features to mitigate errors introduced by data variations. Finally, the motion features of each trajectory point serve as the input to a model to predict the fuel flow at that point, where the prediction model has been developed using a machine learning method, Light Gradient Boosting Machine (LGBM). Experiments have been made on a dataset which contains 18 daily GNSS trajectories of a tractor, and the trajectories were recorded from Nov. to Dec. in 2023. In the experiments, 13 trajectories (including 63,654 points/samples) serve as the training dataset, 3 trajectories (including 21,709 points/samples) as the validation dataset, and 2 trajectories (including 22,342 points/samples) as the test dataset. Experimental results demonstrate that the proposed method achieved state-of-the-art performances in predicting fuel flow with an R2 value of 0.64. The study provides an effective solution for predicting the fuel consumption of agricultural machinery based on their GNSS recordings, holding significant application prospects in the field of agricultural mechanization. The outcomes of this study are crucial for managing fuel consumption in agricultural machinery operations and further advancing agricultural modernization.

Keywords: Fuel consumption prediction, Agricultural machinery, LGBM, GNSS recordings

OP17-3 | Energy management system for charging autonomous viticultural robotic vehicles with photovoltaic stations in a microgrid topology

Vasileios Arapostathis[1], Christos-Spyridon Karavas[1], Athanasios Balafoutis[2], George Papadakis[1]
[1]Agricultural University Of Athens, Department of Natural Resources and Agricultural Engineering, Athens, Greece, [2]Institute for Bio-economy and Agri-technology, Centre of Research and Tehcnology, Volos, Greece

In recent years, there has been an increase in the use of robotic applications in agriculture, such as Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs), which are used for monitoring crops. Their use can enhance productivity and profitability for the producer while also providing workplace safety. However, even commercially available UAVs and UGVs for agricultural use often operate as autonomous solutions rather than part of a combined system where the two types of vehicles collaborate. The main drawback of electrically powered UAVs and UGVs is their limited operational time due to the restricted storage capacity of electrical energy. This issue is exacerbated in agriculture due to difficulties in accessing charging points, as these vehicles often operate in areas remote from the local power grid. A possible solution is the adoption of microgrids, small-scale local energy systems that can operate independently from the grid and are designed to provide reliability, resilience, and incorporate renewable energy sources.

Purpose of this research involves the design and development of an Energy Management System (EMS) for the operation of an autonomous precision viticulture system based on the activities of electrically powered UAVs and UGVs. These vehicles charge at small-scale photovoltaic charging stations in a microgrid topology. The EMS is responsible for determining the charging power of each vehicle's battery using Fuzzy Cognitive Maps, without violating the operational constraints of the microgrid. Additionally, the EMS includes an energy management system using Fuzzy Logic algorithms to prioritize each vehicle in the charging process, taking into consideration the State-Of-Charge of the vehicles' batteries, the distance of each vehicle from the charging station, the State-Of-Charge of the microgrid's batteries, and the energy generated by the photovoltaic panels. The proposed EMS ensures smooth operation in the charging process of the electric vehicles and strengthens the microgrid’s autonomy by covering the system’s energy needs in the most efficient way.

Keywords: Energy Management System, Electric Vehicles, Photovoltaic charging stations in Microgrid, Variable Charging, Fuzzy Cognitive Maps

OP17-4 | Charting the course to the optimal sewage sludge pretreatment method through continuous reactor operation: Process efficiency and microbial community dynamics

Georgia-Christina Mitraka[1,2], Konstantinos N. Kontogiannopoulos[1], Anastasios I. Zouboulis[2], Panagiotis G. Kougias[1]
[1]Soil and Water Resources Institute, Hellenic Agricultural Organization – Dimitra, Thermi, 57001, Greece, [2]Laboratory of Chemical & Environmental Technology, Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, 54124, Greece

This study aimed to evaluate fourteen (14) different pretreatment methods through Biochemical Methane Potential (BMP) batch experiments and identify the two with the highest efficiency in terms of methane productivity. Then, the optimal methods were further evaluated through lab-scale continuous reactor operation to optimize their performance and efficiency before choosing the most reliable for sludge pretreatment. The changes in sludge characteristics caused by these methods and their subsequent impact on reactor performance and microbial structure were also assessed.
The most efficient pretreatments were thermal. The first method (M1) involved the treatment of sludge at 45°C for 48 h and then at 55°C for an additional 48 h, while the second one (M2) indicated sludge heating at 90°C for 3 h. The statistically significant increments achieved in methane yield compared to the untreated sludge were 24% and 22%, respectively.
To further investigate the effectiveness of the two optimal methods, a set-up of three replicate mesophilic continuous stirred reactors (CSTR) was settled with a total and working volumes of 2.0 L and 1.5 L, respectively. The experimental procedure was divided into 3 periods, in each of which the organic loading rate (OLR) was gradually increased from 1.0 to 2.5 g volatile solids/(LReactor×day). Throughout the experiment, the first reactor (R1) was fed with untreated sludge, the second one (R2) was fed with sludge treated with M1, and the third (R3) was fed with sludge treated with M2.
Both methods augmented the hydrolysis of organic matter, leading to enhanced sludge solubilization and methanogenesis. R2 demonstrated the highest methane yield across all applied OLRs, reaching a peak of 240 ± 3.0 mL/g VS at 2.5 g volatile solids/(LReactor×day). 16S rRNA gene sequencing highlighted variations in the microbiomes of the reactors because of the distinct effects provoked in the sludge composition by the different pretreatments. An increase in the abundance of genera associated with foam formation was also revealed when the reactors operated at an OLR of 2.0 g volatile solids/(LReactor×day), underscoring their connection with the sludge foaming incidents observed during the continuous experiment.
It is concluded that low-temperature thermal pretreatment is efficient in disintegrating sludge and enhancing anaerobic digestion performance. Nonetheless, attention should be paid to the correlation between sludge loading and sludge foaming in the digesters so as to obtain maximum energy recovery while avoiding operational problems that could disturb the efficient performance of anaerobic bioconversion.

OP17-5 | A greenhouse plants' heating system based on low temperature long wave radiation emission

George Papadakis[1]
[1]Agricultural University Of Athens, Athens, Greece

Abstract
The present new technology (patent pending, International Publication Number WO 2023/094843 A1) regards a system for maintaining and regulating the temperature of greenhouse plants (rather than the air) at desired values.

The main component of this system is the designed "heated curtains". When the temperature of the plants drops below a desired value (e.g., during cold winter nights), the heated curtains are drawn (extended - spread) with a suitable electromechanical system to completely cover the crop and deliver the required energy to the plants by long-wavelength radiation emission. When there is no need to heat the plants, the heated curtains are retracted to form small packages beside the trusses to minimize shading of the plants during the day. The curtains are made up of two parts, the horizontal and the vertical, and when they are spread out, they form an enclosure that completely encloses the crop. The curtains are heated appropriately so that the long-wavelength radiation they emit towards the crop completely covers the energy losses of the plants.

Calculations show that in a typical case of a tomato cultivation where the required night temperature of the plants is 13 oC, and the air outside the greenhouse has a temperature of 0 oC, the heated curtain (so that the plants maintain a temperature of 13 oC), needs to be maintained at a temperature of only 14 oC, while the air inside the greenhouse will have a temperature of about 11 oC. The energy requirement for heating the curtain is comparatively much lower than the energy required to maintain the whole greenhouse air volume at the levels required by the crop and therefore the proposed system, can achieve significant energy saving.

Compared to today's commercially available heating systems (e.g., hot water circulation in steel pipes or direct hot air distribution in the greenhouse space) energy savings are estimated (as shown in the patent application) at 30% to 65% depending on the outside temperature, (the lower the outdoor temperature the higher the energy saving). Renewable energy may be used to provide the required energy to the curtains.
The curtain can be made of several different materials while the heat to the curtain may be provided by warm air or electricity and of course renewable energy sources may be used to generate the required heat or electricity for supplying the energy to the curtain.

Keywords: greenhouse, heating, energy saving, renewable energy

OP17-6 | Lyophilized inoculum bioaugmentation to improve anaerobic digestion affected by ammonia toxicity

Ioannis Fotidis[1,2], Yixin Yan[2], Dafang Fu[2]
[1]Ionian University-Department of Environment, Zakynthos, Greece, [2]School of Civil Engineering, Southeast University, Nanjing, China

This study aims to evaluate the shelf life of lyophilized ammonia-tolerant consortia and its bioaugmentation performance to alleviate ammonia inhibition in AD reactors. A secondary aim is to investigate microbiome changes in the reactors and their potential contribution to biomethanation recovery.
Inoculum from full-scale biogas plant was acclimatised up to 6.0 g NH4+-N L-1in batch reactors through stepwise ammonia increase, with Avicel used as feedstock. After centrifugation at 1500 rpm, the inoculum solution was lyophilized at -80℃ for 15 hours. Three groups of batch mesophilic AD reactors were set up with digestate and 1.2 g L-1 Avicel, each group had triplicate reactors with 640 mL working volume. Group A was used as the control group with 1.39 g NH4+-N L-1. Group B and C were operated under 5.0 g NH4+-N L-1. After lyophilization, the consortia were stored at room temperature for 180 days and then were added into Group C' reactors to boost the AD process. Meanwhile, another reactor DG containing only basal microbial medium and Avicel was used for the lyophilized consortia reactivation experiments.
The average methane production of A, B and C was 436.5±48.0, 274.8± 27.5 mL and 392.0±45.135 mL, respectively. Bioaugmentation with lyophilized inoculum recovered 28.9% of the uninhibited methane yield. In addition, the maximum daily methane production rate of group A, B and C was 104.1, 49.0 and 77.4 mL L-1 d-1, respectively. Moreover, group C had experienced significantly shorter lag-phase during methanogenesis. The results clearly showed that bioaugmentation with lyophilized inoculum improved methanogenic activity under ammonia stress.
Acknowledgements
Hellenic Foundation for Research & Innovation (H.F.R.I.), "New Researchers-RRF: Basic Research Financing (Horizontal support for all Sciences), SA8. Environment & Energy", project "MicroPower-Bioaugmentation of specialized microbial consortia to optimize the overall anaerobic digestion process" (No: 15547).
References
APHA (2005) Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, DC.
Fotidis, I.A., Wang, H., Fiedel, N.R., Luo, G., Karakashev, D.B., Angelidaki, I., 2014. Bioaugmentation as a solution to increase methane production from an ammonia-rich substrate. Environ Sci Technol 48, 7669–
Thauer, R.K., Kaster, A.K., Seedorf, H., Buckel, W., Hedderich, R., 2008. Methanogenic archaea: Ecologically relevant differences in energy conservation. Nat Rev Microbiol 6, 579–591.
Yan, M., Fotidis, I.A., Jéglot, A., Treu, L., Tian, H., Palomo, A., Zhu, X., Angelidaki, I., 2020. Long-term preserved and rapidly revived methanogenic cultures: Microbial dynamics and preservation mechanisms. J Clean Prod 263.

OP18-1 | Revolutionizing wine production: Innovative traceability solutions and metrology integration for enhanced transparency, efficiency, and sustainability of winemaking practices

Vitor Sousa[1], Sérgio Carvalho[1], Tiago Santos[1], Pedro Moreira[1], Ana Gonçalves[1], António Dias[2]
[1]Data CoLAB, Viana Do Castelo, Portugal, [2]SGS, Porto, Portugal

Nowadays, several markets require wineries to adopt sustainable and transparent practices to attain competitiveness and compliance with regulations. Regulatory bodies have already implemented actions to achieve these objectives, however the industry continues to show resistance concerning the generation and sharing of data. To address this, it's presented a solution that aims to ensure accurate data acquisition and enhance added value for stakeholders. It provides producers and winemakers with a simple tool to collect accurate information regarding their processes, allowing them to use data to support management decisions.
The proposed solution includes a mobile app, IoT devices with GPS, humidity and temperature sensors, and a B2B platform. During harvest season, producers access the app and register each box of grapes through QR code scanning with harvest mode selected. The location of the boxes within the field is registered, allowing producers to link vineyard area and grape quality.
During the transport from the vineyard to the wine cellar, producers select the transport mode, resulting in the collection of critical data, such as trajectory, temperature, and humidity, making it available to winemakers and wine cellar operators. A hardware device assures that the involved processes and information is legitimate and trustable.
Upon arrival at the wine cellars, producers conclude the transport by transitioning to wine cellar mode. In the wine cellars, an automatic QR code reader is installed on the line, registering all crucial information, and the wineries can review the entire harvest activity, including information collected by each producer in all platform modes, allowing them to handle internal resources, schedule delivery processes, and ensure compliance with regulations.
Post-harvest, this solution keeps providing valuable information, including total quantity harvest per vineyard, transportations history, quantity of grapes delivered to each wine cellar and alcoholic grade of each delivery. The monitored information is automatically transmitted to the designated regulatory body, facilitating inspection and verification of procedures. Additionally, climate stations were developed to provide crucial field conditions before harvest, enabling optimization of harvest timing, vineyard management, irrigation levels, and fermentation control. The presented traceability solution enables the streamlining of grape and wine production by collecting accurate information and generating knowledge with better controlled parameters.
The solution was tested in real environment during harvest season, allowing to successfully validate the proof-of-concept. This solution is part of a larger development aimed at tracking the entire lifecycle of a bottle of wine, from the harvest to the final customer.

OP18-2 | A system for predicting the time to ripeness in avocado based on hyperspectral images and artificial intelligence

Netanel Karsanti[1], Noam Alkan, David Zarrouk, Avital Bechar
[1]Ben-gurion University Of The Negev, Be'er sheva, , [2]Institute of Agricultural Engineering, Volcani Institute, Rishon LeTsiyon,

Avocado fruit is known for its high nutritional value, abundant antioxidant vitamins, fiber, and natural sugars. These attributes directly influence the continuously rising consumption rates. According to the statistical database of the Food and Agriculture Organization, annual avocado fruit production stands at approximately 8.06 million tons. Predictions indicate a significant growth in the global avocado market from 1.5 Billion euros in 2018 to 2.4 Billion euros in 2024.
The objective of the current study is to develop a system and a technology to predict the time for ripening of avocado fruit using AI based on hyperspectral images taken on harvest day. Determining the ripening time in avocados poses a significant challenge due to the limited visual changes observed until minimum the maturity stage. In comparison to other fruits that ripe on the tree and are harvested selectively, avocado fruit begins to ripen after harvest. Consequently, there is significant variation in the ripening times among fruits harvested at the same time and orchard. Physiological changes on the fruit are expressed in specific wavelengths in the ranges of 300-2500 [nm] (SWIR, NIR, VIS, UV). As of today, the utilization of wavelengths in the NIR range has been determined to assess the current state of ripeness in avocados. However, to the best of our knowledge there has been no research conducted on predicting the time to ripening based on images taken on the harvest day or close to it.
In this study, images of avocado "HASS" cultivar fruit were taken from different farms and different harvesting days, using a hyperspectral imaging system mounted on a robotic manipulator under controlled laboratory conditions simulating a packinghouse environment. A Pre-processing stage was performed on all images to prepare and label the images for the AI/ML algorithms.
The dataset consists of 400 fruits that ripened between 6 to 14 days after harvest. Several Machine learning (ML) algorithms were developed based on the hyperspectral images dataset. XGBOOST algorithm reached the best results with an F1 of 91% in predicting the ripening of avocados and classifying them into different timeto-ripeness groups. The number of bands in the process was also reduced from 840 to 2 bands, which are suitable to be used with a multispectral camera. This study lays the groundwork for moving from hyperspectral to multispectral imaging, thus paving the way for the real-time application of this technology

OP18-3 | A deep learning approach for automated phenological prediction in barley

Luis Sanchez-Fernandez[1], Gregorio Egea[1], Mariano Miraballes[1], Manuel Pérez-Ruiz[1]
[1]University Of Seville, Seville, Spain

Current and anticipated climate changes are set to profoundly impact crop cultivation, leading to reduced harvests, increased costs, and the need for significant deviations from traditional farming methods. To address the challenge of feeding a growing population and expanding economy, yields must be increased by 70% over the next 30 years. A critical strategy in meeting this challenge is the development of new crop cultivars that are more resilient and adaptable to evolving climate conditions.
However, cereal crops' annual genetic gain hovers around 0.5-1%, falling significantly short of meeting the predicted demands. Moreover, improvements in yield resulting from increased harvest index are becoming increasingly more complex to achieve as we approach the biological limits in our major cereal crops. Future yield improvements must come from more efficient biomass accumulation and, in many cases, under water stress conditions.
Obtaining new cultivars in cereals is labor-intensive and relies on manual measurements of height, vigor, disease resistance, or water use efficiency. Many of these parameters are manually collected by trained technicians, and subjective variables like vigor introduce a level of uncertainty, diminishing the reliability and efficiency of the breeding process. Global efforts are being made to automate the collection of objective data useful for breeders.
Phenotyping platforms can accelerate this process, through phenotypic characterization of multiple cultivars in response to a given environment and during a given phenological stage. To automatically link the measured phenotypes to the phenological stage of the crop, an automatic crop phenology classification method is needed. The BBCH scale is a widely adopted system for categorizing plant growth stages; it is crucial in optimizing agricultural management practices and the plant breeding process. Traditionally, obtaining BBCH in a breeding experimental field is time-consuming and relies on manual observations by technicians.
This research presents a novel deep-learning model designed and trained to accurately predict the BBCH scale of barley based on RGB images, environmental factors, and structural parameters that can be automatically obtained. We gathered BBCH, temperature, crop height and RGB data during 2022-2023 crop cycle on the University of Seville campus farm. Additionally, we captured and labelled 1162 RGB images that we used to train a convolutional neural network (CNN). These images were randomly split into training (80%), validation (15%), and testing (5%) sets. Our model demonstrated an accuracy of $r2=0.97$ in predicting the BBCH scale of the studied barley crop after 24 epochs with a batch size of 32.

OP18-4 | Time-series grain yield predictions based on a Bayesian network approach fusing multi-source data and expert knowledge

Maria Karampoiki[1], Salar Mahmood[2], Lindsay Todman[2], Alistair Murdoch[2], John Hammond[2], Emanuele Ranieri[3], Hans W. Griepentrog[1], Dimitrios Paraforos[1,4]
[1]University of Hohenheim, Institute of Agricultural Engineering, Technology in Crop Production, Garben Str. 9, 70599, Stuttgart, Germany, [2]University of Reading, Agriculture, Policy and Development, Early Gate, PO Box 237, Reading RG6 6EU, United Kingdom, [3]Agricolus SRL, Via Settavalli 320, 06129 Perugia, Italy, [4]Hochschule Geisenheim University, Department of Agricultural Engineering, Von-Lade-Str. 1, 65366 Geisenheim, Germany

Winter wheat (Triticum aestivum L.) is a vital crop, and accurate prediction of its grain yield plays a crucial role in optimising agricultural practices. Although numerous models have been developed and evaluated, reliable yield prediction remains one of the most challenging problems in precision agriculture to date. To solve this problem, data from multiple sources may be required because predicting crop yield depends on a variety of interdependent variables such as weather, soil, crop genotype, and management techniques. However, improved performance is still required.
This study presents a machine learning approach based on the Bayesian Network to predict grain yield of winter wheat in Germany throughout the harvest season by merging data from multiple sources and expert knowledge. Electrical conductivity from the Veris iScan sensor, yield data from a combine harvester, and Sentinel 2 (S2) images were collected from 15 fields in Germany for the 2020, 2021, and 2022 crop seasons. The topographic wetness index, an important indicator of soil moisture, was calculated based on the digital elevation model using ArcGIS 10.6 software and yield data. S2 images were downloaded and processed using the semi-automatic classification plugin in QGIS and the normalised difference vegetation index (NDVI) was calculated for each month. Netica software was used to create a weather model whose parameters and structure were selected based on expert knowledge of extreme events and their potential impact on yield. The weather algorithm has been integrated into the grain yield model in Netica. The inherent potential index, a variable learned from topographic, soil, and historical yield data, the NDVI during the crop season, temporal average yield and normalized grain yield values, formed the basis of the grain yield model's structure. Expectation maximization was used to train the model on the worst and best yield crop seasons (2020, 2022), and the average yield crop season (2021) was used for testing.
The results showed that the model achieved an accuracy of 82% based on the statistical indices, showcasing its ability to make accurate predictions. The correlation analysis (R2) between actual and predicted yield with 50% probability ranging from 0.62 to 0.92. Additionally, similar patterns of spatial variation were observed in the actual and predicted maps with a 50% probability. This shows a robust and consistent predictive ability over a wide range of scenarios by showing a strong correlation between the model's predictions and the observed results.

Keywords: Bayesian Network, inherent potential, yield predictions

OP18-5 | Establishing resilient AI applications in agriculture by redundancy and graceful degradation: Two use cases

Sebastian Bökle[1]
[1]Universität Hohenheim, Stuttgart, Germany

Digital agriculture encompasses the development of AI-supported machines and processes. The resulting intelligent agricultural technologies have the potential to increase process and resource efficiency and to simplify farmers' workflow of crosschecking the validity of certain machinery adjustments. In this paper, the benefits of a digitised and AI-assisted sowing process of cereals is presented. This case study focuses on the documentation of the working progress: (i) the prediction of the remaining working time and (ii) the prediction and order placement of in-time-delivery of seed refill. As farming processes are subject to variable weather conditions, the time windows for their application are narrow, which holds for the seeding process in particular. On the other hand, the integration of AI for digital support of the seeding process may lead to possible constraints due to vulnerable networks and unreliable internet connectivity. This raises the necessity of a high level of technical resilience for the investigated use case of AI-supported seeding. To counteract this connectivity issue, redundant fall-back options for scenarios (i) and (ii) have been developed. More precisely, for (i), we follow a graceful degradation approach. While not maintaining the predictive accuracy level of the cloud-based prediction using the full amount of telemetry data, it still enables a seamless process continuation based on cached data of the most recent calculations. For scenario (ii) another redundant fall-back solution was developed, where the prediction is computed on a farm server proactively caching a permanent status report, traced from the former cloud-based predictions. Thus, the principle behind is not a parallel calculation but a permanently occurring poll, sent to the digital service on the next resilience level assuring permanent access to the required data for on-edge computations during field work. Within the context of food production as critical infrastructure, we finally consider the thoughtful incorporation of technical resilience in AI-enhanced agriculture as paramount to ensure a fail-safe food production system.

OP18-6 | Deliberate image chipping for free UAV deep learning generalization

Jurrian Doornbos[1], João Valente[1], Önder Babur[2]
[1]Wageningen University, Amsterdam, Netherlands, [2]Eindhoven University of Technology, Eindhoven, Netherlands

Deep Learning has been identified as an important tool supporting a more precise and sustainable food system. Furthermore, the use of unmanned aerial vehicle (UAV) imagery in tandem with Deep Learning has already been shown to be useful for identifying diseased plants or predicting yield. Problematically however, is the poor generalization of such results to different sensors, different areas, or even a different moment in time. As the flight of the UAV determines the conditions of the imagery. Furthermore, the adopted Deep Learning frameworks are not specifically developed with UAV imagery in mind, with the model input resolution often being an order of magnitude lower than the UAV provides. Existing studies solve this problem by either slicing the input image to smaller 'chips' that can be used in the Deep Learning model, or down sample the complete image altogether, missing many of the high-resolution benefits UAV imagery offers.

This study explores the chipping step as an opportunity for attaining higher model accuracy and improve out-of-sample generalization by providing four distinct, but compatible chipping techniques for training-set augmentation.

The four chipping techniques are as follows: 1. Overlapping training chips, 2. Rotating training chips, 3. Zooming the training chips, 4. Styling the training chips.
To assess the improvements in generalization, an RGB orthomosaic in the Area of Appellation (AOP) Rias Baixas with the Loureiro subspecies is preprocessed using the four chipping techniques. This is done individually and combined: totaling six distinct training sets (four individual, one with all, one with naïve chipping). These training datasets are then assessed on generalization and accuracy.
Generalization of the various techniques is tested using a different RGB orthomosaic: acquired using a different UAV, different sensor, acquired at a different time, acquired in a different vineyard (AOP Penedès, subspecies Xarel-lo).
The chosen task is the segmentation of individual plants, using the Detectron2 Deep Learning framework from Meta AI. This is evaluated using the mean intersection over union.

The results indicate a small improvement in accuracy across all metrics with every individual technique, partially supported by larger training dataset sizes. However, the combination of results yields large gains in generalization accuracy, as the larger input dataset size makes the model more robust to perturbations when posed with an unseen input.

The four chipping techniques show that model generalization can be improved using better preprocessing techniques. All chipping methods are made available in Python through the python library uavgeo.

OP19-1 | Orchard digital twin: A prototype for smart agricultural monitoring

Kyra Smith[1], Andrea Botta[2], Giovanni Colucci[2], Elena Belcore[1], Marco Piras[1], Giuseppe Quaglia[2]
[1]Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, Turin, Italy,
[2]Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Turin, Italy

This study presents a comprehensive workflow for generating detailed digital twins (DT) of apple orchards using an autonomous navigation vehicle characterized by an articulated mechanical architecture and a combination of handheld laser scanner (HLS), depth camera, and GNSS. Our goal is to provide an updatable 3D geospatial database to automate agricultural processes, such as apple monitoring and collection.

The research is structured into four phases. Phase 1 involves sensor-integration on the vehicle. Phase 2 defines the orchard's geometries and stores them in a 3D georeferenced model. Phase 3 employs a low-cost depth camera and artificial intelligence (AI) algorithm to detect and count apples; this information is projected onto the 3D model. Phase 4 stores and visualizes the data in a queryable GIS database.

The workflow was tested in an apple orchard in northwest Italy.

Agri.Q is an 8-wheeled modular articulated robot designed to navigate in orchards to monitor their status and data for planning agricultural activities. Agri.Q has an orientable frame on which a photovoltaic (PV) panel is mounted along with a robotic arm or a sensors-carrier unit, depending on the application. The latter allows the placement of sensors at the desired height from the ground, ranging from about 0.7m to 1.6m. During the test, the robot was commanded to navigate between 3 rows, each about 90m long, at constant speed (0.2m/s). The robot took about 30 minutes to complete its task.

The orchard geometries were reconstructed with an HLS (Kaarta-Stencil) which provided a point cloud with 21 million points and ±30mm accuracy that was georeferenced using data acquired with a GNSS receiver using a real-time kinematic (RTK) approach (accuracy <2cm) (WGS84-32N). The depth camera generated 4D raster data (R, G, B and depth bands). The HLS and depth camera point clouds were aligned using 16 markers placed throughout the orchard, with the HLS as reference.

Information extraction involved an algorithm for automatic tree segmentation. An Ultralytics YOLOv8 algorithm was used to segment and count apples in RGB depth camera images. The results were projected onto the georeferenced point cloud.

The collected data, including time, geometries, and other depth camera acquisitions, are visualized in a web GIS for efficient data querying. Additional tree-level information can be stored, such as pruning intervals, diseases, and phytosanitary treatments.

This application uses autonomous vehicles to create a highly-detailed, autonomously updated DT.

Keywords: smart farming; agricultural digital twin, mobile robotics; artificial intelligence; crop monitoring

OP19-2 | Can we leverage data sharing benefits to increase adoption of smart farming technologies?

Clare Sullivan[1], Evangelos Anastasiou[1], Marilena Gemtou[1], Havva Uyar[1,2], Spyros Fountas[1]
[1]Agricultural University Of Athens, Athens, Greece, [2]Singular Logic, Athens, Greece

Regardless of farm type or size, growers around the world are struggling to improve farm viability in the face of unpredictable climate and market circumstances. An array of Smart Farming Technologies (SFT) has been developed in the last 25 years to offer decision-making support as farmers navigate economic, social, and environmental challenges. However, the adoption of SFTs remains low in many farming contexts due to the perceived cost and skills associated with using the technologies, and hesitancies about the fate of data generated. Uncertainty about the of the benefits and risks of sharing agricultural data is one of the main barriers that has been identified in adopting digital technologies. Numerous studies have reviewed the factors that influence SFT adoption within different agricultural scenarios, but to the best of available knowledge, none have specifically reviewed the barriers and drivers of agri-data sharing. The objective of this research was to identify and classify the most prominent obstacles and motivators for sharing agri-data across stakeholders, by examining the existing literature.

A Systematic Literature Review was conducted using the PRISMA 2020 methodology. Query strings included the combination of synonyms for ‘smart farming’, ‘data sharing’, and ‘barriers or drivers’, and generated 308 papers from the Scopus and Web of Science databases. Based on inclusion/exclusion criteria, the authors selected 62 papers that discussed factors that encourage or hinder data sharing among stakeholders within smart farming environments. The results of the literature review indicated that factors influencing agri-data sharing can be categorized as socio-economic, technical, and legal. Due to the socio-technical nature of data sharing, the factors are complex and many span across these categories. Regardless of this complexity, the empirical studies on the farmer’s perspective revealed commonalities across farming systems and regions. Lack of clarity around the purpose and benefit of sharing data, mistrust of “who will benefit from their data”, and a desire to maintain data ownership and rights of use were the prominent concerns from the farmer perspective. The potential knowledge gain associated with aggregated data for decision support and risk management, monetary incentives (including data-driven business models), and ease of complying with regulations were common enablers for sharing data. The findings from this paper will help inform on-the-ground social science research in Greece and across the EU focused on feasible options for promoting the benefits of agri-data sharing.

Keywords: smart farming; data sharing; drivers; barriers; systematic literature review

OP19-3 | Harnessing infrared thermometry and spectral indices for enhanced crop water stress monitoring in drip-irrigated rice cultivation with reclaimed wastewater

Gregorio Egea[1], Annkathrin Rosenbaum[1], María Muñoz[2], Manuel J. González-Ortega[1], Manuel Pérez-Ruiz[1]
[1]Agroforestry Engineering Unit, School of Agricultural Engineering, University Of Seville, Seville, Spain, [2]TEPRO Consultores Agrícolas SL, Seville, Spain

Efficient water management in rice cultivation is crucial for sustainable agriculture, particularly in regions facing water scarcity such as southern Spain. This study investigates the applicability of infrared thermometry and spectral indices for monitoring crop water stress in rice cultivation utilizing reclaimed wastewater under varying soil water conditions. A field experiment has been conducted during 2022 and 2023 growing seasons in an experimental field with two irrigation treatments: (T1) rice irrigated at 100% of crop water requirements (ETc); (T2) rice irrigated at 90% ETc. The trial was conducted at the facilities of the Technological Center for New Water Technologies (Carrión de los Céspedes, Seville), which has an experimental wastewater treatment plant whose effluent was used to irrigate the crop. The rice was grown in 100 m2 plots, with three replications per treatment, and the water requirements were calculated according to FAO-56 methodology and the climatic data obtained from a nearby climatic station. One water meter per treatment was installed to monitor the volume of irrigation water applied per treatment. Infrared thermometers and spectral reflectance sensors were deployed to continuously measure crop canopy temperature and vegetation indices (NDVI) in both treatments. Stomatal conductance was also monitored throughout the growing season in both irrigation treatments. Crop temperature and climatic data were used to derive reference non-water-stress baselines needed for calculating the Crop Water Stress Index (CWSI) in rice grown under aerobic conditions. The reference baselines obtained were stable between 12-17h (local time) and between growth cycles. The CWSI index calculated with the reference baselines derived in this study was sensitive to the variations in crop water status caused by the irrigation treatments. The dynamics of CWSI were like those observed with stomatal conductance, demonstrating the validity of the method for continuous monitoring of crop water status in rice grown under aerobic conditions. In the early crop growth stages, where the crop is in the vegetative development phase and the CWSI index is inaccurate due to the decreasing percentage of 'visible' soil within the field of view of the thermal sensor, the NDVI index provides complementary information for the correct interpretation of the CWSI index in these early phenological stages. The study highlights the feasibility of employing infrared thermometry and spectral indices for real-time assessment of crop water stress, offering a valuable tool for precision agriculture and informed decision-making in water management strategies for rice cultivation.

OP19-4 | Season-long stress detection: Maize growth charts augmented with a machine learning approach

Amit Malka[1,2], Yonatan Goldwasser[2], Eitan Goldstein[2], Yafit Cohen[2], Gilad Ravid[1]
[1]Ben Gurion University of The Negev, Beer Sheva, Israel, [2]Agricultural Research Organization, The Volcani Center, Rishon-Le'Zion, Israel

Maize, also known as corn (Zea mays), ranks among the world's foremost cultivated crops with its extensive global production. However, maize is susceptible to water and nitrogen stress during critical growth stages, which can significantly hinder biomass growth, kernel development, and grain yield. To support optimal crop development, there is a pressing need for a tool that provides real-time information on field functionality during the growing season.

To address these challenges, a data-driven approach was employed, encompassing the collection of data from 145 maize fields across 7 farms in Israel spanning the 2018-2021 seasons. Maize yield was categorized into low, medium, and high levels as a proxy for the field's functional level. Utilizing images from Sentinel-2, a multi-spectral satellite with a 5-day revisit period, Spectral Vegetation Indexes (SVIs) were generated. These SVIs underwent spatial, temporal, and spatio-temporal transformations, to identify indices capable of effectively distinguishing between different functional levels throughout the season.

Once the most informative SVIs were identified, target development curves (TDC) and an inhibited development curves (IDC) were constructed for each index, delineating the desired SVI range during the growing season. Adopting the CRISP-DM methodology, a comprehensive machine learning process was established to train, validate, and predict the probability of a field's condition along the season based images up to that point. Leveraging 6 initial SVIs, which were subsequently enriched to a total of 100 spectral, spatial, temporal, and spatio-temporal indexes, four machine learning models, Random Forest, XGBoost, MLP, and SVM were evaluated using two distinct training methods, leave-one-year-out and an 80%-20% split, within a five-fold cross-validation framework, to identify the optimal combination for classification.

The analysis compared double binary classification and a three-class classification approach, highlighting the significance of spectral and spatio-temporal features, which played a crucial role in classification performance. When employing an 80-20 data split, the most successful model achieved a balanced accuracy of 0.8 at 30 days after sowing (DAS) and a remarkable 0.9 accuracy at 70 DAS, towards, the end of the growing season. The leave-one-year-out method demonstrated an accuracy of 0.7, starting from 30 DAS.

Investigating the use of accumulated images or only the latest one shows Inconclusive results. Moreover, a comprehensive basket of all indices, as opposed to relying solely on NDVI or the initial 6 SVIs, resulted in a remarkable 20% increase in accuracy. highlighting the potential of integrating spatial and temporal indices for enhanced predictive modeling in maize agriculture.

OP19-5 | Influence of field, crop and climate variables on corn silage yield maps

Javier Bueno Lema[1], Jorge Dafonte Dafonte[1], José Miguel Edreira Sanjurjo[1], Miguel Ángel Vilar Rivas[2]
[1]Department of Agroforestry Engineering, University Of Santiago De Compostela, Lugo, Spain,
[2]Department of Applied Mathematics, University of Santiago de Compostela, Lugo, Spain

Precision Agriculture with silage corn (Zea mays L.) have the potential to reduce annual agricultural operating costs by optimising the use of resources such as seed, fertilisers and pesticides. Self-Propelled (SP) Forage Harvesters equipped with yield monitor systems record yield data files that can be used to obtain yield maps. In this study we have worked with 199 silage corn yield files recorded by an agricultural contractor company in northwest Spain during four harvest seasons (2019-2022). Yield data files were obtained in 67 different fields and were cleaned with SMS Advanced software (Spatial Management System - Ag Leader Technology) to remove errors.
The main objective of the study was to develop a model to predict the spatial and temporal variability of the corn silage dry yield data gathered by the SP Forage Harvesters. Dry matter yield, fresh matter yield, crop moisture, corn cycle, precipitation, thermal integral, field area, average field slope, average field topographic index (TWI), and corn seeding rate were used as variables. To estimate the precipitation data, data from meteogalicia (Galician regional meteorological agency) and aemet (Spain state meteorological agency) were used. An estimation of the precipitation was carried out using regression kriging with secondary variables (latitude, longitude and elevation) using a script in R computing software.
A random forest model was used to predict the dry yield obtained in the yield maps. Random forest is a machine learning technique that has been proven to be highly accurate in several agricultural applications, including maize prediction. When evaluated to predict the yield of different crops (wheat, corn, and potato) with climate and biophysical variables, at global and regional scales, the random forest algorithm outperformed multiple linear regressions models, adopted as a benchmark, in all considered performance statistics. Random forest is an effective and versatile machine-learning method for crop yield predictions because of its high accuracy and precision, ease of use, and utility in data analysis.
The model obtained explains a percentage of variance of 50% and a correlation coefficient of 0.7. The most important variables in the model were the seeding rate, TWI and precipitation.

Keywords: Precision Agriculture, Yield Maps, Variability, Corn Silage

OP19-6 | A variable-rate spraying system based on RGB-depth and object detection

Qi Gao[1], Alberto Carraro[1], Francesco Marinello[1], Marco Sozzi[1]
[1]Department of Land, Environment, Agriculture and Forestry, University of Padova, Legnaro, Italy

Abstract: Variable-rate spraying technology is designed to reduce the use of crop protection products and their negative impacts on the environment while ensuring spraying effectiveness compared to uniform-rate spraying applications. With the emergence of edge computing technology, RGB-depth combined with object detection can be considered a promising approach for variable-rate spraying applications. In this work, a variable-rate spraying system for vineyards has been developed. The system uses a binocular camera to capture RGB and depth images for reconstructing 3D models of grapevines. A YOLOv8 model, specifically trained on a grapevine dataset, is applied for detecting and segmenting canopies within the 3D model. Afterward, the system estimates the leaf area of the canopies and regulates the spraying volume with a pulse-width modulation (PWM) module. An experiment is implemented to assess the performance of the proposed variable-rate system compared with uniform-rate application and RGB-based variable-rate application. The assessment metrics include the spraying coverage, the drift of the spraying application, and the total volume of product sprayed. The real spraying demand is estimated by the leaf area index (LAI) as they are positively related. Water-sensitive papers are placed on and around the grapevines to assess both the spraying coverage and the drift of the spraying application. The spraying rate is recorded in real-time, hence the total volume of product sprayed is recorded. The result demonstrates that the proposed variable-rate system offers advantages over the uniform-rate application and the RGB-based variable-rate application.
Keywords: Variable-rate spraying, RGB-depth, Object detection, Edge computing, Pulse-width modulation

OP20-1 | Challenges and opportunities for remote sensing in agrivoltaic systems

Sergio Vélez[1], Tamara Bretzel[1], Matthew F. Berwind[1], Mar Ariza-Sentís[2], Gonzalo Mier[3], João Valente[4], Max Trommsdorff[1]
[1]Group Agrivoltaics, Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany, [2]Information Technology Group, Wageningen University & Research, Wageningen , Netherlands, [3]Laboratory of Geo-Information Science and Remote Sensing, Wageningen University & Research, Wageningen, Netherlands, [4]Centre for Automation and Robotics (CAR), Spanish National Research Council (CSIC), Madrid, Spain

Remote sensing technologies have transformed farming by enabling the analysis of crop health, soil conditions, and water levels from the air. This review examines the application of these technologies within agrivoltaic systems, where agriculture coexists with solar energy production, to promote sustainable farming practices. The effectiveness of technology—be it satellites, drones (UAVs), or unmanned ground vehicles (UGVs)—varies depending on the type of crops, the data required, and the scale of operations. Each technology has its own set of strengths and weaknesses, depending on the agricultural setup and the configuration of solar panels. Drones excel in capturing detailed images close to the ground in mixed solar panel and crop areas but may face challenges in narrow spaces or when solar panels obstruct their path. Satellites can survey large expanses swiftly, offering a broad overview of crop health across extensive farms, but their high vantage point may limit their ability to capture fine details due to distance or shadows cast by solar panels. UGVs gather valuable ground-level data, such as soil moisture or temperature, yet navigating rough or densely planted terrain can prove difficult. This review underscores how selecting the appropriate remote sensing technology can enhance crop monitoring in agrivoltaic systems. This enables more accurate decisions regarding irrigation, fertilization, and pest control, leading to improved yields and reduced environmental impact. Implementing remote sensing effectively in agrivoltaic setups supports the dual goal of optimizing food production and solar energy generation, contributing to environmental sustainability. Choosing the right technology for specific monitoring needs significantly improves agricultural management, especially in systems that integrate crop production with solar energy. This strategy not only boosts crop production but also minimizes environmental impacts through targeted and informed farming methods. The integration of remote sensing in agrivoltaic systems marks a step toward more sustainable and efficient agricultural practices, ensuring food security and renewable energy sustainability for the future.

Keywords:
Satellite; Unmanned Aerial Vehicle UAV; Remote Sensing; Precision Agriculture; Crop Monitoring

OP20-2 | Estimating pomegranate fruit cracking through proximal and aerial remote sensing

Georgia Nikolakopoulou[1], Konstantinos-Elenos Grivakis[1], Evangelos Anastasiou[1], Spyros Fountas[1], Manuela Zude-Sasse[2], Christian Regen[2], Nicolas Tapia Zapata[2], Victor Alchanatis[3], Avi Sadka[3], Meytal Laor[3]
[1]AGRICULTURAL UNIVERSITY OF ATHENS, ATHENS, Greece, [2] Leibniz Institute for Agricultural Engineering and Bioeconomy, Potsdam, Germany, [3]Agricultural Research Organization Volcani Center, Rishon LeZion , Israel

In the realm of agriculture, remote sensing technologies play a pivotal role in enhancing crop management strategies, particularly in assessing crop health in relation to water, nutrients, and disease/pest presence. Fruit cracking, a major concern causing significant yield loss, is influenced by a complex interplay of plant traits, environmental conditions, and management practices such as irrigation and nutrient application. This study investigates the effectiveness of remote sensing techniques and analyzes the integration of proximal and remote sensing data, specifically to observe and understand fruit cracking in pomegranate crops. The study was conducted in Argos, central-east Peloponnese in Greece. These experiments involved intensive data collection using proximal methods alongside unmanned aerial vehicles (UAVs). Ground-based data collection was undertaken using RGB and thermal cameras, complemented by Light Detection and Ranging (LiDAR) laser scanners, and manually measuring the yield, leaf water potential (LWP), and the total number of cracked fruits per plot for each treatment. The yield (average fruit size) ranged from 72 g to 1232 g, and LWP values varied from 8 to 12 bar. The UAVs were equipped with state-of-the-art multispectral and thermal cameras. These tools played a crucial role in generating valuable data, such as various vegetation indices including the Normalized Difference Vegetation Index (NDVI), and captured the unique spectral signatures emitted by the crops. Also, this methodology enabled the creation of detailed 3D point clouds under varying orchard conditions, providing essential geometric information about the crop canopy. The integration of these diverse data sources, processed through sophisticated Machine Learning algorithms, offered a comprehensive view of the health and stress levels of the crops. Observations from the NDVI maps of each tree suggested that trees with cracked fruits had higher NDVI values, and plots with lower yield also showed cracked fruits. However, after the analysis of variance, none of the variables (NDVI, yield, LWP) showed a statistically significant impact on the percentage of cracked fruits, based on the ANOVA analysis. For the NDVI value, the P-value was greater than 0.05 ($p = 0.20$), as were the yield ($p = 0.70$) and the LWP ($p = 0.94$). Finally, understanding the applications of proximal and remote sensing technologies provides crucial insights into crop management practices. Such insights are vital for developing more nuanced approaches to agricultural challenges.

Keywords: Remote sensing, Unmanned Aerial Vehicles, Multispectral and Thermal Cameras, Fruit Cracking, Pomegranate Crops, 3D Point Clouds

OP20-3 | The use of sentinel-2 satellite data for spatially variable rate fertilisation of durum wheat crop in the centre of Sicily

Vincenzo Cascio[1], Antonio Comparetti[1], José Rafael Marques Da Silva[2,3], Santo Orlando[1]
[1]Department of Agricultural, Food and Forest Sciences, University of Palermo, Palermo, Italy, [2]Mediterranean Institute for Agriculture, Environment and Development (MED), Department of Rural Engineering, School of Science and Technology, University of Évora, Évora, Portugal, [3]Agroinsider Lda., PITE, Évora, Portugal

Remote Sensing (RS) using Unmanned Aerial Vehicles (UAVs) and satellites, specifically the Copernicus Sentinel-2 satellite, is a valuable technique in Precision Agriculture (PA). It employs the Normalised Difference Vegetation Index (NDVI) as an indicator of vegetation vigour to generate maps for spatially variable rate fertilisation. This study aims at assessing the potential of RS from the Copernicus Sentinel-2 satellite in sensing the spatial variability of vegetation vigour and plant leaf water content in durum wheat fields of inland Sicily. The objective is to integrate this information into a Decision Support System (DSS) for generating fertilisation maps divided into Management Zones (MZs).
For this case study, a continuous durum wheat field of 4.23 hectares ca., located in the centre of Sicily, was chosen. Google Earth Pro was used to identify and delineate the study area, and the resulting polygon was saved as a .kml file. This vector map was incorporated into the AgroInsider online platform. The investigation spanned the growing seasons 2021-2022 (cv. Arcangelo) and 2022-2023 (a mix of cv. Arcangelo, Simeto and Garigliano).
NDVI and Normalised Difference Water Index (NDWI) values were collected, and NDVI images were extracted from the AgroInsider platform during the key phenological growth stages, i.e. seeding, sprouting, raising and harvest. By analysing the NDVI graph, the optimal fertilisation time (06/02/2023) and the sprouting onset (23/03/2022 and 13/03/2023 for the two growing seasons, respectively) were identified. The raising onset (12/04/2022 and 07/04/2023 for the two growing seasons, respectively) was determined by comparing NDVI and NDWI graphs. Subsequently, fertilisation maps divided into two MZs were extracted from the AgroInsider platform for 01/02/2023, immediately before the optimal fertilisation date.
The RS data from the Sentinel-2 satellite proved highly effective in discerning the spatial variability of vegetation vigour and plant leaf water content in the marginal areas of inland Sicily. This underscores the utility of RS as an integral component of a DSS, capable of efficiently generating fertilisation maps divided into MZs.

OP20-4 | Precision nitrogen fertilization strategies for durum wheat: A sustainability evaluation of NNI and NDVI map-based approaches

Carolina Fabbri[1], Lorenzo Guerrini[2], Antonio Delgado[3], Roberto Vivoli[1], Marco Napoli[1]
[1]Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Florence, Italy, [2]Department of Land, Environment, Agriculture, and Forestry (TESAF), University of Padua, Padua, Italy, [3]Department of Agronomy (ETSIA), University of Seville, Seville, Spain

Durum wheat, one of the most important staple crop, faces rising fertilizer use, particularly nitrogen, to meet growing food demands. However, nitrogen mismanagement to meet the crop demand, may harms ecosystems, fuels conflicts, and disrupts supply chains. To address this issue, precision fertilization technologies, specifically variable-rate fertilization based on satellite imagery, are investigated to enhance nitrogen (N) fertilizer efficiency in no-till durum wheat cultivation. The experiment spanned four consecutive growing seasons, from October 2018 to July 2022, and was conducted in Asciano, Siena, Italy. The soil was under no-till and the sowing was performed using a "disc type furrow opener Vella VSD3200A No-till seeder". A total of four N fertilization approaches were evaluated: a uniform N rate, conventionally calculated, and three variable rates based on Sentinel-2 L2A spectral bands. These variable-rate approaches include one utilizing the Nitrogen Nutrition Index (NNI), a proportional NDVI-based estimate (NDVIH), and a compensative NDVI-based estimate (NDVIL). The study reveals that the proportional NDVI strategy, while raising protein and gluten levels, incurs a cost in terms of yield compared to the uniform N rate. On the other hand, the compensative NDVI strategy proves beneficial, increasing both grain yield and protein composition compared to the uniform N rate. In contrast, the NNI strategy, based on satellite imagery, demonstrates promising results by significantly saving nitrogen without compromising grain yield or quality. Furthermore, the NNI approach optimizes protein partitioning and dough technical properties, essential factors for various end-use applications. In terms of nitrogen fertilizer use efficiency (NfUE), the NNI strategy consistently outperforms other approaches. Notably, among the tested strategies, only the NNI significantly reduced the carbon footprint of cultivation, with a decrease of approximately 20 gCO2eq per kg of grain produced (-7.6%) with respect to uniform N rate. Further, the economic analysis underscores the advantages of the NNI approach, showcasing lower social costs and higher rates of return compared to alternative nitrogen treatments. This emphasizes the economic and environmental sustainability of precision fertilization techniques, particularly the NNI strategy, in durum wheat cultivation. These findings collectively contribute valuable insights for the practical implementation of satellite-based N fertilization strategies, specifically highlighting the potential long-term benefits and sustainability of the NNI approach in promoting precision agriculture for durum wheat cultivation.

Keywords: Variable-rate fertilization; Life Cycle Assessment; N fertilizer use efficiency; Social cost; Dough technical properties

OP20-5 | Predicting crop biophysical parameters using high resolution satellite data

Matti Pastell[1], Annimari Hartikainen[1], Hanna Huitu[1]
[1]Natural Resources Institute Finland (Luke), Helsinki, Finland

Remote sensing is used to support farmers decision making for e.g. variable rate nitrogen application and irrigation. Sentinel 2 (S2) based crop biophysical parameter prediction models have been developed and are openly available in ESA Sentinel toolbox and directly trough service providers. The usefulness of S2 data can be limited in cloudy areas due to relatively sparse revisit time of 5 days. Commercial PlanetScope (PS) satellites offer imagery with daily revisit time, however there is lack of open models for predicting crop biophysical parameters. The aim of this study was to developed prediction models for leaf area index (LAI), crop chlorophyl content (CCC) and crop water content (CWC) from PS images using Sentinel 2 images as reference data.
Remote sensing data from S2 and PS 8-channel instrument were obtained from 2 different areas of Finland between 2021 and 2023. The dataset covered in total 1438 hectares and 254 field parcels resulting to 135656 cloud free pixels. Open-source Python implementation of S2 biophysical neural network-models (NN) was developed. S2 and PS images from the same days were selected and PS 3mx3m data was resampled to match the S2 pixels. Existing S2 NN models predict LAI using 3 channels (B3, B4 and B8) and PS images have interoperable channels with B3 and B4 and NIR band highly correlated with B8. Due to the close correspondence in bands, Sentinel 2 models were directly applied to PS images. The NN models for CNC and CWC do not have close correspondence and new 3-layer NN models were developed. The dataset was split by year into training and test datasets for model fitting and evaluation. The data availability of both datasources was also evaluated.
Very high agreement (R2=0.96) between S2 and PS data was reached by directly applying the S2 models on PS data without any retraining of the models. The newly developed prediction models reached high agreement for CNC (R2=0.97) and CWC (R2=0.88). The lower accuracy for CWC is expected as PS instrument does not have spectral bands above 865nm. The median availability of cloud free analysis quality PS images was 3 times higher than for S2 in our dataset.
The results indicate that PS can be used to predict crop LAI and CNC with high accuracy and CWC with good accuracy. The higher data availability of PS imagery makes it attractive for precision farming service development and data assimilation to crop models.

OP20-6 | A UAS based protocol for obtaining high resolution cotton yield maps

Chris Cavalaris[1], Christos Karamoutis[1], Sofia Koukou[1], Evangelia Karakosta[1]
[1]University Of Thessaly, Volos, Greece

Yield maps are critical components for precision farming applications. They are obtained mainly by sensors, established on harvesting equipment that are also equipped with GNSS systems to address a spatial dimension on the yield values. The resolution of such maps is of some meters depending on their technology. While yield maps have been widely used in cereals, the implementation in cotton is rare because on-board sensors on cotton picker machines are few and their performance is often poor. Unmanned aerial systems – UASs is a novel technology introduced recently in agriculture for remote sensing and performing field tasks. The ability of UAS airborne sensors to capture high resolution images has made them a unique tool for monitoring several crop attributes including yield. In the case of cotton, yield is associated with the intensity of the fiber in the field when the crop is about to harvest. The presence of fiber can be easily realized from a simple, high-resolution RGB sensor carried on a UAS platform. The present study capitalizes on that fact and examines different image resolutions and flight altitudes for selecting the most suitable ones for an efficient and effective cotton yield mapping. For that purpose, four pilot fields with irrigated and dryland cotton were monitored in central and northern Greece during the 2022-23 period. A DJI Phantom 4 Pro UAS with a 4K RGB camera was used to monitor the field from four different altitudes (15m, 30m, 45m and 60m) providing corresponding resolutions of 0.40, 0.80, 1.10 and 1.50 cm. The RGB images were converted to binary fiber, non-fiber images using an image classifier tool on QGIS. These binary images were utilized consequently to estimate the Cotton Fiber Index – CFI, defined as the number of pixels attributed to fiber to the total number of pixels on an area. Ground truth samples of the open bolls were obtained from selected spots at each field by repetitive handpicking on fractional intervals. The gradual harvesting along with UAS images captured right after, allowed to build a field specific, CFI based model to address the cotton yield. The model was verified by additional samples obtained randomly from each field providing a high accuracy with an coefficient of determination R2 over 0.80. A clear protocol with well-defined steps was finally established for implementing the proposed process.

OP21-1 | A new mobile robot harvesting prototype for cotton production

Joe Mari Maja[1], Mohd Fazly Mail[2], Michael Marshall[2], Gilbert Miller[3], Van Patiluna[1], Matthew Cutulle[2], William Bridges[2], Edward Barnes[4]
[1]Center of Applied AI for Sustainable Agriculture, South Carolina State University, Orangeburg, United States of America, [2]Clemson University, Clemson, United States of America, [3]Edisto Research and Education Center, Clemson University, Blackville, United States of America, [4]Cotton Inc., Cary, United States of America

The economic impact of cotton extends beyond production and cultivation. Its economic impact is reflected in its role as a crucial natural fiber and oil crop, widely grown in the US, China, and India. The cotton industry worldwide generates more than $600 billion and employs more than 4 billion people. Like other commodity crops, it has its own challenges, e.g., increased pest resistance, shortage of labor, high labor costs, and the labor-intensive nature of its harvesting. Although some farmers have already used mechanical harvesting machines, others still use manual harvesting, especially in cotton production in China and India. These mechanized machines are huge and expensive to operate and maintain, and they exacerbate the soil compaction issue. The harvester, for example, can only be used in 2-3 months of each year. This work focuses on developing a proof-of-concept cotton harvester that addresses the issue of cost and soil compaction. A finger roller concept harvester was developed to pull and extract cotton bolls. The system was attached to a mobile platform where its width and height could be adjusted. An eductor and a blower were used to move the harvested cotton bolls to the storage bin on each side and a secondary finger roller at the back provides the final detachment of the bolls for transport to the bin. The whole platform was tested in 2023; October 30, November 4, 8, and 9, where the field was established with 96.5 cm between rows and 10 cm in row spacing. The field experiment was conducted with a completely randomized block design with three replicates by changing the front roller's rotation at three different duty cycles: 25%, 50%, and 100%. Initial 9 subplots were selected, measuring 3 m in length with a 1 m buffer zone on each side to mitigate the issue of bolls collected from the adjacent row. An additional 10 subplots were added to include the rotation direction of the front roller (forward and backward) after some changes were made to the front mechanism. Results showed that the backward direction with 50% and 100% duty cycles has the highest calculated efficiency, lower losses, and minimal trash limbs in the header. However, the number of bolls collected at the bin was still small due to the bolls getting clogged on the bottom of the eductor. The future work for this project is to address the clogged issues and the platform's autonomous navigation.

OP21-2 | Apple position & orientation estimation for harvesting robotics

Robert van de Ven[1], Trim Bresilla[2], Nick van de Westeringh[3], Evelien Looijen[1], Jochen Hemming[4], Eldert van Henten[1], Gert Kootstra[1]
[1]Agricultural Biosystems Engineering, Wageningen University & Research, Wageningen, the Netherlands, [2]Agrosystems Research, Wageningen University & Research, Wageningen, the Netherlands, [3]AlgroNick, Zeewolde, the Netherlands, [4]Greenhouse Horticulture, Wageningen University & Research, Wageningen, the Netherlands

Pose estimation is important for successfully harvesting apples. To perform the detachment motion of apple harvesting correctly, the 5D pose of the apple needs to be estimated. The 5D pose consists of the 3D position and an orientation axis. As the peduncle and the calyx of the fruit are usually on opposite sides of the orientation axis of the fruit, they can be used for the orientation estimation. A sixth pose dimension cannot be established, as the apple is rotationally symmetric around its orientation axis.

We estimated the 5D pose using the centre position of the apple and the position of the calyx. Using RGB-D images. First, the mask of an apple was detected in the 2D colour images using YOLACT++ and the position of the calyx was detected using YOLOv3. A sphere was then fitted to the point cloud relating to the apple mask, with the centre determining the 3D apple position. The 3D position of the calyx was estimated using the depth map. The vector pointing from the centre of the apple to the position of the calyx determined the 2D apple orientation.

For apple instance segmentation, YOLACT++ was trained & tested on a dataset with images from a real orchard, containing 9563 apples, resulting in an F1-score of 0.71. For calyx detection, YOLOv3 was trained & tested on a separate dataset of 547 masked apples and 597 apples from the fruit360 dataset, resulting in an F1 score of 0.9. We tested the 5D pose-detection algorithm in a lab scenario on apples with known poses. An individual apple, with a pose tracker, was positioned in front of artificial leaves. The apple was positioned in a range of orientations and positions, and with different levels of occlusions. We found a mean Euclidean distance error of 13.4 mm for apple position and a mean absolute orientation error of 7.5° and 8.0° for the two orientation axes.

The calyx is only visible in around 50% of the apples in a tree. We have been able to detect which apples do not have a calyx visible. We trained and validated YOLOv8 OBB on a dataset of 868 apples to detect the orientation. Initial validation resulted in an average rotation offset of 12.4°. Through further tuning, we aim to improve this value. We will combine this with the other part and test this in a lab scenario.

OP21-3 | Optimization of the travel speed and workspace partitioning of multi-armed fruit harvesting robots for increased performance

Natalie Pueyo Svoboda[1], Stavros Vougioukas[1]
[1]University Of California, Davis, Davis, United States of America

Orchard growers are moving towards mechanization due to ongoing labor shortages, leading to a resurgence of research into mechanized fruit harvesting. The cost-effectiveness of robotic harvesting depends strongly on two key performance metrics. Fruit picking throughput (FPT), the average number of fruits picked per unit of time, and fruit picking efficiency (FPE), the percent of marketable fruits harvested. These metrics 'fight' each other, as high FPTs come at the cost of reduced FPEs and vice versa. The focus of this research has been on increasing FPT while keeping FPE above a minimum acceptable grower-defined threshold for a simulated robotic harvester that travels at a constant speed as it harvests fruits with several 3-DOF arms working both in parallel and in series. The arm-to-fruit assignments are scheduled using a greedy First-Come-First-Served policy. One strategy to load-balance the arms is to partition the rows of arms through flexible, software-defined row limits so that all rows contain the same number of fruits. This strategy was compared against partitioning rows at equal heights. A second strategy computes the highest travel speed that maximizes FPT while achieving a minimum FPE. This strategy was compared against using a fixed, pre-determined speed.

Simulations were performed using digitized position coordinates of apples from a V-trellised orchard. Both partitioning methods achieved the minimum 95% FPE, however, partitioning by fruit allowed the harvester to move at faster speeds leading to higher FPTs. As the number of arms increased, the difference in FPT between the partitioning methods increased; for the same number of arms, results were better when the arms were divided into more rows rather than more columns. For the second strategy, low fixed speeds resulted in high FPE but low FPT, while fast fixed speeds had the opposite problem. Choosing the best speed resulted in the best combined FPE and FPT. It led to high FPT while – in most cases - keeping FPE at or above 95%. The insights gained in this paper provide two simple strategies that could be implemented on multi-armed harvesters to improve the combined FPE and FPT.

OP21-4 | Development of an innovative robotic technology and system for apple harvesting

Renfu Lu[1]
[1]USDA Agricultural Research Service, East Lansing, United States of America

Apples are currently harvested manually using ladders and/or harvest assist platforms. Harvesting labor is the single largest cost in apple production for growers in the United States. Hence, there is an urgent need for harvest automation to alleviate the rising cost and growing shortage of labor for apple growers. Many robotic apple harvesting systems have been developed recently, but they are short of meeting grower expectations in terms of harvest efficiency and dexterity at picking apples from clusters and/or occluded by branches and leaves. In the past few years, our team has been engaging in research on robotic harvesting of apples. Specifically, our research has been aimed to address several key technical challenges in the hardware and software design of a robotic harvesting system. Our harvesting robot has a simpler yet dexterous manipulator design with only four degrees of freedom, a specially designed perception configuration integrating a time-of-flight RGB-D camera with an active laser-camera scanner (ALACS) to achieve precise fruit localization, and a soft end effector coupled with a vacuum unit to enable fast and gentle picking of apples from clusters. New algorithms for extracting fruit localization information from the 2-dimensional images acquired by ALACS and for systems control and planning were developed. Moreover, we have also extended a one-arm design in our earlier versions of the robot to a two-arm design in the current version of the robot, to enhance the overall harvest efficiency. Laboratory and field tests of the harvesting robot have been conducted in the harvest seasons of 2021 through 2023. Results showed that the one-arm version of the harvesting robot was able to achieve a picking rate of less than 4 s per fruit, when it was operated in continuous picking mode, without using the ALACS. Incorporation of ALACS in the perception system has significantly improved fruit localization accuracies, especially when the target fruits were occluded by leaves. However, the use of ALACS has also led to a lower fruit picking rate, due to additional scanning times needed. The two-arm robot design has resulted in 20% to 30% harvesting rate improvements, depending on the tree architecture. Further improvements to the coordination of the two picking arms and especially the current vacuum design are being considered, so as to enhance the harvesting efficiency by at least 50%, compared to the one-arm design.

Keywords: Robotics, Automation, Harvest, Apples, Fruit

OP21-5 | Stereo vision system guided variable rate sprayer with electric variable air assist system

Hongyoung Jeon[1], Heping Zhu[1], Roman Carla, Javier Campos, Erdal Ozkan
[1]USDA-ARS, Wooster, United States of America

Pesticide applications are economical and effective ways to protect tree crops from pests and diseases for preserving its crop quality and quantity although they accompany with the potential risks of environmental contamination and unintended exposure. Common approaches to minimize the risks have been variable rate pesticide applications which characterize crop canopies by various advanced sensing technologies, and apply tailored pesticide volume. Although these approaches are effective in reducing pesticide uses substantially, their focus is to modulate spray outputs to match targeted crop canopy characteristics without adjusting other application parameters such as air assist. Since air assist systems of conventional sprayers are mainly designed to discharge vigorous air assist for matured tree crops, they tend to create large amount of spray drift. Therefore, variable-rate sprayers could reduce the amount of pesticide spray but the adverse effects of pesticide applications such as spray drifts are similar to conventional sprayers when they discharge sprays without adjusting intensities of air assist. An electric variable air assist system (EVAAS) was developed to address such issues by applying variable air assist along with spray applications while enhancing penetration and deposition of tree crop spray applications. The EVAAS was built with an air channel, a battery, pulse width modulated controller, and a microcontroller which was integrated to variable rate sprayer (VRS) guided by a stereo vision system to control air assist outputs based on the presence of the tree crop canopy. The performance of VRS with EVAAS was evaluated in an apple orchard for its performance in spray deposition and coverage compared to a conventional sprayer (CS) and VRS with conventional air assist system (CAAS). The results showed that VRS with EVAAS had equivalent spray coverage and deposition compared to CS and VRS with CAAS. In addition, VRS with EVAAS had more than 90% reduction in spray drift compared to a conventional sprayer and a VRS with CAAS. VRS-EVAAS provides an effective solution to improve spray penetration, deposition and coverage while minimizing spray drift.

OP21-6 | Drone- and satellite based variable task maps for precision agriculture

Stephanie Delalieux[1], Yasmin Vanbrabant[2]
[1]VITO, Mol, Belgium, [2]pcfruit, Sint Truiden, Belgium

Precision agriculture, aimed at optimizing resource allocation and increasing productivity, relies heavily on accurate spatial information. The integration of drone and satellite data has emerged as a promising approach to generate detailed and timely maps essential for efficient farm management. This study explores the utilization of these technologies to create variable task maps and make them easily accessible to boost agricultural operations. Machine learning algorithms are used to analyze high-resolution drone imagery and multispectral satellite data.

Through a case study in arable and fruit farming, we demonstrate the efficacy of remote sensing in delineating field variability and identifying management zones based on crop health indices, plant height, and flower maps. Furthermore, with the use of our user friendly WatchItGrow platform, we will highlight the potential of task maps in optimizing field-level operations such as irrigation scheduling, fertilization planning, root pruning and pest management by providing actionable insights tailored to specific crop requirements. The results underscore the significance of leveraging drone and satellite data to enhance decision-making in precision agriculture. The proposed framework represents a valuable tool for farmers, agronomists, and agricultural stakeholders seeking to maximize productivity while minimizing input costs and environmental impacts. Future research directions include the refinement of algorithms for integration of multimodal sensor data, and validation of task map driven management strategies through field trials and long-term monitoring. Overall, drone and satellite imagery for task map generation holds immense potential to revolutionize agricultural practices, paving the way towards sustainable and efficient food production systems.

OP22-1 | A review of the EU rural bioeconomy: Driving the transition towards a circular bioeconomy

Bas Paris[1], Dimitris Michas, Athanasios T. Balafoutis
[1]Certh - The Centre For Research & Technology, Hellas, Athens, Greece

This paper conducts a review of the current status of the European Bioeconomy, split into 5 themes (agriculture, water systems, forestry, bioenergy, biomaterials) with a focus on rural areas. The results presented, covering a wide range of data sources, illustrate the diversity and complexity of the EU bioeconomy and cover biomass flows for each of the 5 themes, general EU bioeconomy employment and value related indicators, as well as national and local small scale bio-based solutions as drivers in the transition to a circular bioeconomy.

Our results highlight that certain sectors, including the bioenergy and biomaterials sectors that are still relatively small as compared to their fossil-based equivalents, are experiencing rapid growth, and are expected to continue to grow rapidly in the medium and long-term supporting sustainable transitions across the wider economy. In addition, our review suggests that a range of small-scale biobased solutions now exist across the EU and that the replication and scaling of these can be a major catalyst towards achieving growth in all bioeconomy sectors and EU sustainability goals.

The paper also presents and discusses bioeconomy related policy developments on an EU and national level while investigating potential trends and opportunities. It is clear that EU policy is supportive of the development of a sustainable EU bioeconomy and the updated EU bioeconomy strategy operates in parallel to multiple other policy initiatives such as the new CAP, Green Deal, Farm to Fork strategy and circular economy action plan. In the short term, the further development of national strategies dedicated to the bioeconomy will strengthen the policy environment.

This study identifies a number of key areas for future research including more detailed overviews of the bioeconomy for all EU member states; an in-depth analyses of specific bio-based value chains; the relationship between economy, society and the environment; the relationship between the bioeconomy, other sectors and the circular economy; indicators that measure the impact and potentials of the bioeconomy and its sectors are being developed and need to be strengthened further; and future research providing projections and scenario analyses on the future state of the bioeconomy in the medium and long-term.

Keywords: Bioeconomy; circular economy; EU policy; biobased solutions.

OP22-2 | Evaluation of water and nutrients use efficiency in a cucumber-melon cascade hydroponic system

Nikolaos Katsoulas[1], Ioannis Naounoulis[1], Sofia Faliagka[1], Efi Levizou[1]
[1]Laboratory of Agricultural Constructions and Environmental Control, Department of Agriculture Crop Production and Rural Environment, University of Thessaly, Fytokou Street, 38446 Volos Magnesia, , Greece

In regions characterized by low-quality irrigation water, hydroponic systems are often implemented as open (free-drainage) to prevent salt accumulation in the rhizosphere environment. As a consequence, this practice leads to water and fertilizer wastage, and therefore groundwater pollution. Cascade hydroponic systems, have the potential to maximize water and nutrient use efficiency while minimizing water and fertilizer leaching into the environment. In these systems, the drainages of a primary (donor) crop are reused to cover the needs of a secondary (receiver) crop. An experiment was carried out to evaluate the efficiency and the productivity of a cascade system, wherein the drainages of a cucumber (donor) crop, were utilized to meet the needs of a melon (receiver) crop. To assess the performance of the system, water (WUE), nitrogen (NUE), and phosphorus (PUE) use efficiency were calculated. In addition, the nitrogen and phosphorus leaching into the environment were estimated. To evaluate the effect of the reused nutrient solution in the secondary crop, a treatment of a melon crop irrigated with a fresh nutrient solution was also included as a control treatment. Based on the results, the application of the cascade system increased the WUE, NUE and PUE by 22.0%, 21.7%, and 21.8%, respectively, compared to the cucumber monoculture system while the nitrogen and phosphorus leaching decreased by 75% and 86%, respectively. Moreover, the growth and yield of the secondary crop were not affected adversely by the recycled nutrient solution. This work is part of the ECONUTRI project funded by the European Union’s Horizon 2020 Research and Innovation Program under the Horizon Europe Grant agreement: 101081858
Keywords: cascade hydroponics; drainage reuse; water; nitrogen; phosphorus efficiency

OP22-3 | Flushed liquid dairy manure solid particle and nutrient distributions

Lide Chen[1], Kevin Kruger
[1]University Of Idaho, Twin Falls, United States of America

Large dairies often use liquid manure handling systems because of their ease of mechanization and low labor requirements. Some Idaho dairies use flushing systems that result in large amounts of liquid dairy manure that are applied via irrigation systems to adjacent cropland during the growing season. Solids and nutrients found in liquid dairy manure pose challenges to manure handling processes and cause environmental concerns. Separating solids and nutrients from liquid dairy manure is a critical step to improve nutrient use efficiency, reduce the negative environment impacts, and reduce manure handling costs. To better address solids/nutrients separation issue, a critical question needs to be answered: what are liquid dairy manure solid particle and nutrient distributions? Experiments were conducted to study the particle density, particle size, and nutrient (total nitrogen and total phosphorus) distributions of flushed dairy manure. Flushed liquid dairy manure samples were collected from three commercial dairies in Southern Idaho. The particle densities of manure solids were determined by the pycnometer method using a methanol medium. Solid particle distribution was determined using a set of 6 sieves (4, 2, 0.5, 0.25, 0.125m and 0.063 mm) combined with the hydrometer method ASTM D7928-17 for particle sizes less than 0.063mm. Total nitrogen and total phosphorus was analyzed using a Hach spectrophotometer (DR 5000) based on Hach methods. The Pipette Methods ASTM D6913/D6913M-17 was used in conjunction with ASTM D7928-17 to exact liquid manure samples. The test results showed that particle densities of flushed liquid dairy manure ranged from 1.32 g/cm3 to 2.20 g/cm3, which are smaller than the density of soil particles (2.65 g/cm3), solids of particles larger than 0.5mm were less than 50% of total solids (dry mass basis) for all three dairies, and liquid dairy manure phosphorus was mainly attached to particles with sizes smaller than 0.5mm. With this new knowledge on solids and nutrients distributions revealed by our lab tests, we worked with a dairy on evaluating on-farm performance of both inclined screens and centrifuges for a year. The on-farm tests showed that centrifuges have the capacity to separate fine particles beyond inclined screens that contain higher nitrogen, phosphorus, and potassium.
Keywords: Liquid dairy manure, nutrient distribution, solid particle distribution, separation

OP22-4 | Composting off-gas as alternative source of carbon dioxide for spirulina cultivation – A preliminary study

Kelechi Ezenwa Anyaoha[1], Christina Dornack
[1]Technische Universität Dresden, Institut Für Abfall- Und Kreislaufwirtschaft, Dresden, Germany

Tackling climate change requires greenhouse gas emissions (GHG) avoidance, reduction and sequestration. While carbon dioxide (CO2) emission from biomass is carbon neutral, any effort to capture it will result in negative emission. CO2 is the main GHG released through composting off-gas, while the others (methane and nitrous oxide) are influenced by process parameters. Spirulina are photosynthetic cyanobacteria that use CO2 for biomass production and contribute to efforts to reduce GHG emissions and climate change. Therefore, the research aims to increase the concentration of CO2 in the composting off-gas and improve its sequestration by photosynthetic organisms for climate change mitigation. In order to capture and economically use CO2 from the composting off-gas, an innovative passive batch composting experiment was carried out in parallel with spirulina cultivation. The composting trail consisted of three vacuum bags used as reactors and another for off-gas storage. In the passive composting process, after the initial loading period, air is pumped through the reactors at predetermined intervals and the off-gas is stored in a bag before being used as source of CO2 for growing spirulina. On the other hand, food waste (samples) are moved from one reactor to the other after predetermined periods of seven days. Off-gas concentrations, sample and ambient temperatures were measured daily. The only source of CO2 for spirulina cultures (treatments) OfgA and OfgB, and AirA and AirB were the off-gas and air, respectively. The treatments received the CO2 at predetermined flow rates and intervals. OfgB and AirB received additional air bubbling. The pH and optical densities of the cultures were measured daily. Preliminary results show zero methane recorded and maximum CO2 concentration of 4.9% in the off-gas. Treatment OfgB recorded maximum spirulina biomass productivity of 20.7 mg/L/day and maximum specific growth rate of 0.126/day after eight days. OfgA and OfgB resulted in highest biomass productivity and maximum specific growth rate than AirA and AirB due to higher CO2 concentrations, demonstrating the importance of carbon source in photosynthesis and the potential for increased GHG sequestration. Therefore, composting off-gas provides a cost-effective source of CO2 for spirulina cultivation and contributes to reduced CO2 emission in the sector. Preliminary results of the innovative composting process have shown that CO2 from off-gas can be harnessed and used economically, similar to biogas. Further research is required to optimise the process and enable the innovation to be implemented at large scale.

Keywords: composting, off-gas, spirulina, carbon sequestration, negative emissions

OP22-5 | Advancing circular nutrient flows through the development of biofertilisers: P2GreeN project perspective

Dimitris Michas[1], Athanasios Balafoutis[1], Bas Paris[1], Michalis Moraitis[1], Ioannis Thermos[1]
[1]Ibo/certh, Athens, Greece

This perspective paper provides an overview of the current research results and expected outputs of the Horizon Europe P2GreeN project which pilots four innovative technology and implementation systems in Germany, Sweden and Spain that capture and turn human sanitary waste into safe bio-based fertilizers for agricultural production. This paper presents the current status of the implementation of these technologies in the pilot regions and the first results of the field trials of the project. Initial results document the process of setting up each pilot region and indicate that the bio-based fertilisers produced are safe for agricultural production and in line with the production efficiency as compared to conventional chemical fertilizers. A policy and governance analysis for the implementation and scaling of these technologies in the pilot regions and the EU is also presented. In parallel the project explores the potential of implementing and scaling these systems to other areas in the EU with a particular focus on Italy, Greece, Hungary and France. In this regard the project undertakes a number of feasibility studies evaluating the potential of each system in specific cases. Initial results document the cases to be explored in each follower region for the final feasibility studies. The paper also presents the results of expert consultations from focus groups and workshops. Results from the focus groups indicate broad support amongst experts for the implementation of these types of technologies and fertilizers emphasizing their potential in various regions, despite challenges such as implementation costs. Various social considerations centered around acceptance and quality were also highlighted. While there is a need for the development of a supportive policy framework at both EU and national levels.
Keywords: circular nutrient flows, farm to fork, air and water pollution control, fertilizer, wastewater management

OP22-6 | Cultivating cucumber in a circular tri-trophic system

Alvarnt Anastasia Mourantian, Michalis Chatzinikolaou, Sofia Faliagka, Christos Athanasiou, Ioannis Karapangiotidis, Nikolaos Katsoulas, Efi Levizou
[1]University of Thessaly, Volos, Ελλάδα

The introduction of circular economy principles in agriculture is gaining momentum. The current study implements a tri-trophic model comprising of three types of organisms, namely plants, fish, and insects, that mutually benefit each other. The larvae of the black soldier fly, which are rich in proteins and vitamins are incorporated into fish feed. The fish are reared in an aquaponics system, where their metabolic waste is diluted in the water that recirculates between the fish tanks and the hydroponically cultivated crops, providing nutrients for the plants.
Finally, plant leftovers (pruned leaves, malformed fruits) are used as food for insects, thus completing the nutrition cycle. The aim of this study is to implement and evaluate the efficiency of this tri-trophic system in cultivating a major greenhouse crop, specifically cucumber. The experiment was conducted in a pilot-scale aquaponics greenhouse, where cucumber plants were grown in combination with red tilapia fish, under three different nutrient solutions; a hydroponic solution (HP) as the control, an aquaponic solution directly derived from the fish tanks (coupled system, CAP), and an aquaponic solution enriched with nutrients by adding fertilizers to achieve the target values of the HP (decoupled system, DCAP). The growth and functional responses of plants were assessed during a three-month experiment, in particular biomass production and fruit yield, gas exchange rates, and photosynthetic pigments content. CAP treatment resulted in reduced growth and photosynthetic performance compared to the HP and DCAP treatments. HP and DCAP showed similar net CO_2 assimilation rates and water use efficiency, and biomass accumulation. In DCAP, the cucumber yield was twice the CAP treated plants, and 15% higher than HP. Conclusively, the tri-trophic system examined exhibited lower efficiency in the absence of external supplementation, however its implementation in the DCAP treatment resulted in improved growth and physiology of cucumber, with lower chemical inputs, compared to HP.

OP23-1 | Estimating the benefits of tractor plugin P4 architecture: A possible solution to reduce CO2 of agriculture

Michele Mattetti[1]
[1]Università di Bologna, Bologna, Italy

Agricultural machinery in Europe produces around 70 million tons of CO2 emissions each year and in order to reduce fossil fuel use, industry and researchers are currently investigating hybrid powertrains to boost CO2 emissions reduction. This paper aims to investigate a plugin P4 hybrid powertrain and to the benefits of such solution using real-world data. Real-world data were collected using a Controller Area Network (CAN-BUS) data logger on a row-crop tractor with an engine power of 190 kW. The tractor was monitored for more than two years of field use. Data were first classified into tasks and then a series of inefficiency indices were defined. Then the plug-in P4 architecture were modelled through a simplified model to use on a large real-world dataset. The plug-in P4 powertrain permits to achieve a significant cost and CO2 savings of around 7.2% and 9.5%, respectively. In the future, as the proportion of electricity from renewable sources increases, greater CO2 benefits could be achieved.

OP23-2 | Sustainability assessment of hydraulic and PTO driven inter-row tillage implements

Massimiliano Varani[1], Michele Mattetti[1]
[1]Alma Mater Studiorum - University Of Bologna, Bologna, Italy

Agricultural machinery manufacturers are looking for innovative solutions to improve the sustainability of their products in terms of environmental, economic and social issues. Regarding specialized tractors, in recent decades a large increase in the available oil flow rate at the hydraulic remotes was observed, which resulted in the possibility of providing high values of hydraulic power to the implements. Thus, many implement manufacturers started to develop Hydraulic-Driven Implements (HDI) to replace traditional PTO-Driven Implements (PDI). HDI could apport many benefits mainly due to the absence of the cardan shaft connection, such as improved comfort and safety during implement connection, less noisiness and an improved implement rotational speed control in active implements. Moreover, generally HDI have lower purchase prices and maintenance costs than the equivalent PDI, since the latter are composed of a greater number of components. However, HDI suffer from lower power delivery efficiency compared to PDI, leading to higher fuel consumption and consequently higher CO^2 emissions. The main purpose of this study was the comparison analysis between HDI and PDI concerning fuel consumption, economic aspects and environmental impacts. The study involved a four-wheel drive specialized tractor with a nominal engine power of 87 kW and a maximum oil flow rate at the hydraulic remotes of 80 L/min. The implements chosen to perform the field trials were an inter-row Rotary Disk and an inter-row Power Harrow, since both were commercially available in their Hydraulic and PTO driven versions. In addition, the chosen implements were produced by the same manufacturer, thus the number of uncontrolled variables due to different design layouts was reduced since many components are shared between the two versions. Implements hitching time were measured, then field tests were performed in an orchard acquiring essential parameters such as tractor engine speed and power, traveling speed, fuel consumption, oil pressure and flow rate at the hydraulic remotes with all the considered implements. Results show that on the HDI the absence of the cardan shaft shortened the implements hitching time and improved comfort and safety during the operation. In addition, the PDI showed lower values of fuel consumption per hectare, with reductions of up to 50% compared with the equivalent HDI performing the same agricultural operation. However, HDI have considerably lower ownership costs compared to PDI, so the economic break-even point using the PDI is reachable only with an intensive usage of the machinery

KW: Farming sustainability; Hydraulic-Driven Implement, Inter-Row Tillage

OP23-3 | The bulbous bow shape adaptability for the soil ripper tool

Egidijus Katinas[1], Regita Bendikienė[1], Vytenis Jankauskas[2], Antanas Čiuplys[1]
[1]Kaunas University of Technology, Kaunas, Lithuania, [2]Vytautas Magnus University, Kaunas, Lithuania

In the agricultural sector, tillage is used for weed control and seedbed preparation. The various tillage technologies in maize production require 16.2-18.1 GJ/ha of energy. The shape of the soil tillage tools highly affects the energy consumption during the processing. The ship's construction incorporates a bulbous bow, which reduces fuel consumption and total resistance by 12-15%. Given the similarities between the bulbous bow and soil ripper movement, the ship's bulbous bow design application can reduce energy consumption during soil processing. Properly designing a soil ripper with a bulbous bow element can help reduce abrasive wear losses that appear during the tilling: the wear outcome for a soil ripper tool can be as high as 60-120 g·ha-1. The study aims to design the bulbous bow shape element for the soil ripper, test it numerically and verify draught force results by laboratory measurements in the soil bin.
The designed soil ripper with various bulbous bow elements (shape of delta, oval, nabla, etc.) is simulated by the discrete element method (DEM) to develop an optimal element shape. To validate the designed element simulation, the 3D printed soil ripper bulbous bow parts are tested in the laboratory's soil bin to evaluate and verify the newly designed shapes by measuring a draught force during the soil processing. The analysis results are compared to an original shape and recently improved soil rippers with bulbous bow shape results. This analysis stage is crucial for future investigation of abrasive wear analysis of newly designed tools.

OP23-4 | Adaptive nonlinear dynamic systemidentification for separation process of combine harvester

Tarek Kösters[1], Oliver Nelles[1]
[1]University of Siegen, Siegen, Germany

In this paper, we propose a novel method to identify the nonlinear input/output behavior of a combine harvesters separation process in an online manner. The combine harvester separation process comprises a nonlinear dynamic process, which is highly dependent on the crop properties of the harvested fruit. Automatic detection of the optimal combine adjustments aligned with the current environmental conditions allows for utilizing the full combine potential. A crucial aspect in automation methods is played by process models. However, models fit to previously collected data are only partially able to describe the process accurately. This calls for methods to adapt the model to the current conditions.

The process strongly depends on the throughput of the combine harvester. Since its dependency on the encountered crop density, which varies throughout the whole field, stationary conditions are hardly achievable. To tackle this problem a dynamic nonlinear model is utilized, which is able to model both the stationary and dynamic process behavior. We use an initial model based on a local model network (LMN) architecture to approximate the nonlinear dynamic process. It is trained by data collected from the previous harvest in wheat. Each local model can be adapted based on the collected data during harvest.
The efficient numerical implementation is ensured by the deployment of the recursive least squares (RLS) algorithm for the local model parameter adaptation.

Combine harvesters operate across diverse fields with varying crop types. Compared to moderate differences in the crop on a single field, changes between different fields can have a noticeable impact on the combine behavior. Consequently, the model adaptation on a newly encountered field needs to react on different harvest conditions. By the situation dependent choice on the adaptation algorithm parameters it is ensured to realize a robust and fast model adaptation.

Deployment during field trials validates the effectiveness of our adaptation algorithm for different fields and crop types. Focused on the threshing and separation system, we aimed to predict the separation efficiency in wheat and canola. Accurate predictions during the adaptation as well as on additionally collected test data show the model accuracy. The decreasing model error progress on the test data also indicate adaptation speed and robustness.

In conclusion, the novel deployment of dynamic nonlinear model adaptation outperforms pure static model adaptation. The situation dependent parameter choice allows for fast and robust adaptation tailored to the current harvesting conditions.

Online-Identification, Nonlinear Dynamic Model, Combine Harvester, Machine-Learning

OP23-5 | Economics of retrofitted autonomous tractors for crop protection spraying: Cases from Greece and Spain

Tseganesh Wubale Tamirat[1], Søren Marcus Pedersen[1], Jens Erik Ørum[1]
[1]University of Copenhagen, 1958 Frederiksberg C., Denmark

High reliance on labour and soil compaction are among the top challenges for European crop farmers. Given the high seasonality nature of field crop farming, the consequences of lack of access to affordable labour when needed would be devastating as was manifested during the COVID pandemic. The issue is alarming in view of aging of the farming population. Moreover, repetitive field crop operations such as spraying of crop protection chemicals expose farm workers to chemicals detrimental to their health and the environment.

Autonomous systems may help tackle the labour challenge while providing opportunities to improve efficiency, curb emission, reduce soil compaction and improve biodiversity. Retrofitting machinery which farmers are familiar with presents interesting aspects (e.g., function both an autonomous and conventional platform, relatively known retrofitting cost). However, autonomous systems involve high upfront investment cost and uncertainty regarding expected benefits, calling for context-relevant cost-benefit-analysis (CBA) studies. This study aims to provide farm level cost benefit analyses of autonomous systems being developed by an European project called ROBS4CROPS which combines smart implements, autonomous vehicles and high-level planning and scheduling software. This paper focuses on autonomous spraying using retrofitted tractors drawing on two case studies (table grapes in Corinth, Greece and apple orchards in Girona, Spain).

Data for the CBA was gathered through interviews with project site managers, field visits, field experiment data, price quotes from technology providers, literature, and expert opinion. Cost of other operations, crop yield and quality are assumed the same between conventional and autonomous systems. Alternative scenarios were defined considering farm characteristics, market price of machinery and inputs, agronomic constraints and robotic system reliability and regulation. In the CBA, reference farm size of 10ha and average field size of 4ha was used for the Greece case and respectively 40ha and 8ha for the Spanish case.

The costs and benefits of the robotic retrofitted systems were evaluated against existing practices using conventional tractors. For the Greece case, the retrofit system is moderately cheaper than conventional system in many of the scenarios considered. In the Spanish case, the autonomous retrofitted system is found to be cheaper than the conventional system under all scenarios defined. In both cases, considerable labour saving appears to be feasible (32% in Greece, 42% in Spain). However, as pesticide costs account for the major share of total private cost of spraying, the robotic systems will not pay off without sizable reduction in pesticide use.

OP24-1| Understanding stakeholder perspectives on decision support tools for livestock farm emission management

Evangelos Alexandropoulos[1], Vasileios Anestis[1], Thomas Bartzanas[1]
[1]Agricultural University of Athens, Athens, Greece

To assess the expected needs for Decision Support Systems (DSS) related to Greenhouse Gas (GHG) emissions in global livestock production at the farm level, the perspectives of stakeholders were sought. Direct communication with stakeholder parties in partner countries was established to explore their experiences with existing GHG-based DSS at the farm scale. Collecting this information was crucial to understanding the current demand for integrating GHG and ammonia emissions estimation into the decision-making process at the farm scale across different countries. Additionally, it aimed to evaluate and present the potential for utilizing these DSS at the farm scale in the near future. Understanding the requirements of potential users can offer valuable insights to developers of emissions-based decision support tools, enabling them to improve existing tools and align them better with users' needs. The majority of respondents were livestock farmers' advisors (73 out of 109), followed by livestock farmers (23 respondents), inventory compilers (9 respondents), and authority officials/policymakers (4 respondents). The survey respondents represented various countries, including Greece, Poland, Germany, France, and Chile. While most stakeholders who responded were aware of software-based DS tools, less than half of them actually used such tools. Furthermore, even fewer respondents reported using software-based DS tools that estimate GHG and ammonia emissions at the livestock farm level to incorporate emission reduction in decision-making. Although the adoption of farm-scale emission-based DSS in livestock farming is limited, it is clear that farmers who embrace technological developments are aware of the potential environmental impact of their farms. In fact, 87% of respondents expressed interest in being informed about software-based DS tools that estimate and utilize GHG and ammonia emissions in decision-making. Around 60% of stakeholders expressed a willingness to participate in a future consultation process for developing software-based DS tools that estimate and incorporate GHG and ammonia emissions in decision-making. This highlights the need for continued development and promotion of such tools across all participating countries.

OP24-2 | Internet of livestock – A smart locatable multifunctional sensor device to enable interconnectivity between operators and actuators in dairy cattle farming

Susanne Demba[1], Sebastian Schäfer[3], Peter Schneider[3], Sarah Jahn[4], Doreen Nitsche[2], Steffen Pache[2], Kirsten Kouvert[2], Sandra Rose[1]
[1]Hochschule Neubrandenburg, University Of Applied Sciences, Neubrandenburg , Germany, [2]Saxon STATE OFFICE FOR ENVIRONMENT, AGRICULTURE AND GEOLOGY , Köllitsch, Germany, [3]Schneider Elektronik GmbH & Co.KG, Großharthau, Germany, [4]Friedrich-Loeffler-Institute of epidemiology, Greifswald-Insel Riems, Germany

The objective of the project "Internet of Livestock" (IoL) was the development of a multifunctional sensor to record health-related data from dairy cows and to directly connect these data with operators, e.g. barn climate control operators.
The sensor (NECKTAG®) was developed for attachment to the cow's collar located on the back of the neck. It has a length of 90 mm, a width of 50 mm and a height of 20 mm. The multisensor is designed according to a modular principle and contains of different sensors for data recording.
With the developed sensor it is possible to measure the environmental traits illuminance (lux), relative humidity (%), air pressure (hPa), temperature (°C), as well as the air quality directly on the animal. The selected traits are suitable for detecting and describing deviations in behavior and animal welfare from the biological normal state. With the new sensor system, a localization of the cows in the barn is possible as well. Therefore, an antenna system for networking the sensors as well as the connection to the host computer based on BLE_5.1 including 3D real-time localization was set up. Based on the NECKTAG® real-time localization, the integrated positioning system detects the whereabouts of the cows as well as the positions of actors, machines and equipment and provides defined XYZ coordinates for them.
Data were transmitted using energy-saving Bluetooth 5.1 technology (BLE_5.1) to the host computer, in order to create a standardized information provision for farm management and information systems at the farmer. Furthermore, the BLE_5.1 technology makes it possible for the first time to develop bidirectional communication for controlling actuators on the animal, on machines/devices or at the operator. The location data achieves sufficient measurement accuracy and reproducibility (within +-1m) to create animal-specific tracking routes and derive animal behavior characteristics.
The host computer with integrated software was set up in the dairy cattle barn and is used for NECKTAG® data aggregation, pre-processing, localization and tracking. By means of the developed application-open host computer software interface, the platform-independent data exchange and the networking option to higher-level farm management and information systems (Internet, cloud or farm network) as well as the feedback of control functions to the above-mentioned sensor technology were realized. NECKTAG® real-time sensor and location data as well as dairy cattle tracking results are presented on the iol.farm website.
Keywords: Bluetooth 5.1, Multi-Sensor, animal welfare, animal behaviour, dairy cattle tracking

OP24-3 | Cattle behavior patterns classified automatically with SimCLR using an inertial measurement unit: A self-supervised machine learning method

Yingqi Peng[1]
[1]Sichuan Agricualtural University, Ya'an , China

Cattle behavior reflects their welfare and health. The status of livestock is critical in farming and their condition, including the rate of fattening, reproductive stages, and diseases or infections could be monitored through several indicative behavior patterns. At pre-sent, along with the prevalence of sensors and novel algorithms, automatic monitoring sys-tems provide alternative methods for detect-ing animals' behavior changes under preci-sion livestock management (Peng et al., 2020; Y. Peng et al., 2019). Effective, non-invasive, and real-time monitoring methods help farm-ers to make decisions in various contexts.As shown in Fig 2, we developed a self-supervised simple contrastive learning (simCLR) model to classify six cow-behavior patterns using inertial measurement units (IMUs). The IMU data including data of 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer (Fig 1). In order to repre-sent spatial connection among data with 3-axes, IMUs' time-series data were reshaped into images as the input and the un-labeled data were used for pre-training a Resnet18 system and a few labeled data were used for fine-tuning. The best overall classification accuracy among the four models was 90.05%. with a batch size of 256 over 200 epochs. In this model, the classification accuracy of par-ticular behavior patterns was 95% (feeding), 94% (lying down), 86% (ruminating), 88% (rub scratching (leg)), 86% (rub scratch-ing(neck)) and 92% (self-licking) were suc-cessfully detected and the classification accu-racy of all behavior patterns was above 81%. The results show the potential of a self-supervised model for classifying cattle behav-ior patterns automatically without large amounts of labeled data. In the future, video of cattle behavior will be analyzed with image processing methods to complement behavior classification. Moreover, several unsuper-vised learning algorithms will be selected for comparison.
Keywords: Cattle behavior classification, Self-supervised learning, simCLR, IMU, Res-net.

OP24-4 | Authentication of cattle finishing diets (conventional vs. vegetable by-products) using near-infrared spectroscopy

Sara León-Ecay[1], Ainara López-Maestresalas[1], Irantzu Goenaga[2], José Antonio Mendizabal[1], Kizkitza Insausti[1]
[1]IS-FOOD, Universidad Pública de Navarra, Pamplona, Spain, [2]Tratamiento Subproductos Agroalimentarios, Milagro, Spain

European strategies such as Farm to Fork promote the acceleration towards a sustainable food production model. This leads to the search for new input sources to enhance the circularity of the economic system. In this sense, ruminants can make use of the inedible part of the by-products generated throughout the production process of food for human consumption. However, the shift to novel feeds requires a rapid tool capable of authenticating that the animals have received a ration based on by-products.

The aim of the study was to discriminate cattle finishing diets, either vegetable by-products-based (VBPR) or concentrate-based diets (C). Twenty-three Pirenaica calves were involved in the study (nVBPR=11, nC=12). Spectral data were collected on the carcasses at the abattoir 24h postmortem and on the intact meat after 7 days of aging. Near-infrared (NIR) data were collected using a portable Luminar 5030 NIR spectrophotometer in the 1200-2200 nm range with a bandwidth of 2-nm. A total of 20 reflectance spectra were recorded on the surface of the left carcass, 10 spectra between the 5th and 6th ribs, and the remaining 10 entries at the 12th and 13th ribs. Ten replicates per steak were obtained from the intact meat to calculate the average.

The spectral matrixes were imported into PLS_Toolbox 9.3 software under MATLAB R2023b for analysis. Partial Least Squares-Discriminant Analysis (PLS-DA) and Support Vector Machines (SVM) machine learning algorithms were used for data classification. Several pre-processing techniques were applied prior to chemometric modelling. To reduce data dimensionality, variable selection was performed by interval Partial Least Squares (iPLS), where a number of intervals with size between 10 and 20 were automatically selected in increments of 2nm.

Using the discriminant approaches, carcasses were authenticated with a subtle improvement over intact meat (>90% vs. >75% in train and >80% vs. >65% in cross-validation for C and VBPR, respectively). PLS-DA and RBF-SVM combined with iPLS showed improved classification for both locations. Variable importance in projection (VIP) scores revealed how variables ≈1700nm had higher weight in the discrimination process, where fatty acid hydrocarbon bonds were absorbed. This is a key aspect as the fatty acid profile of the meat can be modified by varying the diet of the animals. The results achieved showed the potential of NIR technology as a sustainable, fast, chemical-free tool to assist the meat industry integrate into the digital age of connectivity and digitization.

Keywords: beef, feeding diet, vibrational spectroscopy, machine learning

OP24-5 | Advancing dairy farm management: Leveraging Data, neural networks, and interactive web design

Razieh Abdollahipour[1], Sabrina Hempel[1], David Janke[1], Thomas Amon[1], UZ Barbara Amon[1]
[1]Leibniz Institute Of Agricultural Engineering And Bio-economy E.v. (atb), Potsdam, Germany

Within the framework of the ET4D project, we introduce a data management system (DMS) designed to transform dairy farm management. This system builds on findings from a social diagnosis of attitudes along the dairy production chain and detailed analysis of on-farm communication ecosystems. It is at the forefront of technological innovation, employing deep neural networks for detailed data analysis and predictive insights, coupled with an interactive and intuitive web application aimed at enhancing operational transparency and sustainability.
The transdisciplinary ET4D initiative is spearheaded by the Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB) in Germany alongside partners from seven countries representing academia and industry: UZ, TOGU, AgHiTech, MIGAL, EMU, UPWr, AU, AKI, UOULU and INNVITE. It provides a data space and leverages the power of advanced neural networks to process and interpret vast arrays of farm data. This approach enables modeling of farm dynamics, yielding predictions and insights with remarkable accuracy. Key focus areas include enhancing animal welfare, optimizing productivity, and minimizing environmental impact.
At the heart of this project is a user-centered web application, characterized by its interactive and engaging design. This platform goes beyond mere data presentation; it invites active user interaction and personalized experiences. Users from various segments of the dairy industry, including farmers, regulatory bodies, and consumers, are equipped with tailored tools and dashboards. This not only empowers stakeholders with real-time, actionable data but also fosters an environment of transparency and collaboration.
Our methodology is meticulous and data-driven. Deep neural networks analyze sensor-generated data, uncovering complex patterns and predictive insights. These insights are then integrated into the web application, providing users with a dynamic and responsive interface. The application's design prioritizes user engagement, offering interactive visualizations and customizable reporting features. This ensures that each stakeholder has access to relevant, up-to-date information, facilitating informed decision-making and strategic planning.
In conclusion, this segment of the ET4D project is setting new standards in dairy farm management. By blending cutting-edge neural network technology with a focus on interactive web design, we aim to usher in a new era of data-driven decision-making. This project not only enhances farm productivity and sustainability but also reshapes the interaction between technology and agriculture, driving the industry towards a more informed, responsible, and collaborative future. ET4D is part of the ERA-NET Cofund ICT-AGRI-FOOD, with funding provided by national sources and co-funding by the European Union’s Horizon 2020 research and innovation program, Grant Agreement number 862665.

OP24-6 | Linear mixed models for corrections of milk components in AMS dairy farms

Mattia Ceccarelli[1], Marco Bovo[1], Daniele Torreggiani[1], Patrizia Tassinari[1], Ben Aernouts[2]
[1]University of Bologna, Department of Agri-Food Science and Technology, Viale Fanin 48, 40127, Bologna, Italy, [2]KU Leuven, Biosystems Department, Kleinhoefstraat 4, 2440, Geel, Belgium

The introduction of Automatic Milking Systems (AMS) in dairy farming has led to new variations in milk measurements, primarily due to the voluntary nature of the process. Unlike traditional milking parlors, the milking interval (MI) depends on cows' behavior. MI has been found to correlate with total milk production, fat and protein content. Furthermore, it exhibits significant variability both within and between animals. Although precise milk composition measurements are fundamental to perform genetic evaluations and assess milk quality and cow's health, few studies focused on correction models to reduce these types of natural variation in milk composition.
We propose a methodology based on linear mixed models (LMMs) to adjust fat and protein measurements for MI, past MIs, seasonal effects, hour of the milking, and milk yields of the current and past milking sessions. An LMM was developed with data coming from AMS and laboratory analysis of single milkings from three farms located in Belgium. The main structure of the LMM is a linear Wilmink lactation model, to resemble lactation stage effects, both in the fixed as well as the random effects.
Data gathering began in January 2019 until August 2021. One milking sample per cow was collected once every seven days. Information on single milkings, namely milk yield, MI, days in milk and parity of the cows were collected from the AMS. A cleaning procedure ensured unperturbed samples, unaffected by mastitis or incomplete milkings, which could alter milk composition. 807 unique cows, 1315 unique lactations and 31 000 milk samples were used for fitting the LMM. The models covered 74% and 85% of the variation in fat and protein content, respectively. Moreover, we provide a comparison with two established correction methods for fat measurement, which show inferior results compared to our proposed methodology, in terms of explained variability.
In conclusion, we propose a novel technique for correcting milking-to-milking fat and protein measures taking into account MIs and milk yields of the current and previous milkings, and seasonal and circadian effects. The obtained models can help to reduce variation in milk fat and protein time series from cows milked by an AMS and likewise improve genetic evaluations and monitoring of animal's health and milk quality. Additionally, we provide two predictive models for milk content of individual milkings that can be used to forecast expected milk fat and protein percentages under healthy conditions, enabling farmers to make more timely decisions.

OP25-1 | The importance of rural extension and advisory services to achieve a sustainable viticulture in a climate change scenario

Miguel Cachão[1], Ana Chambel[1]
[1]Avipe, Palmela, Portugal

A healthy and dynamic agricultural sector is an important foundation of rural development, generating strong bonds to other economic sectors.
The success of sustainable rural development depends on developing and implementing comprehensive strategies for dealing with climate change, drought, territorial desertification and natural disasters. Improving access to information, education, extension services and learning resources, will lead to a strong and more resilient rural community.
Climate change is one of the main challenges of the viticulture sector. The European Green Deal and "Farm to Fork Strategy" are ambitious and innovative, it demands a decreasing of 50% on the use of conventional active substances by 2030. This could be considered an opportunity but is also a challenge and very demanding for farmers.
The availability of active substances in the EU, comparing 2011 and March 2023, the number of approved substances decreased 20%, and the substances not renewed increased almost 500% comparing 2018 and March 2023 data.
The rural extension and advisory services play a huge role in supporting farmers to achieve all the demands. Through a face-to-face presence in the field, but also with the help of digitalization, precision farming, AI and data analyses, it's possible to create methodologies enabling farmers to deal with the new demands.
AVIPE is a wine grape growers association working with around 350 farmers, covering an area of 4000Ha of vineyards. Its main activity is on-field consultancy, supporting farmers in decision- making To have a higher impact with farmers, it was created a living-labs/ demo-farm. It's considered crucial to enable farmers to see "in loco" the implementation of new technologies and practices.
AVIPE's dermo-farm, with an area of 40Ha of vineyards, is used to develop an applied research center that could give response to farmers difficulties and future challenges by implementing several trials in the different vineyard's plots:
NDVI and NDWI's vineyard mapping using satellite images, mapping soils by electrical conductivity , plant water potential measurement using pressure chamber in 22 different varieties for 16 consecutive weeks; plots exclusively treated in Organic; plots treated according to the LWA; weed mechanical control instead of herbicides use; cover crops; effectiveness tests of techniques to reduce sunburn phenomena; installation of functional margins and ecological infrastructures, notably according to the Miyawaki forest concept.
All these trials have allowed the development of several dissemination/awareness actions reaching more than 300 winegrape growers, in a pathway to a more sustainable and resilience viticulture

OP25-2 | Finnish future farm - A physical and virtual co-creation platform for RDI, education and business acceleration

Hannu Haapala[1], Annimari Lehtomäki[1], Jyrki Kataja[1]
[1]Jamk Institute of Bioeconomy, Saarijärvi, Finland

Finnish Future Farm (FFF), spanning from 2023 to 2026, is a research project that aims to develop a unique co-creation platform for RDI, education, and startup acceleration in precision farming and smart farming technologies. Upon completion, it will provide a versatile testbed and living lab for User-Centered Design. Both an existing physical smart farm and its digital twin are utilized.

The main goal of the project is to accelerate the adoption of technologies with high potential to realize the UN Sustainable Development Goals (SDGs).

The physical smart farm and a partner farm network are utilized to test and demonstrate the technologies, while the digital twin is used to simulate and optimize them. The physical farm is heavily instrumented and further developed to include different forms of production. The development of the digital twin involves the use of GIS data and a metaverse environment.

A Multi-Actor Approach is employed, wherein experts and users collaborate on use-cases to enhance the acceptability of products.

To be effective, FFF focuses on potential technologies mainly close to market readiness (TRL 7+). Consequently, solutions are developed in collaboration with leading companies and innovative startups that recognize business potential in these technologies. The near-market solutions are initially analyzed to identify core reasons for poor adoption. Subsequently, appropriate research, development, and innovation management actions are applied. Tailor-made education for users, designers, or marketers is designed as necessary. Additionally, business development and acceleration services are available through the BioBoosters acceleration program, including investors and venture capital.

The presentation describes the development of FFF based on results from preceding projects and the outspoken needs of the participating stakeholders. The development of the Smart Bioeconomy Testbed, a member of the Nordic Testbed Network since 2022, is reported. The Smart DIH (Digital Innovation Hub), developed under the Smart AgriHubs HEU project, is also described. Conclusions regarding the realization of a future center of excellence are outlined.

The operation is situated in Central Finland at the Bioeconomy Campus, offering an excellent testing environment for technologies, including challenging soil variation, plant production, animal husbandry, fields, forests, and waters. Close cooperation is established with leading technology manufacturers (Valtra Inc., Nokian Tyres Inc., and Neste Inc.), along with a vast number of startups and growth companies.

Key words: Smart Farming, Testbed, Digital Twin, Education, Business Accelerator

OP25-3 | Irrigation and population dynamics in depopulated rural environments: Causes, implications, and sustainable solutions

Maria Teresa Gómez-Villarino[1], David Pereira[1], Ana Isabel García[1], Alvaro Sanchez de Medina[1], Esperanza Ayuga-Téllez[1], Manuel Hidalgo[2], José María García-Asensio[2], Francisco Ayuga[1]
[1]BIPREE Research group, Universidad Poitecnica De Madrid, Madrid, España, [2]Grupo TRAGSA-SEPI, Madrid, Spain

The demographic evolution of Spain in recent years reveals an undesirable depopulated rural environment with internal imbalances and severe population decline. While various factors contribute to depopulation, such as aging, low birth rates, masculinization, and infrastructure deficiencies, a fundamental cause is the low profitability of agricultural operations, given that it is the main source of income for the population in these areas. This low profitability is linked to the Spanish agricultural structure, where 76% of the nearly 17 million hectares of cultivation are dedicated to rainfed agriculture, and only 24% to irrigation, in a country with a severe hydric deficit. Demographic analysis over the past decade indicates that provinces with a lower proportion of irrigated crops experience greater population loss, while those with higher proportions maintain or increase their population. Therefore, the work hypothesis states that the transformation into irrigation can be key to establishing and increasing the population in depopulated rural areas, highlighting the importance of guaranteeing the sustainability of irrigation to improve its contribution to population fixation. Study objectives include establishing a scientific model for rural development in depopulated areas, analysing elements of population fixation and growth, and exploring interdependence in irrigation sustainability and resilience. The systematic methodology involves comprehensive data collection on depopulated areas, focusing on the "España Vaciada," and irrigation interventions using GIS tools. Subsequently, demographic data collection will address economic, social, and environmental factors influencing population evolution in rural areas. The next phase involves selecting demographic study areas, identifying those representatives of the issue, and highlighting model areas with successful population fixation through irrigation. The development of a survey, crucial in these areas, will be followed by the creation of an initial systems dynamics model, evolving into a definitive model after survey processing and statistical analysis of results. The conclusions summarize findings to provide a solid foundation for decision-making and implementing measures to promote irrigation sustainability and population fixation in rural areas.

OP25-4 | A critical analysis of the impact and challenges of education and rural development in Nigeria

John Ikechukwu Njoku[1]
[1]Credo Hub Networks, Lagos, Nigeria

Governments are duty bound to ensure that every citizen is given a fair chance in life regardless of his/her socio-political and economic placement especially because of the great divide between urban and rural areas. However, it is noticeable that the difference in living standards between people residing in urban and rural areas is more obvious in underdeveloped and developing countries. Several African governments responded to this by initiating various rural development programs which were aimed at improving the lives of people living in rural settings if nothing else. The paper employs a qualitative methodological approach using desk literature survey as well as content analysis. Moreover, it examines four selected rural development schemes in Nigeria such as Rural Infrastructural Development Scheme, Rural Electrification Scheme, Rural water supply scheme and Integrated Rural Development Scheme. The study found that, despite Nigeria's government and international communities' effort in using billions of naira to better the life of villagers, there were little triumphs recorded from these programs. The research paper concluded that poor government appraisal schemes, wrong supervisory patterns, a deeper gap between theory and practice and half-heartedness in Nigerian National Development Planning programs during the 1960s through 1980s and 1990s was the reason for this failure. It also emerged that socio-economic and political constraints of rural societies in Nigeria have remained perennial challenges facing all governments since independence in 1960.

OP26-1 | Commercial ROBOTTI based optimized weeding with less soil disturbance and energy use, while minimizing chemical use by using on-board cameras for site specific applications

Ole Green[1,2], Gareth Edwards[1], Rasmus Nyholm Jørgensen[3], Claus Aage Grøn Sørensen[3]
[1]Agro Intelligence Aps, Aarhus, Denmark, [2]Aarhus University, Dept. of AgroEcology, Aarhus, Denmark, [3]Aarhus University, Dept. of Engineering, Aarhus, Denmark

The paper presents results from full scale farm testing of the enhanced CropEye Integration on the Agrointelli ROBOTTI combined with the patented route planning technology.
As Robotti traverses the fields, high-quality images are seamlessly captured. These images are automatically transmitted to the Agrointelli server, where they are analysis using the specialized crop models (Jørgensen, 2022; Jørgensen et al., 2024; Teimouri et al., 2022)).
The commercial cutting-edge crop models, trained on European crops and weeds, meticulously examine the images, providing detailed insights into the number and size of crops and weeds present in the field. This high-quality data forms the foundation for informed decision-making. The ROBOTTI Control Tower enables the farmer to create customized maps based on your preferences. These maps highlight areas requiring attention and become a visual blueprint for further optimize farming operations and practices already advanced by a robotic system itself (Vahdanjoo et al., 2023).
The generated maps seamlessly integrate with the ROBOTTI Control Tower. Using a patented methodology (Green & Edwards, 2021), a precise action plan is formulated. This ensures that ROBOTTI operates only where weeding is essential, maximizing efficiency and minimizing unnecessary soil disturbance. By focusing on targeted areas identified through the intelligent analysis, weeding operations become significantly more efficient. This results in resource optimization and reduces operational costs. With farm scale testing documenting +95% less area being treated as the robot only treats the areas in need.
With the ability to create tailored action maps, the risk of accidental crop damage is minimized. Precision application ensures that interventions are precise and only where needed. But the solution not only optimizes farming practices but also contributes to environmental sustainability. Minimizing soil movement and focusing on specific areas for intervention aligns with eco-conscious farming, with results of 41 % shorter driven distance in field, resulting in a significant increase in capacity for the robot from a farm perspective.
By leveraging ROBOTTI CropEye's capabilities, farmers can strategically allocate resources based on field variations. This targeted approach enhances operational efficiency and minimizes unnecessary resource use. Each operation is summarized in a clear and concise manner, providing essential information for the farmer, such as when the operation was completed, its duration and efficiency, and the covered area. This summary ensures that farmers have a quick and informative snapshot of their field activities.

OP26-2 | Development of autonomous robotic platform for pinpoint weed management using multi spectral imaging system

Asi Lazar[1,3], Ran Gorali[1], Liad Reshef[1], Lavi Rosenfeld[1], Ran Lati[2], Avital Bechar[1,3]
[1]Agricultural Research Organization, Institute of Agricultural Engineering, Rishon Lezion, Israel, [2]Agricultural Research Organization, Department of Plant Pathology and Weed Research, Ramat Yishay, Israel, [3]Ben-Gurion University of the Negev, Department of Industrial Engineering and Management, Beer Sheva, Israel

Weeding of crops such as watermelons is usually conducted manually due to the unstructured growth towards all direction and the limitation on herbicides that can be used. The automation of the weeding process will contribute to coping with the decline in the number of workers in agriculture and the high variability among working days due to weather, time of operation, crop growth status, and more. The weed detection process is a key aspect for the operation by a robotic agent. In the presented study, a real time weed management robotic agent was developed. The system was composed of a custom built autonomous robotic system equipped with a custom-built multispectral imaging system that uses four monochromatic cameras, each with a 10nm band pass filter. The centers of the filters are at 480, 550, 680 and 750 nm. Two experiments were conducted to test the robotic system. The first experiment was conducted in June 2022, with 20 crop plants of the cultivar 'Mallali' watermelon and 47 plants of different weed types, 20 Solanum nigrum, 20 Setaria and 7 Sinapis alba. The plants were captured in five different days and time during the days, to conclude different environmental conditions such as the light intensity, shades etc. A semi-automatic labelling process used NDVI filter to segment the vegetation from the background. The images with only watermelon plant were labelled as crop where the other images with single vegetation type were considered as weed. More than 11 million pixels were extracted from the images, 48% of the pixels labelled as crop. The labelled data was used to train an XGBoost classifier with an 80-20 train and test split. The data that was used is only the spectral reflection that was captured by each of the filtered cameras. The classifier showed 69% accuracy on the test data. To validate the classifier the images with the mixture of crop and weed plants were used. The classifier was able to classify in the mixed image the crop leaves with high accuracy. The second experiment was conducted in 2024, to check the accuracy of the system, 15 targets were placed on different heights boxes, that were positioned randomly several times, the robot was used to perform 10 repetitions of each setting to reach the targets. The experiment showed that the system was able to reach all the targets with less than 15 mm from the center of the target.

OP26-3 | Factors influencing the working time requirement and work rate of field robots when weeding organic sugar beet

Franz Handler[1], Michael Haider[1], Andreas Ettlinger[1]
[1]HBLFA Francisco Josephinum, Wieselburg, Austria

Introduction

In Austria, field robots have been used since 2021 to sow sugar beets and control weeds. Although the robots can sow and hoe autonomously, they require an operator to transport from field to field, teach in the field boundaries, adjust and monitor the quality of work and resolve faults. This paper analyses the factors influencing the work rate and annual utilization of the robots as well as the working time requirement of the operator.

Method

A three-row and a six-row robot with camera- and RTK-GNSS-controlled in-row weeding tools were available for the investigations.

Based on a process analysis, the work sub-processes of the operator and the robot to be recorded were determined. The time measurements were carried out as part of work observations during use in organic sugar beets. Irregularly occurring downtimes were recorded based on the error messages via the web portal of the robot and through recordings by the operator. Based on the working time requirements for the sub-processes determined through the statistical analysis of the collected data, simulations were carried out in order to systematically examine the effects of influencing factors.

Results

The work rate depends on field size, field shape, working width, working speed, time required per turn and frequency of robot malfunctions. For example, an increase in field size from one to ten hectares in rectangular fields for a robot with a working width of 2.70 m leads to an increase in work rate from 0.12 to 0.18 ha/h. The reason for this is the increase of the proportion of the execution time (weeding tools working) on the total time from 58 to 94%. This is because the relative importance of time required to transport the robot to the next field, teach in the field boundaries, and make turns is decreasing.

The operator has to transport the robot from field to field, teach in the field boundaries, adjust the tools, check the quality of work and correct malfunctions. For this, the operator needs 10 to 61% of the robot's working time. It depends on field size, field-yard distance and operating conditions.

The robots can work around the clock. However, an operator must therefore be on standby around the clock. If the operator is not available, the robot will have to wait in the event of malfunctions and after finishing the field. This leads to a decrease in the annual utilization of the robot.

OP26-4 | A hybrid design of a soft robotic finger for safe and versatile grasping

Laiquan Luo[1], Gert Kootstra[1], Eldert van Henten[1]
[1]Wageningen University and Research(WUR), Wageningen, Netherlands

To safely handle delicate fruits and vegetables, robots should be equipped with a soft touch. For a safe yet firm grasp, it is necessary to increase the contact surface area to reduce the pressure on the product during gripping, meanwhile having a firm grasp during object manipulation. Soft robotic grippers are intrinsically adaptable and deformable due to their architecture compliance and material softness, which allows them to deal with variations in shapes and sizes. However, many soft grippers suffer failures during the object manipulation due to a lack of stiffness. This work aims to develop a versatile soft gripper with adaptable stiffness.

Different mechanisms are used to develop soft robotic grippers, which can be categorized into three technologies: grasping by actuation, grasping by controlled stiffness, and grasping by controlled adhesion. We propose a novel hybrid gripper finger design combining two mechanisms that were selected from grasping by actuation and grasping by stiffness respectively: a multi-segment, granular jamming bionic finger. The sequentially tendon-driven control of the multi-segment finger offers global adaptability by approaching and forming a grasping posture around objects, while the soft pads with grains offer local adaptability by providing adaptive deformation and the granular jamming offers adaptive stiffness by adjusting the vacuum pressure. Such hierarchical design allows the finger to adapt to the shape of a product both on the larger scale and in the fine details as well as firmly manipulation.

To design and evaluate the proposed finger, global and local adaptability experiments were conducted. The global adaptability experiments measured the contact area between the object and the finger with varying segment numbers (2, 3, 4, 5). The results indicated an increase in contact area with segment number, plateauing after four segments, thus determining four segments as the optimal number. Local adaptability experiments tested different types of grains and membranes, which identified coffee powder and a latex membrane as the most suitable for this application. Additionally, local adaptability experiments measured the contact surface area between grain pads and objects, demonstrating a significant increase in contact surface area compared to the use of soft sponge pads. Adaptive stiffness experiments are ongoing to determine the appropriate vacuum pressure for jamming to securely hold objects of varying weights. Overall, our proposed gripper finger promises enhanced performance in adaptive grasping and robust holding for agri-food items with vast variability.

OP26-5 | Design and implementation of a robotic gripper for secure, precise handling and manipulation of stem plants

Konstantinos Kalovrektis, Apostolos Xenakis
[1]Department of Digital Systems, University Of Thessaly, Volos, Greece

Robots have been designed to simulate human workers in greenhouse settings, where many tasks involve handling plant stems. These tasks demand specialized skills, particularly in delicately managing the narrow diameter of the stem. For instance, an average carnation stem typically ranges from 1 to 3 millimeters in diameter. This paper introduces the design of an open hardware device—a gripper for a robotic arm—specifically engineered to handle carnations during production without causing damage.

The gripper incorporates specially designed force sensors integrated into a soft material that mimics the fingers of the gripper. The sensor was a High Precise Resistance Thin Film Pressure /Force Sensor (RP-S5-ST). The soft material consists of a ball membrane filled with a thickening liquid that acts as a shock absorber. The gripper's control software is developed using LabVIEW, ensuring the application of minimal grasping force, enabling it to handle unknown or delicate objects with precision and care. Upon securely holding an object, the system identifies the required grasping force based on the specific model.

The experiments is conducted at NG-DSALab, at Digital Systems and and comprised two phases. Three single stem carnation plants in pots, filled with peat of different diameters (plant A: 1mm, plant B: 1.8mm, and plant C: 2.3mm), were used for the experiments. Phase A involves testing the developed gripper using Glycerin (viscosity 1.5 Pa*s) inside the ball membrane. Phase B involves testing the gripper using Motor oil SAE 30 (approximate viscosity 0.5 Pa*s) inside the ball membrane. During the experiment, the gripper periodically grasped and released the stem 50 times (time period of open/close operation: 10sec). The speed closing of finger was 0.2s/degree. On each grasp, the robot gripper moves the stem in a slope of ±10 degree one time. A data acquisition system using an Arduino Mega platform (10bit ADC) is used to measure the force applied by the gripper's fingers. A typical Resistance-Voltage Conversion (FSR402) was used as module of signal condition to amplify the signal from sensor force.

The measurements were stabilized within a 10-15% tolerance (Vforce = 1.5mV) for plants A, B, and C using Glycerin and within a 15-30% tolerance for the same plants using Motor oil SAE 30-40%. The results indicated that the developed robotic gripper could handle stems typically ranging from 1 to 3 millimeters in diameter. The viscosity of the liquid used as the soft material in constructing the gripper's fingers affected the measurement tolerance.

OP26-6 | Potential of exploitation and use of robots in viticulture: Results from the BACCHUS projects

Remigio Berruto[1], Patrizia Busato[2], Zoe Dulgeri[3]
[1]University Of Turin, Torino, Italy, [2]Polytechnic of Turin, Torino, Italy, [3]ARISTOTELIO PANEPISTIMIO THESSALONIKIS, THESSALONIKI, GREECE

The BACCHUS project, as part of the Horizon 2020 initiative, has several key objectives aimed at revolutionizing agricultural practices. It seeks to integrate advanced robotics into agriculture, focusing on enhancing productivity, sustainability, and the quality of crop cultivation. It aims to blend advanced robotic technology with traditional farming practices, particularly in vineyards, to improve efficiency and sustainability. The project also studies the impacts of robotic integration on labor dynamics, social acceptance, and overall agricultural practices. Contributing to the growth and advancement of robotic technologies in agriculture, the BACCHUS project aims to set new standards for productivity and sustainability in the sector. The solution proposed by the project focuses on developing a dual-arm robot with human-like capabilities for tasks such as inspection, data collection, and precise harvesting. It incorporates innovative features like bi-manual operations, a modular design, and advanced decision-making abilities.

A primary focus of the trials was the comprehensive evaluation and comparison of the performance of the BACCHUS robotic system against human labor in agricultural settings, with a special emphasis on vineyards. This includes assessing the system's efficiency and effectiveness in natural agricultural settings and its capabilities in precision agriculture tasks such as inspection and harvesting.

The project demonstrated that while robotic systems in vineyard operations achieved high precision and selectivity, they took more time per bunch than human labor. For instance, the time to harvest grapes was 40 seconds per cluster for robots, compared to 8 seconds per cluster manually.

The robotic system achieved a 92% accuracy rate in yield prediction, surpassing traditional manual methods that are around 70-80% accuracy rate. The robots were also proficient in identifying and managing specific bunches such as small grapes and those infected, although they were slower than human counterparts.

The BACCHUS system demonstrated its ability to provide selective harvest (e.g. selective harvest based on sugar content) without any training, a task human labor cannot accomplish. It opens up possibilities for using robots not just as replacements for people but also for enhancing the quality and quantity of vineyard production.

Accounting on energy impact of robotic operations compared to mechanical operations is also presented in the work. Although in its initial development, the project lays a foundation for transformative changes in agricultural practices through robotics.

OP27-1 | Vertical greenhouse production of baby leaf vegetables and rainbow trout in a high-tech aquaponic system

Ioanna Chatzigeorgiou[1], Maria Ravani[1], Georgios Liantas[1], Aphrodite Tsaballa[1], Georgios Ntinas[1]
[1]Hellenic Agricultural Organisation-Dimitra, Thermi, Greece

Aquaponics, as an integrated food production system linking recirculating aquaculture with hydroponics, can alleviate the significant detrimental effects caused on the environment by both intensive crop farming and aquaculture. The fish wastewater from the Recirculating Aquaculture System (RAS), which is rich in nitrates and needs to be replenished, serves as a nutrient solution for hydroponic cultivation. That leads to freshwater and synthetic nutrients savings. Various types of aquaponic systems have been developed. The purpose of the current work was to evaluate a vertical decoupled aquaponic system, where lettuce plants were grown in a Deep-Water Culture in a greenhouse, and rainbow trout was reared in a RAS in the underground space. The greenhouse was covered with polycarbonate sheets both sideways and on the roof, having roof openings for natural ventilation and a pad and fan cooling system for climate control. Gutters set around the greenhouse collected rainwater, stored in a tank outside the greenhouse, filtered, and transferred in a rainwater tank in the fish rearing system space, available for use in the RAS when needed. RAS consisted of two fish tanks, a mechanical filter to remove solids like fish feed or feces, a biological filter where the nitrification process took place, and two Sump-tanks, serving as storage tanks. Fish water was constantly recirculating in the rearing system, through pipes and pumps. The greenhouse with the RAS were connected likewise, transferring fish water depending on the cultivation needs. Lettuce was cultivated in six treatments; having three different nutrient solutions of various concentrations, and two different substrates. More specifically fish wastewater was used either plain (Fish treatment) or enriched with regular fertilizers (Mix treatment) until reaching Hoagland’s nutrient solution concentration, which served as control (Hoagland treatment). Lettuce plants were sown both in peat and perlite, to test plants’ growth and yield in organic and inert substrate. Yield was the main criterion upon which treatments were evaluated, while water, land and energy use efficiency were also calculated. Mix-Peat treatment resulted in higher yield, with no statistically significant differences from both Hoagland treatments, and Mix-Perlite, while utilizing approximately 10% less fertilizers. Furthermore, reusing the Fish water led to a higher water use efficiency in Mix-Peat treatment, being the best also in land use efficiency, yet significantly lower than the Hoagland treatments in energy use efficiency.

Keywords: Hydroponics, Recirculating Aquaculture System, Resources Use Efficiency, Greenhouse

OP27-2 | Closing the loop for sustainable agriculture: The impact of partial or full substitution of chemical fertilizers with digestate on soil health and maize yield

Charitini Nikolaidou[1,2], Magkdi Mola[1,2], Vassilis Aschonitis[1], Ioannis Milonas[3], Nikolaos Monokrousos[2], Panagiotis Kougias[1]
[1]Soil and Water Resources Institute, Hellenic Agricultural Organization-Dimitra, Thermi, Thessaloniki, Greece, [2]University Center of International Programmes of Studies, International Hellenic University, Thermi, Thessaloniki, Greece, [3]Institute of Plant Breeding and Genetic Resources, Hellenic Agricultural Organization Dimitra, Thermi, Thessaloniki, Greece

The use of anaerobic digestate as a soil fertilizer has gained attention in the agricultural sector, especially due to its role in the circular economy by closing nutrient loops. The potential benefits of digestate in enhancing plant growth and soil microbial biomass have been stated before. However, there is a lack of knowledge regarding digestate effects on specific soil microbial groups and higher trophic levels, such as nematodes. Moreover, field studies reflecting the real agro-pedo-climatic conditions, are not adequately represented. This study aims to assess the effects of digestate, chemical fertilizer, and their joint application on the microbial and nematode communities, as well as plant yield on fodder maize crops.
Pilot maize crop plots, each covering 9 m² with 3 replicates, were established in a randomized design on a previously cultivated field at ELGO-Dimitra’s campus in Thermi, Thessaloniki. In total, 4 fertilization treatments were examined: a) mineral NPK, b) anaerobic digestate, c) joint application, d) no fertilization. A systematic monitoring of plant growth was carried out including plant height and weight measurements and nutrient uptake at various growth stages. The soil’s microbial profile was mapped using the Illumina MiSeq platform. Finally, nematodes were extracted from the soil following a sieving method and identified through microscopy.
Results indicated significantly higher plant weight and height at the early growth stage after digestate treatment, while during later stages of plant development, all fertilization treatments resulted in similar weight and height levels. Maize seeds after digestate and mixed treatment presented similar protein and oil concentration values compared to those after conventional fertilizer. Profiling of the soil’s microbial community revealed that digestate fertilization induced higher biodiversity, based on the Shannon index, suggesting a more balanced community in terms of species prevalence. Nematode abundance was higher in the control and after digestate application, compared to soils treated with chemical fertilizer, indicating that organic amendment induced the least disturbance to the soil ecosystem. Finally, the dynamics of the microbial-nematode community will be examined through network analysis to identify the most resilient community structure.
In conclusion, the present study highlights the potential utilization of digestate as an efficient and cost-effective alternative practice in agriculture, that will contribute to the reduction of chemical fertilizer use. Based on the results, digestate is beneficial both for crop yield and seed quality, while maintaining the soil's biological health in the long term.

OP27-3 | Oenotrace – A data-driven approach to trace sustainable practices in wine-growing

Marco Bignardi[1], Andreas Heiß[1], Nikos Tsoulias[1], Dimitrios Argyropoulos[2], Dimitrios Davarakis T[2], Marco Moriondo[3], Davide Cammarano[4], Cristina Dobre M[5], George Suciu[5], Dimitrios Paraforos S[1]
[1]Hochschule Geisenheim University, Geisenheim, Germany, [2]University College Dublin, Dublin, Ireland, [3]National Research Council - CNR-IBE, Florence, Italy, [4]Aarhus University, Tjele, Denmark, [5]Beia Consult International, Bucharest, Romania

The wine-making industry plays a significant role in the agri-food sector and there has been an increasing emphasis on assessing its environmental impact. Numerous studies based on life cycle assessments (LCAs) have demonstrated the substantial environmental impact of cultivation operations. However, the estimation of emissions from field operations can be intricate and it may lead to inaccurate analysis due to the lack of site-specific data. It is essential to examine the factors contributing to the environmental impact of grapevine cultivation, particularly as it is vulnerable to the effects of climate change while holding significant potential to mitigate it by acting as a C sink. Oenotrace is a European project that aims to establish a data-based infrastructure for tracing sustainable practices in grapevine growing. A major challenge within the project is to quantify the environmental impact of grapevine cultivation comprehensively. The project aims to provide sustainability metrics that can be used by various stakeholders within the wine-making sector and communicated to customers.
In the initial phase of the project, the prevailing aspects that contribute to the environmental impact have been identified in two different territories, Italy and Germany. To estimate the balance in the CO_2 fluxes from anthropogenic and natural origins observable during the growing season, an experimental sensor-based data acquisition architecture has been designed. A carbon balance model accounting for biomass growth of vines and weeds will estimate the net CO_2 emission of the agroecosystem, leveraging weather, soil and optical sensors. A machine telemetry module will allow for monitoring the machine-related emissions during field operations. A further IoT-architecture was designed to transfer this monitoring approach to a use case on a commercial winery in Germany. This architecture encompasses the entire value chain up to the distribution of the wine to transfer the vineyard-related sustainability metrics to the customers. A thorough mapping of the actual state at the use case winery highlighted significant technical challenges, such as the considerable diversity in farming practices and organizational structures that can affect the impact factors or the absence of compatibility among the existing production management software. These will be overcome by means of IoT technology and a data platform, which will serve as a pivotal point for automated data aggregation and management, as well as the involvement of stakeholders. These first results propose a starting point for developing precise data-driven environmental impact analysis approaches for future viticulture.

Keywords: Sustainability assessment; Agro-environmental modeling; IoT system

OP27-4 | Investigation of production of grapevine seedlings inoculated with AMF and grown using organic compost with wine lees under water stress conditions

Pinelopi Baltzoi[1], Ioannis Tsirogiannis[1], George Patakioutas[1], Olga Kostoula[1], Vasileios Papantzikos[1], Eleni Lampraki[1]
[1]University Of Ioannina, Department of Agriculture, Arta, Greece

The production of grapevine seedlings is a dynamic agricultural sector. The need for drought tolerant and well adapted to environmental stresses grapevine seedlings is essential for a successful establishment in the vineyard. Nursery plants hardening against environmental stresses can be enhanced by arbuscular mycorrhizal fungi (AMF) symbiosis. In the framework of sustainable agriculture management, the production and use of organic compost is encouraged. Also, the re-use of winery residues can enrich the organic substrates and benefit the environment.
The scope of the experiment was to evaluate an organic compost with untreated wine lees used to grow grapevine nursery plants of "Debina" wine variety and to test the production of AMF-inoculated grapevine plants under water limited conditions aiming to produce robust grapevine seedlings. The wine lees was used without any processing for removing phenolic compounds.
The experimental treatments included two deficit irrigation treatments (IRR1 and IRR2) for inoculated plants with two types of mycorrhizal inoculums (AMF1 and AMF2) and for no-inoculated plants. The applied irrigation water amount was set at 90% of ETc (moderate water stress, IRR1) and at 75% of ETc (substantial water stress, IRR2).
Plant growth parameters were measured and the relative growth rate (RGR) was computed. The mycorrhizal colonization in plants was detected by histological examination. The leaves total chlorophyll content, total phenolics and proline content were measured as stress indicators. Regarding water management, the water use efficiency (WUE) and the water footprint (WF) at whole plant level were computed.
The usage of organic compost with untreated wine lees as substrate, did not inhibit plant growth. Mychorrhiza colonization was not affected by the organic compost with untreated wine lees and by the applied deficit irrigation practices. Inoculated plants irrigated at 90% ETc, showed higher shoot, leaves and roots dry weight, total biomass and RGR% compared to no-inoculated plants. Plants inoculated with the single fungus inoculum AMF1 under both water stress levels, showed higher phenolic content in comparison to no-inoculated plants. Deficit irrigation did not affect the chlorophyl content of leaves neither the proline content. Regarding the water management, inoculated plants performed higher WUE from no inoculated plants while plants irrigated at 75% ETc had lower WF. The practical value of the research is the evaluation of usage of wine lees in composting and the successful production of grapevine saplings with high potential to thrive under water stress conditions.
Keywords: Debina; Arbuscular mycorrhizal fungi; grapevine; water stress; water footprint

OP27-5 | Environmental assessment of green walls' design choices using life cycle assessment

Enrica Santolini[1], Milad Reyhani, Alberto Barbaresi, Marco Bovo, Patrizia Tassinari, Daniele Torreggiani

[1]University Of Bologna, bologna, Italy
Considering the remarkable growth of cities and the increase of built-up areas, mitigation of urban heat island effects has become one of the crucial challenges in urban sustainability, due also to its significant impacts on public health. An influential factor in climate change is the environmental impact of the building's life cycle, However, innovative solutions can lead to reductions of buildings' energy consumption and consequently to mitigation of the effects of structures at the urban scale. In particular, nature-based solutions are used as a sustainable way to face urban problems and expand green space. The use of urban green infrastructure (UGI) can help to reduce these concerns and make the urban environment greener and a more desirable living place. Then, new technologies and materials for green walls and roofs have become available, allowing to improve the design and to further develop these systems. The purpose of this study is to emphasize the components and materials used in the green walls system. By determining the environmental impact of each element, it can be replaced with another component with the same function. This approach ultimately leads to the sustainable design of systems. In fact, two green wall systems were chosen for the environmental assessment using the life cycle assessment method (LCA). Data related to all processes and components involved in each system are reviewed for a 10-year lifespan. Several scenarios (16) of green walls set ups have been performed to evaluate the impact of the life cycle of 1 square meter (functional unit). The analyses have been carried out by impact assessment method ILCD, in OpenLCA software, using Ecoinvent® v3.7 database. The results clearly underline that the components and materials used for production and construction of the green wall system have a very high impact on the environmental performance of these systems. In particular, the material adopted for the plant pots, the fertilization mix and the adopted plants, in terms of water consumption, can play a key role on the system impact. A better design can be achieved by doing an environmental assessment, identifying the undesirable components in the system, and replacing them.

OP27-6 | Fostering pyrolysis products application to decrease the carbon footprint of European agriculture and forestry: The PYRAGRAF concept

Dobrochna Augustyniak-Wysocka[1], Catarina Nobre[2], Paulo Brito[2], Duygu Celik[3], Olgu Birgi[3], Muhittin Onur Akça[4], Oğuz Can Turgay[4]
[1]Łukasiewicz Research Network — Poznan Institute of Technology, Center of Sustainable Economy, Poznan, Poland, [2]2VALORIZA – Research Center for Endogenous Resource Valorization, Portalegre Polytechnic University, Campus Politécnico, Portalegre, Portugal, [3]WIP – Renewable Energies, München, Germany, [4]4AU-Ankara University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Dışkapı, Ankara, Turkey

Reducing carbon footprint and fostering the implementation of a circular economy are among the highest priorities in the European Union Agenda. These goals have become even more urgent considering the recent climatic and energetic crises. Agriculture and forestry can play a key role for achieving the target goals but to do this a large-scale collaboration among farmers, foresters, policy makers, technicians and researchers is essential. Pyrolysis is considered as one of the most promising processes to develop products and by-products which can help agriculture and forestry sectors to decrease their carbon footprint, by implementing a circular economy approach. The main product of pyrolysis is biochar. However, the pyrolytic process also generates liquid and gaseous products, with potential applications in both agriculture and energy sectors. Despite their potential pyrolysis and its products are still not widely present at the European market. Two main reasons can be identified: difficulties in the logistic chain and limited knowledge of these products by the end consumers and stakeholders. The PYRAGRAF project, funded by Horizon Europe Programme under the call HORIZON-CL5-2022-D3-02 properly aims at fulfilling these gaps by developing efficient supply chains for the four products of the pyrolysis process. The project will focus on biochar and wood vinegar for application in agriculture as ecosystem services and on pyrogas and bio-oil for stationary bioenergy applications. PYRAGRAF will develop an innovative solar-assisted mobile pyrolytic unit, able to carry out the pyrolytic process directly at the field headlands or at the landing sites in forests. In this presentation we are going to show the main outlines of the project, with particular reference on the participatory approach with the stakeholders and on the potential social aspects of the PYRAGRAF concept.

OP28-1 | Efficiency comparison of mechanical and electrically driven implements

Emilio Dicembrini[1], Alessandro Biglia[1], Lorenzo Comba[1], Cristina Tortia[1], Paolo Gay[1], Davide Ricauda Aimonino[1]
[1]Università Di Torino, Grugliasco, Italy

The reduction of the environmental impact of the agricultural operations is a critical challenge. This involves addressing various aspects of agricultural process, such as the reduction of greenhouse gases emission and minimizing the use of chemicals for crop protection and fertilization. As a consequence, in the last two decades, many manufacturers have focused their research efforts on the electrification of tractors and agricultural machinery. The replacement of mechanical and hydraulic components with electric actuators can lead to many benefits in terms of performances, energy saving, as well as enhanced safety and comfort in implement connection thanks to the elimination of the cardan shaft in Power Take Off (PTO) driven machines. Additionally, the advanced control capabilities of electric actuators enable to the development of new functionalities for implements.
Despite the number of prototypes of electric agricultural machines that have been developed, only a few of them are available on the market. The main obstacle to the diffusion of electrification in agriculture is the need for high-power electric energy to supply implements that conventional tractors cannot provide. External PTO-driven electric generators connected to a tractor, or installed on implements, represent a viable solution waiting for electrified tractors to become available on the market.
This work is focused on the energy performance evaluation of four full electric implements (ditcher, leveller, four-rotor tedder and a vine leaf stripper), developed within the “Macchine Agricole Elettriche (MArcEL)” research project. The full electric implements were tested and compared to their conventional counterparts in the same operating conditions. The implements were supplied by external PTO-driven generators hooked to a tractor. Specifically, the ditcher and tedder were connected to a 700 V generator (50 kW), while a 48 V generator (10 kW) was adopted for the leveller and the leaf stripper.
In all cases, the full electric implements have shown a reduction in the electrical power absorption respect to the mechanical power in the conventional ones. The percentage of energy saving in hydraulically driven implements was significantly greater than in PTO-driven ones, owing to the less energy efficiency of hydraulic systems. However, this study highlights the efficiency of electric power generation as the critical component of the electrified system for reducing PTO power consumption. Despite the higher efficiency of single electrical actuators, the overall efficiency of the electrified implements depends on the concatenation of the electrical elements.
Keywords: Precision Agriculture, Electrification, Electric Implements.

OP28-2 | Terrain aware monoplotting for ortho UAV images

Ufuk Can Bicici[1], Peter Riegler-Nurscher[1]
[1]Josephinum Research, Wieselburg, Österreich

Aerial photography of agricultural fields, facilitated by affordable and reliable UAVs, has become an invaluable tool. This data offers insights into crop growth, soil changes, pest invasion, and plant diseases. Typically, these images undergo Photogrammetry algorithms, including rectification, matching identical points, solving camera equations, and bundle adjustment, before further processing.

In practical UAV photography, obtaining overlapping images, crucial for structure-from-motion algorithms, may not always be feasible due to time or cost limitations. In such cases, the Monoplotting technique can be used for georeferencing, typically involving Ground Control Points (GCP) and a Digital Elevation Map. In the absence of GCPs, alternatively, readings from UAV sensors, such as GPS coordinates, barometer altitude, and camera metadata, can also facilitate Monoplotting, a scenario considered in this work.

Our work introduces a Terrain Aware Monoplotting framework for generating georeferenced 2D images compatible with GIS tools like QGIS. Unlike a straightforward method relying only on UAV sensor readings for georeferencing, our approach leverages terrain properties. Our first algorithm employs efficient ray tracing to calculate terrain intersection points of rays from the camera going through image pixels. Using a least-squares approach, a plane parallel to the xz-plane is fitted to minimize the geometric error between the plane and terrain intersection points, providing a horizontal mathematical approximation of the terrain surface. This allows a direct affine transformation from image coordinates to geographical ones.

Our second algorithm generates a warped image in the image space, adhering to perspective constraints such as foreshortening caused by terrain altitude differences. Once again utilizing ray tracing, it identifies camera ray and terrain intersection points and fits a minimum rotated rectangle to their 2D geographic coordinates. Treating this rectangle as the image canvas, real-world terrain coordinates for each pixel are calculated, and rays are shot from these coordinates toward the camera center. Intersecting with the sensor plane, these rays indicate sampling locations in the original image. Bilinear interpolation calculates color values, filling the canvas with a perspectively correct projection of the mapped area. The resulting projected image can still be georeferenced with a basic affine transformation. This second algorithm generates a more refined result, however it is computationally heavier than the first one.

Visual and measurement results of our algorithms are provided; highlighting the perspective transformation effect of our methods and the measured deviation from the actual marker locations.

OP28-3 | Hitched two sides windrowing and chipping prototype development for olive pruning management in an only tractor wipe

Sergio Peña-Valero[2], Francisco J. Castillo-ruiz[1], Francisco J. Soto-Torres[1], Gregorio L. Blanco-Roldán[1]
[1]University Of Córdoba, Córdoba, Spain, [2]Trituradoras Serrat, Construcciones Mecánicas Alcay SL, Castejón del Puente, Huesca, Spain

Pruning is essential to keep olive (Olea europaea L.) in adequate conditions for both keep high olive production capacity, and adapt canopy volume, and shape to different harvesting systems. On this matter, there are different olive categories which could be simplified to three: Traditional olive orchards; high density olive orchards adapted to trunk shaker harvesting; and hedgerow orchards adapted to straddle canopy shakers. All of these olive orchards require pruning, windrowing, and chipping or shredding operations to keep olive orchards in adequate condition. Currently, the most common practices were pruning using hand held chainsaws, windrowing manually or using tractor hitched rotary vertical shaft windrowers, and tractor hitched auto feed shredders. All these operations were performed in different wipes which makes the orchard not available for other operations between pruning and chipping. The objective of this research was to develop a tractor hitched windrowing and chipping prototype for olive pruning management in an only tractor wipe to improve orchard availability and attempt to reduce pruning management costs. The prototype was developed, tested and redesigned to achieve an adequate windrowing efficiency. The prototype consisted on two side windrowers, vertical and horizontal auto feed system and disk blade mounted chipper. The first approach used endless screw feeders as windrowers, but provoked branch blocks and low windrowing efficiency. To improve these problems, windrowers were substituted by rotary horizontal shaft windrowers which provided much better results. The auto feed system included a controlled rotary speed which made possible to adapt the fed amount of pruning to chip according to machine load. This feature made possible to avoid chipper block or tractor overload when idle time was reduced as much as possible depending on available pruning amount. The prototype was designed to be adapted to all olive orchard categories except those which rows spacing were under 5 m. Furthermore, once the pruning residues were chipped, it is possible to lend them to cover soil or harvest them through a vacuum system to use as biomass. Final prototype theoretical weight and dimensions were 4,500 kg and 4.9 x 2.2 x 3.32 m (width, height and length). These features made the prototype heavier and wider than conventional shredders which varied from 1000 to 2500 kg, and 1,5 to 2,4 m. These features reduced labor required to windrow olive pruning for the prototype, but made necessary to use tractors with high three-point hitch lifting capacity.

OP28-4 | Development of a numerical rating system for the selection of agricultural and fisheries machinery in the Philippines

Rossana Marie Amongo[1], Ralph Kristoffer Gallegos[1], Adrian Borja[1], Arthur Fajardo[1], Arsenio Resurreccion[1], Adrian Daniel Pantano[1], Julius John Paul Cunan[1]
[1]UNIVERSITY OF THE PHILIPPINES, Los Banos, Philippines, [2]UNIVERSITY OF THE PHILIPPINES, Los Banos, Philippines, [3]UNIVERSITY OF THE PHILIPPINES, Los Banos, Philippines, [4]UNIVERSITY OF THE PHILIPPINES, Los Banos, Philippines, [5]UNIVERSITY OF THE PHILIPPINES, Los Banos, Philippines, [6]UNIVERSITY OF THE PHILIPPINES, Los Banos, Philippines, [7]UNIVERSITY OF THE PHILIPPINES, Los Banos, Philippines

The purposive acquisition and distribution of Agricultural and Fisheries Machinery (AFM) by the Philippine government has improved the level of agricultural mechanization in the country over the years. However, the lack of unified protocols and limited considerations in selecting the best machine has resulted in machinery mismatches, leading to over-utilized, under-utilized, or not-utilized AFM in agricultural production and postproduction systems. This study addresses the knowledge gaps by developing a decision tool for the selection of AFM using a numerical system that presents the overall machine rating. The Multiple Criteria Decision Making (MCDA) approach was used to establish the numerical rating system. Three major factors, namely performance-based, manufacturer-based, and end-user-based factors were considered. Specific criteria for each factor were identified. Analytical Hierarchy Process (AHP) and Rank Sum (RS) method were used to determine the weights of the factors and their respective criteria. Six target machines were considered in this study, namely, 2-wheel tractors, 4-wheel tractors, small engines, threshers, combine harvesters, and pump sets. The rating scales were established using 20-year test data from the Agricultural Machinery Testing and Evaluation Center (AMTEC) for the performance-based criteria, while results of the field surveys conducted were used to identify the manufacturer and end-user-based criteria. Data analyses and consultations reveal that the three identified major factors influenced the holistic performance of the machine/technology which should be considered in the machinery distribution program of the government. The results of this study can aid in the planning and formulation of policies by the government for the selection of the best machine for specific end-users' needs. This will also aid in the efficient use of resources that would help uplift the lives of Filipino farmers.

Keywords: Agricultural and Fisheries Machinery, Numerical Rating Scale, Multiple Criteria Decision Making, Analytical Hierarchy Process, Rank Sum Method.

OP28-5 | Enhancing aquaculture sustainability: Application of photo-electrocatalysis in recirculating aquaculture systems

Eleonora Buoio[1], Gian Luca Chiarello[2], Simone Livolsi[2], Luca Maistrello[2], Alessia Di Giancamillo[3], Lucia Aidos[1], Giorgio Mirra[1], Chiara Bazzocchi[1], Chiara Cialini[1], Raffaella Rossi[1], Edda Mainardi[1], Daniela Bertotto[4], Giuseppe Radaelli[4], Martina Bortoletti[4], Nadia Cherif[5], Tarek Temraz[6], Katia Parati[7], Annamaria Costa[1]
[1]Department of Veterinary Medicine and Animal Science, University Of Milan, Lodi, Via dell'Università 6, 26900, Italy, [2]Department of Chemistry, University of Milan, Milano, via Golgi 19, 20133, Italy, [3]Department of Biomedical Sciences for Health, University of Milan, Milano, Via Mangiagalli 31, 20133, Italy, [4]Department of Comparative Biomedicine and Food Science, University of Padua, Legnaro, Viale dell'Università 16, 35020 , Italy, [5]Aquaculture Laboratory, National Institute of Sea Sciences and Technologies, Salamboo, 28 Rue de 2 Mars 1934, 2025, Tunisia, [6]Department of Marine Sciences, Faculty of Science, Suez Canal University, Ismailia, Egypt, [7]Istituto Sperimentale Italiano Lazzaro Spallanzani, Rivolta d'Adda, Loc. La Quercia, 26027, Italy

In recent years, aquaculture has experienced rapid growth, raising concerns about environmental pollution and depletion of natural resources. To address these challenges, farms need cutting-edge technologies to minimise water pollution and preserve biodiversity and human health.
To mitigate pollution, advanced techniques such as photocatalysis (PC) and photo-electrocatalysis (PEC) have emerged as promising low-cost and effective methods. Particularly, PEC can boost ammonia oxidation, avoiding its accumulation in water, by converting it into harmless molecular nitrogen.
The Fish-PhotoCAT project (founded by PRIMA) focuses on evaluating the efficiency of PEC on recirculating aquaculture systems (RAS), introducing a simple improvement to the usual technology used in RAS, i.e. biofiltration and UV-sterilization technology.
This study reports the first trial of the project, in which three 500 L tanks, equipped with the standard water filtration system (mechanical and biofiltration + UV-lamp), were compared to three tanks equipped with the same setup in terms of mechanical-biofiltration, with a photo-electrocatalytic reactor instead of the classic UV-lamp. The two systems were tested in a RAS lodging adult rainbow trout (90 g) reared for one month at a density of 15 kg/m³.
To achieve our purpose, water quality parameters were monitored, including nitrogen compounds (NH_3, NO_2^-, NO_3^-), biological oxygen demand (BOD), chemical oxygen demand (COD), and physical parameters, i.e. temperature, pH, dissolved oxygen and water saturation. To ensure animals' welfare also stress gene expressions and health performance have been analysed (still under evaluation).
No significant difference was found in NH_3 mean concentrations between the control and treatment tanks (0.15 mg/L vs. 0.16 mg/L); the mean concentration of nitrites was higher in the control tanks than in the PEC tanks (1.210 mg/L vs. 0.740 mg/L; with a significance tendency $p < 0.08$), an encouraging result considering its higher toxicity for fish. Finally, the mean concentration of nitrates demonstrated a statistically significant difference between the control and treatment tanks (122.211 mg/L vs. 108.510 mg/L; $p < 0.001$), likely due to the parallel ammonia oxidation to molecular nitrogen. To enhance system efficiency, NaCl will be added in the next trials since chlorine radicals can undergo several reactions in the aqueous phase, that can further react with ammonia.
In conclusion, the research findings could allow the development of eco-friendly aquaculture systems that can reduce negative impacts on water quality and promote the well-being of aquatic organisms, contributing to the sustainable advancement of aquaculture practices.

Keywords: Sustainable aquaculture, Photo-electrocatalysis, Water quality, Nitrogen compounds

OP28-6 | Plant factory technology as a powerful tool for improving vegetable quality: Lettuce as an application example

Li Zhang[1], Tao Huang[1], Bo Song[1], Jie Peng[1], Yuejian Li[1], Qichang Yang[1], Li Zhang[1]
[1]Institute Of Urban Agriculture, Chinese Academy Of Agricultural Sciences (IUA-CAAS), Chengdu National Agricultural Science and Technology Center , Chengdu, China

Consumer demand for higher quality and nutrient-dense fresh vegetables is increasing. In this regard, greater effort is needed to improve the appearance, taste, aroma, texture, and nutritional value of vegetable products. Plant factory technology (PFT) offers an advanced agricultural system in which environmental factors may be precisely controlled, yet is remains necessary to study and predict the influence of PFT on vegetable quality due to the long breeding processes required in dynamic artificial environments. To achieve stable vegetable quality, a powerful strategy of breeding and cultivation practices using PFT was developed in this study. PBT contributes to vegetable breeding by facilitating breeding and selection as a speed-breeding facility to shorten the life cycle and induce early flowering and maturity by manipulating the optimal environmental conditions. The parallel integration of PF-based vegetable speed-breeding facilities with other technologies, such as crossbreeding, mutagenesis, transgenic breeding, genome editing, and genomic selection, can greatly accelerate vegetable improvement. Also, high-quality vegetables were produced using PFT by precisely controlling environmental factors, such as light recipes, temperature ranges, CO2 levels, and nutrients, which resulted in a higher nutritional content over a much shorter period of time than would occur under open field cultivation. Consequently, PFT shows great potential in facilitating breeding and cultivation practices and achieving stable vegetable quality among harvests.

OP29-1 | The effect of the wind direction on sampling strategies for measuring ventilation rate in a naturally ventilated pig barn with an outdoor exercise yard

Xuefei Wu[1], David Janke[1], Sabrina Hempel[1], Thomas Amon[1,2], Eberhard Hartung[3], Qianying Yi[1]
[1]Atb, Potsdam, Germany, [2]Department of Veterinary Medicine, Free University Berlin, Robert-von-Ostertag-Str. 7-13, 14163 Berlin, Germany, [3]Institute of Agricultural Process Engineering, Christian-Albrechts-University of Kiel (CAU), Max-Eyth-Straße 6, 24118 Kiel, Germany

The accurate quantification of the ventilation rate is the basis of environmental management. The constant fluctuation of outdoor wind directions enhances the difficulties in the determination of the ventilation rate for naturally ventilated animal buildings. This study aimed to evaluate the impacts of the wind direction on the estimation of ventilation rate based on an atmospheric boundary layer wind tunnel study. A 1:50 scaled model of a pig barn with an outdoor exercise yard was built. High-resolution measurements at the openings of the scaled model were carried out in the cases of wind directions 0°, 60°, 120°, and 180°. Additionally, high-resolution measurements were conducted along the vertical and horizontal directions of the openings. Those measurements were analysed based on four levels of subsets with different numbers and positions of the measuring points to find suitable measuring strategies under different wind directions. This dataset was used as a reference to assess the accuracy while systematically reducing the number of sensors and varying their positions under different wind directions. The results showed that when the wind was vertical to the opening façade (cases of 0° and 180°), more sensors were required in the vertical direction rather than the horizontal direction. When the wind was inclined (cases of 60° and 120°), more sensors should be arranged in the horizontal direction instead of the vertical one.

OP29-2 | Optimization of poultry house ventilation system using computational fluid dynamics

Timothy Akpenpuun[1], Sunday Oluwaseun[1], Oyindamola Toye[1]
[1]University of Ilorin, Ilorin, Nigeria

Effective ventilation is crucial for the well-being and productivity of poultry, responding to the growing global demand for poultry products. Properly designed and managed ventilation systems help remove contaminants and maintain uniform environmental conditions, benefiting both animals and workers in poultry houses. Computational Fluid Dynamics (CFD) modeling has become an essential tool in designing and evaluating ventilation systems, offering control over influencing factors and cost-effective solutions to address indoor environmental challenges in poultry housing. Through CFD simulations, airflow patterns within the poultry house are analyzed to pinpoint areas for potential enhancement. A detailed 3D model of the poultry house and ventilation system was created within the CFD software, considering various simulation scenarios such as air inlet and outlet locations, fan settings, and environmental conditions. The process iterates until an optimal configuration is achieved, ensuring improved indoor air quality and enhanced poultry well-being and productivity. Simulation results indicate a moderately even temperature distribution but uneven air velocity in the baseline poultry house due to natural ventilation. Other results present the mass fraction distribution of NH3, H2O, and CO2 for both systems, along with variations in air velocity and ammonia concentration in the baseline system. The analysis and comparison of the baseline and optimized poultry house ventilation systems reveal significant improvements with the optimized system.

OP29-3 | Floor cooling for growing finishing pigs during warm conditions – impact on pig hygiene, thermal and gaseous environment

Cecilia Hagberg[1,2], Cecilia Lindahl[1], Erik Sindhöj[1], Axel Sannö[2], Knut-Håkan Jeppsson[3], Anna Wallenbeck[2]
[1]Research Institutes of Sweden, Uppsala, Sweden, [2]Swedish University of Agricultural Sciences, Uppsala, Sweden, [3]Swedish University of Agricultural Sciences, Lomma, Sweden

The changing climate, with higher temperatures, is challenging pigs' abilities to lose metabolic heat. This study was conducted during two summers (2022 and 2023) on a commercial pig farm in Sweden, latitude 59.7°N, using a change over design. In one pig unit the solid floorings, in partly slatted pens (8.96 m2, solid lying area 71% and slatted dunging area 29%), were cooled whilst the solid floorings in the adjacent pig unit had no cooling. Each pig unit had 38 pens with 9-10 pigs/pen (LYxH, mixed sexes, ~35-115 kg, undocked). Cooling was conducted by circulating chilled water (~11°C) in the waterborne pipes casted in the concrete. Concentrations of ammonia (NH_3) and carbon dioxide (CO_2) were measured with a photoacoustic gas monitor 1512 and a multipoint sampler 1409 (Lumasense Technologies A/S, Denmark) above four focal pens/pig unit, in addition to sampling points by one air inlet and by one exhaust fan in each unit. Temperature and relative humidity were continuously registered with loggers (Gemini Data Loggers Ltd., UK) mounted next to the sampling points of NH_3 and CO_2, and close to the lying area in the focal pens. Pig hygiene was assessed according to a protocol developed based on literature. Statistical analyses were performed using PROC GLM in SAS version 9.4. Preliminary results show that the proportion of pigs with the mildest hygiene score (<20 % of the body dirty) were higher in cooled compared to control pens (on average 44.6±1.30 vs. 28.8±1.03 % of pigs in the pen (LSM±SE), $p<0.001$). In accordance, the corresponding proportion of pigs with the most severe hygiene score (>50 % of the body dirty) were lower in cooled pens compared to control (on average 31.8±1.37 vs. 47.9±1.37 % of pigs in the pen (LSM±SE), $p<0.001$). In addition, the results show lower levels of both NH_3 and CO_2 with floor cooling compared to the control (2.9±0.03 vs 4.0±0.03 ppm NH_3 and 1345±3.9 vs 1376±3.9 ppm CO_2 (LSM±SE), $p<0.001$ for both). The average temperature was lower in the unit with cooled floor treatment compared to control, both in the sample points above the pen (20.7±0.03 vs. 21.2±0.03 ºC (LSM±SE), $p<0.001$) and closer to the floor in the lying area (26.3±0.06 vs. 27.7±0.07 ºC (LSM±SE), $p<0.001$) while there were no significant differences in relative humidity between treatments. The results indicate a favourable effect of floor cooling on pig hygiene, thermal and gaseous environment.

swine, heat stress, indoor environment, cleanliness

OP29-4 | Machine learning models for real-time dissolve oxygen and temperature predictions in fish ponds

Alaa Jamal[1]
[1]Agricultural Research Organization, Rishon LeZion, Israel

Dissolved oxygen (DO) and water temperature (T) are vital factors in ponds, as they directly affect several production-affecting factors such as feed intake, fish growth, and health. Therefore, precise control of pond aquaculture relies on accurate monitoring based on dissolved oxygen and water temperature predictions. In this study, machine learning regression models were developed to predict DO and T in hourly resolution for a few days. Decision Tree (DT), Adaboost (AB), Extreme Gradient Boost (XGB), and Gradient Boost (GB) were developed as single-step (one-hour) models in which the current DO and T, weather (temperature, radiation, wind speed, and wind direction), and aeration are used to predict the DO and T at the next time step. The models were trained on the recent data from the last few days (denoted as the learning window). In hourly resolution, they predicted the DO and T for the upcoming days (denoted as prediction horizon). The prediction is conducted using the predicted DO and T at the previous step, weather forecasts, and planned aeration. The models were tested on common carp ponds with different scales and water quality dynamics. The models accurately predicted the DO and T compared to pre-assumed averages based on the measured values, especially for 24-hour predictions. Optimizing the parameters of these models enhanced their accuracy, particularly DT and AB, which improved by 20%. Using long learning windows (days) with more data, it reached about 50% enhancement over short periods (hours). An error of 50% accompanied one-day predictions compared to the error of 4-day predictions. These impacts were diminished with longer learning windows and prediction horizons. The usefulness of the predictions was analyzed by conducting fish growth simulations based on the predicted DO and T by a bioenergetics simulation model. An accurate weight simulation was obtained compared to pre-assumed DO and T averages over the measured data.
Keywords: Aquaculture; Water Quality; Fish Growth; Machine Learning

OP29-5 | Energy harvesting for a multi-sensor on dairy cattle

Susanne Demba[1], Annett Baudisch[3], Danilo Zimmermann[3], Doreen Nitsche[2], Steffen Pache[2], Sarah Jahn[4], Kirsten Kouvert[2], Sandra Rose[1]
[1]Hochschule Neubrandenburg, University Of Applied Sciences, Neubrandenburg , Germany, [2]Saxon STATE OFFICE FOR ENVIRONMENT, AGRICULTURE AND GEOLOGY , Köllitsch, Germany, [3]nubix Software-Design GmbH , Dresden, Germany, [4]Friedrich-Loeffler-Institute of epidemiology, Greifswald-Insel Riems, Germany

The world is now positioned in the first stages of the Fourth Industrial Revolution, complete with the Internet of Things (IoT) connected devices and non-IoT connected devices numbering in the billions. According to Statista, there will be just over 10 billion non-IoT active devices by 2025. Installing, maintaining, and replacing billions of batteries is a big logistical issue. In addition, improperly discarded lithium-ion (Li-Ion) batteries leak into the soil at landfills and cause air contamination.
A special focus in the "Internet of Livestock" project is pointed on the topic of energy harvesting at the sensor level, since long-term life cycles must be assumed for practical acceptance, especially in the case of sensors on animals.
A number of approaches to self-power a Multi-Sensor NECKTAG® have been investigated, but not all harvesting methods have been successful. It was also determined whether there is enough light available in the barn for energy generation via a solar cell even in darker periods such as autumn and winter.
The energy yield due to the Seebeck effect was surprising. By means of a Peltier element, the cow's body heat can be used to generate a flow of electricity. Especially in the cold and dark season, this effect can support energy production very well. Furthermore, an appropriately balanced solar module was used on the NECKTAG® housing to enable energy supply even in diffuse lighting conditions.
The energy generation by a piezo element was interesting, but had to be excluded due to the potentially too low energy yield. Piezo elements, which can achieve significant amounts of energy, require a significantly larger installation space, which was not available in the existing housing. Radio Frequency Energy harvesting (RFEH) was also considered, but the cost-benefit factor was disproportionate. However, this technology is not hopeless, as there will be highly efficient antennas with a small size in the future, so the RFEH method should be considered as an outlook for further research.
Keywords: energy harvesting, Multi-Sensor, longevity of sensors, self-power, dairy cattle

OP29-6 | Source segregation in dairy housing effectively separates organic matter and nutrients and facilitates acidification for ammonia emission reduction

Jihane EL Mahdi[1], Peter W.G. Groot Koerkamp[1], Jerke J.W. De Vries[1,2], J. Deru[3]
[1]Agricultural Biosystems Engineering, Department of Plant Sciences, Wageningen University and Research, P.O. Box 16, 6700 AA Wageningen, the Netherlands , Wageningen, Netherlands, [2]Applied Research Centre, VHL University of Applied Sciences, P.O. Box 9001, 6880 GB, Velp, Netherlands, Velp, Nederland, [3]Louis Bolk Instituut, Bunnik, Netherlands

Source segregation (SS) of faeces and urine in the animal house is a novel strategy to reduce emissions and improve nutrient management, but its performance in dairy housing is unknown. This study aims at unveiling separation efficiencies of nutrients and organic matter (OM) of a novel SS floor in dairy housing and to explore its effect on nutrient losses in the animal house. In addition, the study aims to unveil dynamics of urine acidification as a potential alternative to traditional slurry acidification, because urine is hypothesized to require less acid and a lower frequency of acidification. For this, faeces and urine were collected from the novel floor and slurry from a traditional slatted floor at an experimental farm in the Netherlands. The chemical composition of each fraction was then analysed and served to calculate the separation efficiency (SE(x)) for selected compounds: (dry matter (DM), organic matter (OM), total nitrogen (TN), total ammoniacal nitrogen (TAN), total phosphorus (TP), and water soluble phosphorus (SP)). For the acidification test a titration curve was drawn using 5M sulfuric acid to determine the amount of acid needed to reach pH 5.5, then the pH of the acidified urine was monitored for 30 days. The results showed that on average 87%, 94%, 94%, 97%, 67% and 23% of the DM, OM, TP, SP, TN and TAN accumulated in the faeces, respectively. Further, the SS system had higher N balance than the slurry system during the first collection and a lower one during the second collection. The reasons for this remain unclear and need further investigations. In the acidification test, urine was found to require 1.7 ml kg-1 of sulfuric acid to reach a pH of 5.5, which is lower than the range reported for slurry (2.8 to 5.7 ml kg-1). In addition, the urine maintained the 5.5 pH (5.4 ± 0.3) for the totality of the test with the one time acidification performed. We concluded that the novel SS system effectively separates N, P, and OM as compared to post-separation of slurry, which additionally requires more energy and inputs. Further, SS can improve acidification of excreta, which is widely used to control emissions, by substituting slurry with urine because less acid is required and foaming is limited. Further investigations are needed to understand the implications of the segregation on emissions in-house and management further down-stream.

OP30-2 | Training needs analysis for integrating bioeconomy approaches into the EU's agricultural sector

Dimitris Michas[1], Athanasios Balafoutis[1], Bas Paris[1], Ioannis Thermos[1], Duarte Pimentel[2], Carlota Silva[2]
[1]Ibo/certh, Athens, Greece, [2]Terinov, Terceira, Portugal

This paper presents the result of a Training Needs Analysis (TNA) conducted with both training providers and learners across four partner EU countries (Greece, Italy, Portugal, and Sweden). These results are based on a survey with 196 respondents. Based on multiple presented data points and sources we reach three main conclusions. Education and training in bioeconomy reflects megatrends associated with the green transition in terms of generating hybrid and emerging knowledge subfields, often embedded in traditional scientific disciplines such as farming or forestry that require a fast adaptation to new and promising professional profiles. Moreover, our results also reflect digitalization megatrends. Specifically, education and teaching institutions are still biased towards in-person teaching methods, while learners show a significant preference for blended or online learning methods, especially among those with higher qualifications (agronomists, consultants, and policymakers). Importantly, significant trends in bioeconomy education and training were also detected. For instance, due to its novelty, bioeconomy education and training is becoming more relevant across the European Union, but developments are not homogeneous. Importantly, secondary education programs and VET supply seem to be slowly adapting to the demand for competencies and skills in this sector.
Finally, we highlight that according to the learners involved in our training needs analysis it is vital to disseminate comprehensive curricula in the bioeconomy sector, targeting technical, but also digital, entrepreneurial, soft, and transversal skills to address current professional requirements. Based on our conclusions, we offer some recommendations which may improve the quality and effectiveness of programs, in this field. Our recommendations cover issues such as curricula content, skills update of teachers and trainers, human-centred approaches to training design or appropriate use of digitalization.
Keywords: bioeconomy; education; training; training needs analysis; HEI; VET.

OP30-3 | Growing together: Enhancing skill and cultivating sustainable winegrowing communities

Manuel Pérez-Ruiz[1], Abdul Mouazen[2], Anastasios Michailidis[3], Daniele Sarri[4]
[1]Agroforestry Engineering Area, Department of Aerospace Engineering and Fluid Mechanical, University of Sevilla, Sevilla-Utrera Road km1, 41013 , Sevilla, Spain, [2]Department of Environment, Ghent University, Coupure Links 653, 9000, Ghent, Belgium, [3]Department of Agricultural Economics, School of Agriculture, Aristotle University of Thessaloniki, 54124 , Thessaloniki, Greece, [4]Department of Agriculture, Food, Environmental and Forestry (DAGRI), University of Florence, Piazzale Delle Cascine 15, 50144, Florence, Italy

Today's agricultural machinery e.g., tractors, planters, harvesters, and sprayers are far from what our parents used. Thanks to advances in sensors, telemetry, precision technologies, and cloud-based data management, data collection has become simpler, allowing us to transform this data into valuable information and insights. This necessitates a shift in the approach of education and training for stakeholders within the agricultural sector. The VTSkill project was born to be highly useful and broad-reaching in the viticulture sector of Mediterranean Europe. This initiative brings together four higher education institution (HEI), three vocational education and training (VET) institutions, and seven labour market actors. The consortium aims to foster the adoption of environmentally, socially, and economically responsible practices within the viticulture industry. Sustainable Precision Viticulture (SPV) merges the principles of precision agriculture with those of organic farming, facilitating the intelligent utilization of technology in harmony with preserving an agricultural ecosystem. This project aims to develop an innovative, transnational curriculum tailored to viticulture studies. It is designed to equip HEI students, consultants, managers, technicians, and farmers with a comprehensive set of skills in digitalization, sustainability, and resilience, specifically tailored to the nuances of SPV. This process will begin by identifying the key digital, ecological, and resilience/entrepreneurial competencies lacking in the viticulture industry. The research will employ natural language processing (NLP) and data mining techniques and will be validated through interactive research with farmers. Following this, partners will design a new SPV curriculum tailored to the needs of HEIs and VET centres. The training courses will use a micro-credentials approach, be tested in partner organizations, and involve HEI learners, VET learners, farmers/workers, and consultants. Finally, partners will design and test the VTskills e-demofarm, a new model of demo-farm that features three primary components: formative (delivering challenge-based learning educational experiences), informative (referring to events and EU-funding opportunities that might benefit farmers), and demonstrative (virtualizing good practices already carried out by farmers). By implementing effective and efficient communication strategies, the project enhances its visibility and engage with over 20,000 European stakeholders, fostering new skills and creating synergies for sustainable precision viticulture.

Keywords: precision viticulture, education, competencies, e-demofarm, resilience

OP30-4 | Acceptance of cutting-edge technologies in viticulture: A students' perspective

Tetiana Pavlenko[1], Dimitrios S. Paraforos[2], Megan K. Bartlett[3], Spyros Fountas[4], Eva Gößwein[5], Jacob Kambuta[6], Francesco Marinello[7], George Papadopoulos[4], Léo Pichon[8], Bruno Tisseyre[8], Magnus Liebherr[5]
[1]University Of Hohenheim, Stuttgart, Germany, [2]Hochschule Geisenheim University, Geisenheim, Germany, [3]University of California, Davis, Davis, USA, [4]Agricultural University of Athens, Athens, Greece, [5]University of Duisburg-Essen, Duisburg, Germany, [6]Lincoln University, Lincoln, New Zealand, [7]University of Padova, Legnaro, Italy, [8]University of Montpellier, Montpellier, France

A significant push in technology development brought a wide number of innovations for precision farming. Sensors, information technologies, and site-specific applications are meant to facilitate farming operations and deliver environmental and economic benefits. Acceptance of these new technologies is a key factor in their implementation. However, despite their rapid spread, farmers' reluctance to adopt them is leading to low adoption rates. This is particularly true in traditional sectors such as viticulture.
Therefore, this study aims to understand the status quo of digital technology acceptance in viticulture. To investigate the current attitudes and visions of potential future farmers or/and future farmer advisors, an online questionnaire was developed and distributed to students involved in viticulture studies. Germany, France, Italy, the USA, New Zealand and Greece participated. The main objectives were to determine the students' level of trust in precision viticulture, their personal beliefs and expectations, to understand their experience in applying precision viticulture technologies in vineyards, and to identify the impulses toward modern technology development.
Additionally, participants' perspectives on the issue of climate change were taken into account, as well as their characteristics related to viticultural farming practices and their experience in this field.
The study is still in the ongoing process of collecting more data for subsequent analysis. The first results obtained show an increasing interest in learning about new precision farming developments that can be used for viticulture. However, more effort is needed to raise awareness and facilitate technology uptake.
The novelty of the work is that similar studies have not yet been conducted in the field of viticulture. The final results will be the first valuable input in obtaining an overview of the current status of precision viticulture technology acceptance in different countries and are regarded as a first step for conducting further detailed investigations. The data obtained and the conclusions drawn will also provide a sound basis that can be used to compare the acceptance rates related to viticulture technologies to the acceptance rates of precision farming technologies in general in agriculture, as relevant studies have already been conducted.

Keywords: precision viticulture, acceptance, adoption, students, education

OP31-1 | Field monitoring for assessment of weeding robot performance

Victor Bloch[1], Eerikki Kaila[2], Reetta Palva[2]
[1]Luke, Helsinki, Finland, [2]Työtehoseura, Rajamäki, Finland

Field robots is an important tool improving efficiency and decreasing the climatic impact of food production. Although several commercial field robots are available, the advantages, limitations, and optimal utilization methods of this technology are still not well understood due to its novelty. This study aims to evaluate the performance of a commercial field robot specifically designed for seeding and weeding tasks. The evaluation was carried out in a 2-hectare sugar beet field with a row width of 0.5 meters. The testing involved five rounds of weeding during the initial two months of growth. Approximately three percent of the field was left untreated as a control area, while other five percent was treated with chemicals. Plant detection was based on precise plant location without the use of image processing. The robot was equipped with six weeding tools, including passive between-rows harrow hoes and active hoes for cutting between plants within rows. It operated at a maximum speed of 0.9 km/h.
The robot performance was assessed by image processing. The field images were collected by an action camera with the height 2 m and resolution 27M pixel installed on the robot and by a drone with a 16M pixel camera flying on 4 m height. To detect sugar beet and weeds with maximal robustness and applicability for different environments, YOLOv8 model was trained with transfer learning from two available datasets. Preliminary analysis of the entire field revealed that in areas treated by the robot, the average±STD weed density was 2.5±2.7 weeds/m2, compared to 0.5±0.9 weeds/m2 in the chemically treated area and 24.3±12.5 weeds/m2 in the untreated area. Within the rows, the average weed density ranged from 2.0±1.5 weeds/m, compared to 0 weeds/m in the chemically treated area.
The information about the robot performance has high importance for using robots for field tasks. By field monitoring with an open access software, performance of a robot can be assessed several times during the growth according to the weeding frequency. This enables farmers to gain insights into the field's condition and the efficiency of robotic treatments across the entire area. Moreover, farmers and researchers can develop optimal strategies for robot usage, including timing for seeding and weeding, robot settings, and considerations of plant and field parameters and geometry. Additionally, robot producers can obtain quantitative data from real working environments, enabling them to enhance their robots based on this information.

OP31-2 | Shaping the αgricultural future: Engaging stakeholder feedback for the development of agricultural robotic solutions

Maria-Zoi Papantonatou[1,2], George Papadopoulos[1,2], Havva Uyar[1,3], Frits Van Evert[4], Spyros Fountas[1]
[1]Department of Natural Resources Management and Agricultural Engineering, Agricultural University of Athens, 11855 Athens, Greece, [2]Faculty of Crop Science, Agricultural University of Athens, 11855 Athens, Greece, [3]SingularLogic, 14564 Athens, Greece, [4]Agrosystems Research, Wageningen University & Research, P.O. Box 16, 6700 AA Wageningen, The Netherlands

Smart farming technologies and robotic solutions may enable farming to move towards a more environmentally friendly agriculture landscape. These solutions, whether already commercially available or still under development, represent the future of agriculture and will play a crucial role in supporting farmers in crop production. The involvement and opinions of farmers, advisors, and agriculture students are vital in ensuring the adoption and smooth transition from traditional to smart, robotic, and data-driven methods. Field demonstrations are an important method to familiarize these stakeholders with the new technologies. We demonstrated autonomous robotic solutions for weeding and spraying applications developed within the EU-funded project Robs4Crops in Greece. We collected feedback from farmers, advisors and students who attended the demonstration. The survey aimed to engage them by documenting their opinions and beliefs during these demonstrations. The aim of the study was to present and analyse their feedback on the effectiveness of such demonstrations, the level of understanding of the presented robotic solutions, and insights into challenges and potential solutions for market adoption. The main results of the survey showed a very positive reaction towards the new innovative agricultural robotic solutions. The demonstrations significantly improved the participants' understanding of robotic technologies, with an impressive 100% expressing full agreement and approval of the presented solutions. In addition, 96% reported that their perception of the potential benefits of robotic agriculture was positively altered by the demonstrations, highlighting a transformative effect on their views. This collective agreement of opinion among farmers, advisors, and agricultural students illustrates the effectiveness of the demonstrations in providing valuable information and promoting a more informed perspective on the potential and benefits of robotic agriculture technologies. The findings suggest that such demonstrations could play a key role in accelerating the adoption of smart agriculture technologies, paving the way for a more efficient and sustainable agricultural sector.

OP31-3 | Robotic arranging of full chicken bodies for automated handling

Eldert van Henten[1], Bastiaan Vroegindeweij[2], Chit Ho Cheng[1], Laurens Philippo[3], Rehka Raja[4], Rodrigo Pérez-Dattari[5], Gert Kootstra[2]
[1]WUR - Agricultural Biosystems Engineering Group, Wageningen, Netherlands, [2]Livestock Robotics, Ochten, The Netherlands, [3]Marel Poultry, Boxmeer, The Netherlands, [4]Radboud University, Nijmegen, The Netherlands, [5]Mechanical, Maritime and Materials Engineering, Delft University of Technology, Delft, The Netherlands

In modern food processing plants, many processing steps are highly automated. Still, quite a number of steps require significant manual input. In poultry processing plants, for example, the hanging of slaughtered chickens into shackles for further processing remains a human activity due to the complex nature of this task. In this research, we explore a robotized fork-and-slide approach as a first step in the automated shackling of pre-chilled birds. A key challenge here is arranging the birds from a chaotic pile into a more structured fashion. It is expected that the actual shackling can also be executed by mechanical solutions, similar to those readily available in industry.

For reliable operation, the proposed solution requires awareness of the birds present coupled with detailed status information such as their orientation and the position of relevant elements like legs and body. By employing a distributed image processing system pipeline on RGB-D images, with the deployment of Mask R-CNN, an object mask and keypoint based skeleton are provided for body and legs separately. Subsequently, this information is merged in a reasoning module to select the bird that is most suitable for moving from the pile. Once a grasp pose is calculated for this chicken and a delivery location is identified, a dragging path is calculated using imitation learning-based stable motion primitives (Pérez-Dattari 2023). After confirming suitability of this path, a Kinova Jaco 2 manipulator with adaptive gripper is used to grasp and slide the bird to its desired pick-up location. Basic feedback is used to ensure the desired bird is successfully grasped, otherwise the operation is cancelled and a new attempt is made.

Systems performance was evaluated at component level, with initial results showing that about 90% of the objects and the keypoints were correctly detected, resulting in proper allocation of over 80% of the grasping poses. The motion planning and execution realized 75% success rate for properly grasping and delivering to the desired location with cm-level accuracy.

Specific challenges that remained in this approach are a proper reasoning to select which bird to be handled first, and more advanced motion planning that also includes some knowledge on the dynamic and elastic behaviour of chilled chickens. Still, this demonstrator shows that with a proper determination of the core problem building an automated system for shackling pre-chilled birds boils down to selecting and integrating existing algorithms for detection and motion control.

OP31-4 | Weighted complete coverage path planning for collaborative manure removing robots in dairy barns

Luis Angel Ponce Pacheco[1], Gert Kootstra[1], Kees Lokhorst[2], Wijbrand Ouweltjes[2], Marjolein Derks[1], Congcong Sun[1]
[1]Agricultural Biosystems Engineering, Wageningen University & Researchh, P.O. Box 16, 6700AA, Wageningen, The Netherlands, [2]Wageningen Livestock Research, Wageningen University & Researchh, P.O. Box 338, 6700 AH, Wageningen, The Netherlands

The escalating demand for food production, coupled with growing concerns surrounding environmental impact, animal welfare, and labor shortages, presents multifaceted challenges for the dairy sector. One pivotal issue is the efficient removal of cow defecation in barns using manure-removing robots, as unclean environments can lead to ammonia emissions and compromise cow health and welfare.

Current manure-removing robots operate on static pre-programmed routes, lacking adaptability to varying degrees of dirtiness in different areas over time and cow behaviors, compromising effectiveness. Furthermore, despite the abundance of path planning algorithms for multi-coverage scenarios, none has been applied in the dairy sector.

This paper introduces a novel path planning approach using a grid environment that facilitates easy modeling of various barn layouts for computing, visualizing, and simulating multi-coverage path planning. A Python-based GUI software solution has been developed for this purpose. The simulator enables straightforward drawing of barn layouts, customization of robot settings, and algorithm selection (weighted and unweighted). We use the Multi-Robot Weighted Coverage Path Planning method, based on the state-of-the-art DARP algorithm, to compute efficient paths for manure-removing robots and simulate the results. The simulation incorporates relevant cow behaviors, including individual location and defecation timing, with the resulting simulated manure distribution serving as input to weigh the importance of grid cells. This enables the calculation of more efficient robot paths.

Simulation experiments, encompassing variations in robot scheduling and a comparison between adjustable and static paths show a positive correlation between reducing robot waiting time and cleanliness, enhancing it by 69%, and a 44% improvement in balancing manure collection compared to existing static paths. This strategic adjustment effectively prevents overloading the robots' capacity. Consequently, the generated paths prioritize areas requiring greater attention, ensuring a more targeted and balanced cleaning process. Notably, interactions between cows and robots increased by 66%, as a consequence of the larger time cleaning, as preliminary results demonstrate.

In conclusion, our approach addresses multiple challenges faced by the dairy sector by introducing a state-of-the-art path planning strategy for multiple manure-removing robots. The utilization of the Weighted Complete Coverage Path Planning method, coupled with simulations that consider both environmental factors and cow behavior, results in a significant enhancement in barn cleanliness. This research contributes to the optimization of robot-assisted tasks in dairy barns, offering a promising avenue for improving environmental sustainability, animal welfare, and overall operational efficiency.

Keywords: manure-removing robots, simulations, multi-robots, path planning, animal welfare

OP31-5 | Operational limits for UAV livestock counting based on foundation models

Ricardo Sánchez, Adrien Lebreton, João Valente

In the face of scarce resources and an increasing challenging environment, resource-efficient management driven by drone services can shape a more resilient society implementing precision livestock farming. Livestock causes different pressure with different effect on the ecosystem depending on its number. From negative environmental impact such as erosion, to positive environmental impact such as reducing fire risks intensified by climate change. A better counting livestock method contributes to a stronger monitoring system to ensure long-term sustainability in ecosystem services. In this paper, two foundation models are compared across different livestock imagery taken by UAV to determine what factors leads to a better counting performance. GroundingDINO and T Rex were the two state-of-the-art detection-based models. These pre-trained models does not require any supervised training with annotated images. The dataset tested included heterogeneous scenarios with different spatial resolution of various groups of animal species, under different weather conditions. Its metadata, including spatial data such as altitude or its location, which defines different scenarios and flight conditions. Previous works evaluate the performance and limitations of foundation models on different objects, from small items to dense or camouflaged entities. However, this paper aims to identify operational limits that facilitates a safe counting accuracy for cattle farmers when current limitations and risks of these foundation models applies. UAV imagery taken between 34 and 52 meters height with a 28 to 52 number of target animals scored the best performance using T-Rex as well as Grounding-DINO by offering the lowest Mean Absolute Error (MAE). However, as the complexity of the scenarios increases with smaller sizes of animals observed from higher heights, only T-Rex is able to count livestock to some extent. On the other hand, the qualitative analyse revealed that an oblique angle increases the count performance of small target animals in moderate and high heights in this dataset. Defining operational limits for aerial footage reduces the limitations of emerging foundation models predictions, facilitating its immediate application in real-world scenarios.

Keywords: Livestock management, UAV imagery, Object detection, Counting, Computer vision, foundation models

OP31-6 | Adaptive path planning for drones based on detection certainty

Rick van Essen[1], Tom Lensen[1], Eldert van Henten[1], Gert Kootstra[1]
[1]Agricultural Biosystems Engineering, Wageningen University and Research, Wageningen, Netherlands

Drones are used for many applications in agriculture. One of the challenges when using drones is their battery capacity, which limits the area that can be inspected in a single flight. To make inspection of agricultural fields more efficient, we propose an adaptive path planner that adapts the altitude based on object detection and the uncertainty level in this detection. In case the detection uncertainty is high, the altitude is lowered to acquire higher resolution information to increase the certainty of the detection. We show the benefits of such path planner in agriculture for the use-case of weed detection. The objectives are to (1) investigate the effect of altitude, (2) evaluate the effect of different uncertainty measures for weed detection and (3) test the performance on a real drone.

The path planner has two layers: a non-overlapping row-by-row flight path to cover the field quickly at high altitude and an online planned flight path to capture images at a lower altitude. The row-by-row flight path has an altitude of h_high and while flying the row-by-row flight path, a detection network (yolo-v8) is used to detect weeds. The trained network has a validation mAP of 0.80 and 0.53 at 12 and 28m altitude respectively, showing higher accuracies at lower altitudes. When weeds are detected with an uncertainty that lies within a predefined interval, a new path is planned that aims to detect the weeds with a higher certainty by lowering the altitude to h_low. After executing this low altitude flight path, the drone resumes the row-by-row flight path at higher altitude.

As baseline for the performance evaluation of our adaptive path planner, a row-by-row path at an altitude of h_low is used. First results on a real drone using a simplified setup showed that such adaptive path planner can be 24% quicker than the baseline, however, at cost of a 15% lower detection accuracy. To assess the influence of altitude, different values for h_high and h_low are tested, ranging from 12m to 28m. To examine the influence of the detection uncertainty estimation, we compare the confidence returned by yolo-v8 against the modeled epistemic uncertainty. We optimize the path planning parameters using a high resolution orthomosaic of a grass field containing similar looking plants as proxy for weed. We test the path planner using a DJI M300 drone with a Zenmuse P1 camera with a customized flight app in a grass field.

OP32-1 | Are farm to fork strategy goals reasonable and achievable? State of the art of Península de Setubal's winegrowers

Miguel Cachão[1], Ana Chambel[1], Goreti Trindade[1], Sergio Pinto[1]
[1]Avipe, Palmela, Portugal

The European Union's "farm to fork" strategy sets out several objectives to be achieved by farmers, who, among others, relate to increasing biodiversity, protecting soils and reducing the use of pesticides. The use of pesticides in 235 winegrowers in the Palmela region was evaluated between 2016 and 2023. To support some of the answers, a socio-economic survey was also carried out. The data analysed included the number of treatments, the dosages used, compliance with the pre-harvest interval, the reason why winegrowers performed phytosanitary treatment and how they chose a pesticide. In addition, residue analyses were carried out at the entrance of the grapes into the winery to assess whether the MRL was exceeded and whether were not authorised pesticides were used in the vine. For each year, it was found that, on average, farmers spray seven times, although the trend was to decrease and the most used pesticide belong to groups 3 (Triazol), according to the FRAC Codes. It was concluded that fear of diseases and pests and "empirical experience" sometimes go beyond knowledge and technology. In addition, the weak valorisation of grapes and discouragement with the implementation of some poorly reported strategies are factors that fuel the concern about the difficulty in achieving the goals.

OP32-2 | Policy gaps and policy guidelines for accelerating the adoption of fossil-energy-free technologies and strategies in the EU agricultural sector

Athanasios T. Balafoutis[1], Bas Paris[1]
[1]Certh - The Centre For Research & Technology, Hellas, Athens, Greece

The results presented in this paper provide a policy gap analysis of the EU agricultural sector and the outputs of 19 associated policy briefs, submitted to the European Commission, focused on supporting and accelerating the adoption of Fossil-Energy-Free Technologies and Strategies (FEFTS) in the EU agricultural sector.

This policy gap analysis is based upon a detailed assessment and evaluationof the current energy use status in EU agriculture, a survey with over 400 farmers and experts about FEFTS adoption, the content available through the AgEnergy Platform content, and interactive innovation processes with a range of relevant actors through workshops in national and transnational level. An in-depth analysis of these supported the identification of policy gaps and led to the development of three broad categories of policy recommendations: horizontal policy recommendations on energy related issues in farming that can be applied to any type of farm and FEFTS, those relevant to specific agricultural production systems that can assist specific FEFTS to be applied and generic policy recommendations to policies that are necessary for green growth in EU farming, including FEFTS integration. Each policy brief starts with the statement of the challenge that must be overcome, followed by the policy gaps and recommendations proposed and closing with the expected impact after its implementation.

The topics of the policy briefs under the horizontal policy briefs are: enabling the creation and growth of energy communities in rural areas, farm energy audits, European low energy/carbon label of agricultural products. the topics of the policy briefs relevant to specific agricultural production systems are: agrivoltaics for open field agriculture, alternative fuels for agricultural machinery, precision agriculture as energy consumption reduction strategy, carbon farming for carbon removals, conservation agriculture to enhance soil carbon stock and reduce GHG emissions in European agriculture, alternative crop nutrient providers, building management systems for agricultural constructions, heat pumps for HVAC of agricultural constructions, photovoltaics and photovoltaic thermal collectors and systems for agricultural constructions rooftops. biogas production from agricultural waste and other innovative feedstock/biomethane upgrading for local consumption or grid injection, facilitating the development of energy independent farming in livestock, livestock building energy upgrading/renovation, the use of thermochemical fluids for energy saving and storage in agriculture. The generic policy briefs are financial support to fossil energy free technologies and strategies, regulatory support to fossil energy free technologies and strategies, technology, knowledge transfer, and awareness building provisions to support fossil energy free technologies and strategies diffusion.

OP32-3 | Harmonizing agroecology and digitalization for sustainable European agriculture

Andreas Meyer-Aurich[1,8], Friederike Schwierz[1], Alma Moroder[2,8], Jochen Kantelhardt[3], Karl Reimand[3], Søren Marcus Pedersen[4], Andrea Landi[4], Karl Behrendt[5], Elias Maritan[5], Andreas Gabriel[6], Spyros Fountas[7], Evangelos Anastasiou[7]
[1]Leibniz Institute for Agricultural Engineering and Bioeconomy ATB), Potsdam, Germany, [2]Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany, [3]BOKU - University of Natural Resources and Life Sciences, Wien, Austria, [4]University of Copenhagen, Copenhagen, Denmark, [5]Harper Adams University, Newport, UK, [6]Bayerische Landesanstalt für Landwirtschaft, , Germany, [7]Agricultural University of Athens, , Greece, [8]Humboldt-Universität zu Berlin, Berlin, Germany

In response to the pressing challenges confronting European agriculture, including societal expectations for biodiversity conservation, pollution reduction, and the need to adapt to climate change and market dynamics amid aging rural populations and labour shortages, there is a need to explore the transformative potential of digital tools and technology in fostering more sustainable agriculture.
Within the framework of the EU funded Horizon Europe Coordination and Support Action (D4AgEcol) a consortium comprising twelve partners from eight European countries is actively investigating the potentials, barriers, and pathways for utilizing digitalization to enhance European agriculture, particularly through the lens of agroecology.
The ongoing project employs Digital Tool Scoping Workshops to engage farmers and stakeholders in the analysis of technologies like virtual fencing, robots in arable farming, weed detection, and animal health sensors. The workshops include an analysis of the compatibility of the selected technologies with the concept of agroecology. Furthermore, the adoption potential was specified. To date, these workshops, conducted in the UK, Denmark, and Germany, have involved 80 participants, including farmers, advisors, researchers, and stakeholders.
Preliminary results from the workshops reveal promising potentials for the analysed technologies, yet underscore challenges related to profitability and partial compliance with the agroecology concept. These include potential impacts on agroecological principles, in ways perhaps not planned during the development of the tools. The consortium acknowledges the need for further analysis and stakeholder engagement across participating countries and aims to develop a roadmap that paves the way for the harmonious integration of agroecology and digitalization in European agriculture.

OP32-4 | Mechanical termination of cover crops - corn cultivation for less erosion and less herbicide use

Markus Demmel[1], Hans Kirchmeier[1]
[1]Bavarian State Research Center for Agriculture, Institute for Agricultural Engineering and Animal Husbandry, Freising, Germany

Problem / Purpose

Soil erosion control requires the soil to be covered with plant residues / organic material (>30% coverage) and therefore no-till, min-till or mulch-till in combination with cover crops is necessary. Typically, no-till, min-till and mulch-till with or without cover crops require the use of a total herbicide (e.g. Glyphosate) before planting corn to reach good germination and perfect plant growth of corn. The European Green Deal and the Farm-to-Fork strategy require a reduction of pesticide resp. herbicide use as well as a maximal control of erosion. To solve this conflict of goals a research project was conducted to investigate the possibilities and limits of different measures to mechanically terminate cover crops to reduce the use of herbicides as well as ensures high erosion control.

Methods

To reach the purpose of the project, field trials on two locations during four years have been conducted. Three factors and their combinations have been investigated: The factors cover crop (4 variants), methods of termination (3 variants), and herbicide strategy (3 variants). All 36 factor combination have been repeated 4 times and randomised at each location. Corn germination, soil coverage, weed coverage, plant height, and corn yield have been measured and statistically analysed.

Results

The investigations showed that there are measures and options to reduce the use of herbicides and optimize erosion control at the same time without significantly reducing the yield. This includes the cultivation of winter cover crops, which offer better erosion control in spring and the use of a roller crimper or mulching mower to terminate them. The study has shown that good field emergence and yields can be achieved without seedbed preparation and without the use of a total herbicide. Shallow seedbed preparation (mulch-tillage) increased corn yields significantly but also reduced erosion control clearly.

Conclusions

Therefore, the recommendation is to establish dense and lush (hardy) cover crops, even if there is only a small risk of erosion, but also to be able to reduce herbicide use. In dry years or dry regions, it can be difficult to establish optimal cover crop stocks. They must be free of weeds and volunteer grains, that terminating with a roller crimper or mulching mower and reduced herbicide use brings the desired success.

OP32-5 | Usage of artificial lighting to promote seed germination for microgreen production

Christos Vatistas[1], Dafni Despoina Avgoustaki[1], Thomas Bartzanas[1]
[1]Agricultural University Of Athens, Athens, Greece

Growing vegetables in controlled environmental agriculture (CEA) systems has contributed significantly in recent years to increasing local production within urban areas, providing consumers with fresh vegetables. The use of artificial lighting during cultivation in these systems promotes plant growth by providing them with the required daily amount of photosynthetic photon flux density (PPFD) and at the same time enables precise planning of the harvest time from the moment of sowing. One category of cultivation in CEA systems is that of microgreens, where seedlings are consumed just a few days after sprouting. Cultivation takes place on shelves, utilizing artificial lighting to provide the necessary energy to the seedlings. The purpose of this experiment was to investigate whether lighting facilitates faster germination of cabbage and arugula seeds, and if any specific spectrum has a better effect on them. The seeds were placed under 9 different light spectra for photoperiods of 4, 8 and 16 hours daily. The spectra studied were in the range of UV, blue, green, orange, red, farred, combination of blue-red, combination of blue-red-farred and a full spectrum cool-white LED. The results of the experiments showed that lighting has a positive effect in terms of time and the percentage of seeds that germinate, compared to their germination in the dark. The seedlings grown had different morphological characteristics under different spectra and a different amount of biomass was produced under the different lighting treatments. Production can be increased by using combinations of lighting during cultivation. An initial exposure of seeds to the spectrum with the highest germination rates increases the number of produced seedlings, while exposure to the lighting spectrum that produced the most biomass subsequently increases the quantity of the final yield.

Keywords: microgreens, seeds, control-environmental agriculture, lighting, germination

OP32-6 | Indoor vertical greening for regulating building microclimate

Fabiana Convertino[1], Evelia Schettini[1], Giuliano Vox[1]
[1]University of Bari, Bari, Italy

The integration of vegetation in buildings can increase the environmental sustainability of urban contexts as well as produce other relevant unquantifiable effects. Vegetation can be applied both on the exterior side of the buildings' envelope and inside, in different ways and layouts. Green façades are a specific kind of vertical greening for buildings consisting of plants covering vertical walls of buildings. The presence of vegetation on the envelope positively affects the building's thermal and acoustic performance, air quality, aesthetics, with relevant consequences in terms of energy and cost savings and human well-being. Until now, research has focused mainly on vertical greening systems applied to the exterior side of the buildings, but indoor applications deserve attention as well. This is the reason behind the present research: assessing the physical functioning of an indoor green façade. To this end, an experimental prototype of an indoor greening system was designed and realized to be monitored, at the University of Bari. The prototype consists of a sealed chamber, with evergreen plants, properly equipped with sensors for collecting air, soil and plant parameters, needed for studying the system functioning. The database created with the collected data enables investigations of the green façade behaviour and effects. A better understanding of this green technology, allowing for informed design and knowledge of induced effects, can promote the spread of indoor green façades.

Keywords: Urban agriculture, Green façade, Evapotranspiration, Canopy temperature, Heat transfer

OP33-1 | Spray deposition assessment using an unmanned aerial vehicle in coffee crop

João Paulo Arantes Rodrigues Da Cunha[1], Artur Rodrigues Junqueira[1], Luana de Lima Lopes[1]
[1]UFU, Uberlândia, Brazil

The coffee cultivation is a significant agricultural and economic activity in Brazil and worldwide. One of the major challenges faced by producers is the plants' susceptibility to various pests and diseases, often necessitating phytosanitary control through the application of pesticides. However, this operation is often complex, especially in areas with sloping and irregular terrain, which hinders mechanized treatments in the crop. Additionally, the crop canopy has a large leaf area index, which makes it difficult to achieve good target coverage. Therefore, an option for producers is the use of unmanned aerial vehicle. It is a relatively new technology that still needs to be evaluated in many crops. This study aimed to analyze the spray deposition on coffee leaves using an unmanned aerial vehicle ("drone") as a sprayer at two flight heights (2 and 3 m) and three spray nozzles (flat-fan XR 11001, air-injection flat-fan AirMix 11001, and hollow-cone COAP 9001). The research was conducted in an 11-year-old Arabica coffee plantation. The octocopter DJI AGRAS MG-1P was employed as the aircraft. Four treatments were applied: XR 11001, COAP 9001, and Airmix 11001, all flying at 3 m height, and Airmix 11001 at 2 m height. The solution included the tracer Brilliant Blue at a concentration of 50 g/L. Leaves from the upper and lower parts of the plant canopy were collected, and the tracer was extracted and quantified using spectrophotometry. Leaf area was determined using a leaf area meter. Results indicated that flat-fan nozzles provided the highest depositions, both on the upper and lower parts of the plants. The flat-fan nozzle with air induction technology proved to be suitable, showing positive results at both 2 and 3 m flight height, with no significant difference between them. This also emerged as a relevant technique for drift reduction.

OP33-2 | Development of an inline injection and mixing system for sensor-guided variable-rate sprayers

Heping Zhu[1]
[1]USDA-ARS, Wooster, United States of America

The laser-guided intelligent spray technology has been rapidly adopted by specialty crop growers to significantly reduce pesticide waste, increase production profitability, and safeguard the environment. However, the technology still needs improvements to eliminate the tank mixture leftover waste which is a common problem for all variable-rate sprayers. An inline injection and mixing system was developed as an attachment to the laser-guided variable-rate orchard sprayer. Major components of the system consisted of a chemical metering pump, a water pump, a two-stage static mixer, a premixing tank, a buffer tank, an electric motor operated shut-off valve, a chemical container assembly, electronic control boards, a graphic user interface, and an embedded computer with a touch screen unit. Liquid level sensors were mounted in all tanks and the chemical container to control the liquid discharge process and prevent overflows. The graphical user interface with visual operation functions was designed for operators to communicate with the system and monitor the system operation status. During spray applications, the system performed with loops in dispensing, mixing, and transferring desired amounts of water and chemical concentrates automatically to maintain spray mixture with a constant concentration for variable-rate nozzles to discharge. The system could be rinsed automatically when the spray application task was completed. In addition, the user interface was designed for operators to manage the system operation and view the operation status shown on the touch screen. Test results demonstrated that the simulated pesticide and water could be accurately delivered into the injection line and could be mixed well in the buffer tank before the spray mixture was discharged to the nozzles. The inline injection and mixing system would be a potential technique to further reduce pesticide waste and improve environmental stewardship for both conventional and new precision variable-rate sprayers.

OP33-3 | Assessing the adaptive capability of an intelligent recycling tunnel sprayer system to vine canopy size

Ramón Salcedo[1], Nehad El Aissaoui[1], Bernat Salas[1], Jordi Llop[1], Francisco García-Ruiz[1], Emilio Gil[1]
[1]Universitat Politècnica de Catalunya, Castelldefels, Spain

Air-assisted recycling tunnel sprayers for trellised vineyard's PPP applications incorporate panels, enabling the recovery of the majority of the sprayed liquid fraction that remains unretained by the leaves during the process. In this study, a new tunnel sprayer has been developed with an automatic variable-rate application (VRA) control unit (Waatic, Abrera, Barcelona). This system is able to execute previously generated prescription maps based on canopy characteristics (satellite imagery) and accurate agronomic decision tools can read spray volume prescription maps generated from vegetative vigor data obtained from remote sensors (such as satellites), supported by a validated Decision Support System for vineyards (Dosaviña®). However, these maps do not account for variations in canopy width along a row. Therefore, this sprayer also includes ultrasonic sensors to identify canopy width and adjust panel spacing accordingly, enhancing product recovery effectiveness. Based on data provided by ultrasonic sensors, and applying the corresponding correlation, several hydraulic pistons act to place the two sprayer panels accordingly in order to maintain the distance to the canopy, increasing the recovery capacity. Several practical evaluation tests of the system's performance have been conducted using artificial canopies with variable width dimension. Variations on panel's distance have been contrasted with actual vine size, and the prototype's response time has been estimated too. The forward speed of the sprayer was also taken into account for a correct reading of the sonic sensors, but always within the range desired by the farmers. In parallel, the effect of these adjustments on air stream patterns between panels has been studied. A 3D ultrasonic anemometer (Gill Instruments, Hampshire, UK) was used to record the instantaneous three components of the air velocity at different heights and depths between panels. Two distances between panels have been evaluated. The measurements were made with the sprayer static and without the presence of obstacles between the panels under laboratory-controlled conditions. Velocity vectors have been calculated. This analysis has allowed us to estimate the degree of influence of this row-width adjustment method on the generated airflow. This work highlights the potential for integrating proximal sensors to enhance the efficiency of a VRA-sprayer based on prescription maps.

Keywords: Tunnel sprayer, Vineyard, Adaptive control, Ultrasonic sensors, Airflow analysis

OP33-4 | Evaluation of agrochemical aerial distribution from UAS on a vineyard

Alberto Sassu[1], Vassilis Psiroukis[2], Francesco Bettucci[3], Luca Ghiani[4], Spyros Fountas[2], Flippo Gambella[1]
[1]Department of Agricultural Sciences, University of Sassari, Sassari, Italy, [2]Laboratory of Agricultural Engineering, Department of Natural Resources Management & Agricultural Engineering, School of Environment and Agricultural Engineering, Agricultural University of Athens, Athens, Greece, [3]Department of Land Environment Agriculture and Forestry, University of Padova, Padova, Italy, [4]Departement of Biomedical sciences, University of Sassari, Sassari, Italy

Plant protection products (PPPs) represent the standard worldwide tool in crop safeguarding, essential to avoid plant disease proliferation and yield losses. Addressing the challenge of replacing airplane and helicopter spraying characterized by distribution inaccuracies, product overdoses, and losses, Unmanned Aerial Spraying Systems (UASSs) emerge as a transformative solution with unique capabilities such as navigating complex terrains and executing low-altitude flights. This study explores the impact of UASS flight height, speed, and position on vineyard spraying coverage, canopy penetration, and off-target dispersion employing Water Sensitive Papers and a MATLAB image analysis script. The investigation revealed the optimal performance of the UASS operating at a 2 m height while flying over the inter-row (IR), minimizing off-target and ground dispersion. The IR flight configuration with strategically positioned nozzles above the canopy facilitated canopy penetration, reaching lower sections, and reducing off-target dispersion. The performance exhibited sensitivity to changes in flight speed, where faster rotation aided canopy opening and droplet penetration. The positive relationship between higher speed and improved efficiency underscores the significance of speed optimization in achieving optimal flight outcomes. The positioning of the flight significantly impacted the deposition of droplets on the target, off-target, and ground, leading to an increased coverage area in over-row (OR) treatments with higher flight heights. In IR treatments, a lower flight height was associated with reduced product dispersion, resulting in greater coverage area and penetration rate. Flight position and speed correlate closely, as higher speed and propeller rotation induce increased downward flow. OR treatments exhibit heightened influence in lower positions, facilitating ground and side-row waste. The droplet analysis method presented in this study showed potential in refining UASS spraying strategies in vineyards and open to further research to comprehensively assess the aerial PPP distribution effectiveness and environmental impact in agriculture. These investigations are crucial for the responsible implementation of this technology, particularly in regions where aerial treatments lack regulatory approval.

OP33-5 | Preliminary evaluation of a knapsack sprayer prototype that combines electrostatic technology and hydraulic spraying

Alba Vigo-Morancho[1], María Videgain[1,2], Mariano Vidal[1], Antonio Boné[1], F.J. García-Ramos[1,2]
[1]Escuela Politécnica Superior, University of Zaragoza, Ctra. Cuarte s/n, 22071 Huesca, Spain, [2]Instituto Agroalimentario de Aragón – IA2 (CITA-University of Zaragoza), EPS, University of Zaragoza, Ctra. Cuarte s/n, 22071 Huesca, Spain

Technological development and implementation for improving pesticide application has proven to be a valuable tool in designing and producing innovative equipment aimed at achieving sustainable practices in line with farmers' objectives. Electrostatic technology based is one of those advancements that, despite having been studied decades ago, has not yet been widely incorporated. Regarding Pesticide Application Equipment (PAEs), particularly focusing on small knapsack sprayers, it should not be dismissed that their utilization remains high in many countries, both in greenhouses and for spot applications in larger crops such as vineyards. However, the lack of regulation and control of these sprayers makes it difficult to track their acquisition and usage. Therefore, pesticide application research and improvement efforts must encompass this category of PAEs, ensuring that any incorporation aligns with the expected ease of use and economic cost associated with the purchase of such equipment.
The objective of this study was to conduct a preliminary evaluation of an electrostatic knapsack sprayer prototype designed to operate at 1 kV and equipped with a hydraulic nozzle that provides a range of droplet size values of Dv50 from 136 to 386 µm in the pressure range between 2 and 6 bar. In this sense, two sprayer configurations associated with connected or unconnected electrostatic system (ES or NES, respectively) were tested. Horizontal and vertical liquid distribution, as well as qualitative evaluation of deposition using water-sensitive papers, were carried out under laboratory conditions. Results showed no differences between ES and NES in terms of flow rate (L min-1) provided by the nozzle at any pressure. The total accumulated volume when evaluating the vertical distribution profile with NES was higher than with ES and this difference decreased at greater distances of application. However, percentage values of coverage, both on the side facing the nozzle and on the opposite side, were significantly higher when using ES, with increments of up to 20% compared to NES in some cases. The results obtained suggest that this technology could be a feasible option for enhancing treatment efficacy and integrating it into this type of equipment. Therefore, further experiments in terms of quantitative deposition and crop trials will be conducted to support these findings.

Keywords: Crop protection, charged droplets, pesticide, coverage.

OP33-6 | Performance evaluation of different pumps and pumpsets for agricultural application

Arthur Fajardo[1], Charleen Deniega[2], Fatima Joy Raytana-Aying[1], Marie Jehosa Reyes[1], Jerson Jose Menguito[1], Yaminah Mochica Pinca[1]
[1]University Of The Philippines Los Baños, Los Baños, Philippines, [2]Sorsogon State University, Castilla, Philippines

The Philippine government has identified agricultural mechanization as one of its strategies for addressing the country's food security. Performance evaluation of different bare pumps and pumpsets serves as a guide for government agencies and private institutions deciding on the unit to buy, distribute, and install on the farms. This study aimed to evaluate the performance of agricultural pumps and pumpsets tested by the Agricultural Machinery Testing and Evaluation Center (AMTEC) from 1989 to 2022, based on Philippine Agricultural Engineering Standards (PAES) 115:2000.

A total of 487 centrifugal pumpsets and 342 bare pumps were used in the study. The selected sizes for both pump and pumpset include 50 x 50mm, 75 x 75mm, and 100 x 100mm. For the pumpsets, only the engine-powered were selected. These were the common sizes and prime mover used for shallow tubewell (STW) and low-lift pumps (LLP) in the Philippines. The performance of the agricultural pumps was evaluated using two schemes. Scheme 1 was patterned to Resurreccion, et al (2008) while Scheme 2 was a modified version. In Scheme 2, a higher weight was assigned for the efficiency (40%), and equal weights for the total suction lift (30%) and pump speed (40%). Also, the discharge-to-input ratio was not included and the point system for the pump speed was modified.

Results showed that most bare pumps passed (6 points and above) using Scheme 1, with all 100 x 100mm non-self-priming passed. Meanwhile, the number of pumps passing the evaluation was reduced using Scheme 2, with 100 x 100mm self-priming obtaining the highest reduction (71 to 41/72). However, for the pumpsets evaluated using Scheme 1, most of the 100 x 100mm self-priming, close coupled (17/25); 75x75mm self-priming, close-coupled (79/100); 50 x 50mm self-priming, belt drive (6/6); and 50 x 50mm self-priming, close coupled (101/109) failed the evaluation (less than 6 points). On the other hand, the number of pumpsets that passed using Scheme 2 was reduced and had no change, except for 100 x 100mm non-self-priming, belt-driven, with the number of passing units increased from 73 to 81/97. With the modified scheme, putting weight on the efficiency (pump or system) has an impact on the performance evaluation of pumps and pumpsets. Appropriate tool (i.e. statistical) or system should be utilized to determine the optimum weight assignment for the evaluation scheme.

OP34-1 | Comparative analysis of deep learning models for a dairy cow face recognition framework

Hao-Ping Chen[1], Chen-Yu Liao[1], Jih-Tay Hsu[1], Ta-Te Lin[1]
[1]National Taiwan University, Taipei, Taiwan

In dairy farming, cow face recognition stands as a crucial technology, particularly for individualized health monitoring. This approach allows farms to effectively track individual cows' health conditions, such as body temperature and nutritional intake, which directly influence milk production and overall farm efficiency. This study aims to assess and enhance the accuracy and reliability of deep learning models in identifying individual dairy cows. Large-scale cow face images were collected from two dairy farms, comprising 104 unique cows. We built deep learning models utilizing different backbone architectures (Vision Transformer and ResNet) and loss functions (Arcface and Softmax Loss) based on the collected image datasets. Additionally, these models were trained on datasets with varying numbers of dairy cow and image quantities. This setup allows us to thoroughly investigate how these key factors affect model performance. Our findings revealed remarkable achievements in cow face recognition accuracy. When tested on a dataset with 104 cows, the Vision Transformer model reached 98.8%, and the ResNet model achieved 98.5% accuracy, both utilizing Arcface loss function for model training. We compared critical factors such as model backbone architecture and loss functions, observing that these factors significantly influenced model performance. Notably, the choice between Arcface and Softmax loss functions played a crucial role in the precision and effectiveness of dairy cow identification. Overall, our study sheds light on the potential of deep learning models for enhancing the accuracy and reliability of cow face recognition systems in dairy farming, with implications for improved individualized health monitoring and farm management.

Keywords. Cow Face Recognition, Deep Learning, Arcface, Precision Livestock Farming

OP34-2 | Image-based fish classification: Novelty detection via open-set fish recognition

Manuel Córdova[1], Maria Sokolova[1], Gert Kootstra[1]
[1]Wageningen University & Research, Wageningen, Netherlands

Seafood is one of the main elements for feeding the world's population. Recently, some regulations have been established stimulating an environmentally conscious use of marine resources, for example, the European Common Fisheries Policy Landing Obligation that aims at reducing fish discards focusing on the registration of all listed species. To comply with such regulations, machine-learning tools have been developed to collect and to process vast amount of data coming from fisheries. Similar to other fields, computer-vision applications have been proposed to deal with tasks, such as fish detection, classification, and weight estimation. Nevertheless, one of the main limitations of the current approaches is their closed-set nature, i.e., they are designed to only recognize fish species that were present during the training phase. In the real world, however, samples of unknown fish species can appear during execution in different fishing regions or seasons.

Differently from existing literature, this work focused on the use of open-set recognition to automate the registration process of fish, dealing with novel species. We compared the use of two well-known open-set methods: Multiple Gaussian Prototype Learning (MGPL) and Open-Set Nearest Neighbor (OSNN). MGPL uses a conditional variational auto-encoder to calculate the latent image representation, then Gaussian models are used to define the boundaries of the known classes in order to deal with the unknown. OSSN is a simple but powerful approach based on the k-nearest neighbors (k-NN) algorithm, which uses as input features extracted with a backbone trained on the known species, its inference stage uses the distance in feature space from the new sample to the training samples. To the best of our knowledge, this is the first work evaluating the performance of open-set methods in the context of fish recognition.

In our experiments, we used the publicly available FDWE dataset, which contains 2216 fish instances from 9 species. To use standard classification metrics, all unknown instances were put together in one category labeled as "Unknown". Experimental results demonstrated that OSNN was the best performing method with a weighted F1-score of 86.78±4.03 surpassing MGPL by 15.26 percentage points. Using OSNN, 82.45±5.67 of novel fish species were correctly detected, while keeping an accuracy of 86.38±0.70 among the known species. Open-set fish recognition brings real-world challenges not present in standard computer-vision datasets, such as distinguish among fish species that look visually similar, different levels of illumination, partly occluded fish, among others.

OP34-3 | From pixels to airflow: Exploring image similarity methods for barn ventilation analysis

Ali Alaei[1], Sabrina Hempel[1], David Janke[1], Thomas Amon[1]
[1]Leibniz-institut Für Agrartechnik Und Bioökonomie E.v., Potsdam, Germany

Accurate determination of air exchange rates in agricultural environments is critical for animal comfort, worker well-being, and economic sustainability. Current measurement methods face challenges in spatial and temporal variability, resource-intensive processes, and ambiguity in defining inlets and outlets.
This study introduces a novel approach utilizing Computational Fluid Dynamics (CFD) and image similarity methods for barn ventilation analysis. A diverse dataset of barn environments was synthetically generated through ANSYS software, ensuring precise control over variables. Image similarity metrics such as Mean Squared Error (MSE), Structural Similarity Index (SSI), and others were selected for evaluation.
Baseline and specialized testing were conducted to assess the capability of image similarity methods to quantify modification of airflow under various conditions and the sensitivity of image similarity methods to the degree of change.
Statistical analysis revealed significant differences between image similarity metrics. The Mean Squared Error (MSE) method emerged as a robust choice for quantifying air exchange rates in naturally ventilated barns and excelled in detecting subtle differences. The normalized cross correlation (NCC) demonstrated superior performance in maximizing image similarity. Practical implications and contextual considerations for metric selection as well as potential contributions to advancing methods for evaluating barn ventilation will be discussed in this contribution.

OP34-4 | Cultivating knowledge: A comprehensive dataset for monitoring germination of cannabis sativa in greenhouse-controlled environments

Carmen Rocamora Osorio[1], Ana María Codes Alcaraz[1], José Antonio Brenes[2], Francisco Javier Ferrández Pastor[3]
[1]Instituto de Investigación e Innovación Agroalimentaria y Agroambiental, Universidad Miguel Hernández, Orihuela, Spain, [2]Universidad de Costa Rica, , Costa Rica, [3]Grupo de Investigación de Informática Industrial y Redes de Computadores, Universidad de Alicante, Alicante, Spain

Controlling the number of plants produced during the germination process is crucial. By carefully managing the germination rate, growers can ensure that the available space, nutrients, and environmental conditions are utilized effectively. This control allows for better monitoring and management of potential issues such as diseases, pests, and environmental stressors. Additionally, controlling the number of plants aids in planning and maximizing crop yields, contributing to sustainable agriculture practices. Furthermore, in the cultivation of Cannabis sativa L., precise control over the number of plants during the germination process is critical due to legal and regulatory restrictions associated with the cultivation of this crop, since many regions have stringent regulations on the number of cannabis plants that can be grown per cultivation site. By carefully managing germination rates, cultivators can adhere to these legal limits, ensuring compliance with local laws.
To assist growers in tracking germination progress, we planned to developed a classifier that informs them precisely when a plant has successfully germinated in the seedbed. A well-curated dataset is essential for teaching the algorithm to recognize different features. The dataset should encompass a diverse range of examples to ensure that the classifier can accurately identify and categorize instances it encounters during its operation. The quality and diversity of the dataset play a pivotal role in the performance and reliability of the developed classifier. Due to the limited information available on cannabis crops, we undertook the task of constructing an image dataset from the ground up. This dataset was meticulously crafted through a rigorous process, enabling its use for training the classifier.
The images were taken in a greenhouse. For the experiment, we used two seedbeds of 72 cells. Two varieties of cannabis were sown: Finola and Kompolti. One variety was sown in each seedbed. A camera fixed above the seedbeds, connected to a Raspberry Pi 4B, took one image every hour throughout each iteration. Four iterations were carried out: two without controlling climatic conditions, and two with controlled conditions and photoperiod. We cropped the images and applied a homography process to correct perspective. The resulting images of each cell for each date and hour were labeled, using 6 categories: germination, not germination, only cotyledon, true leaves, invasion and not invasion. The result was a comprehensive dataset comprising around 88,840 images of seedbed cells showcasing plants at various growth stages. This paper outlines the step-by-step process employed in creating this image dataset.

OP34-5 | AI-enhanced language support for advanced operation in controlled environment agriculture

Ramesh Arvind Naagarajan[2], Kiran Kumar Sathyanarayanan[1], Nadja Bauer[2], Philipp Sauerteig[1], Sebastian Bab[2], Stefan Streif[1,3]
[1]Chemnitz University of Technology, Chair for Automatic Control and System Dynamics, Chemnitz, Germany, [2]University of Applied Sciences and Arts, Department of Computer Science, Dortmund, Germany, [3]Fraunhofer Institute for Molecular Biology and Applied Ecology, Department of Bioresources, Giessen, Germany

Optimization-based control of greenhouses and indoor farms has gained popularity due to the growing demand for energy-efficient and sustainable crop production. Model Predictive Control (MPC) is an advanced optimization-based control strategy that regulates the greenhouse climate based on a mathematical model and weather forecast data. Despite gaining popularity among researchers, the acceptance of this method among suppliers of greenhouse climate control systems and growers remains limited. The primary reasons are the lack of transparency and the understandability of the control algorithms. Additionally, there is difficulty in quickly comprehending the output generated by the control algorithm for various goals and grower-defined bounds.
In this work, we introduce a language-based support system designed to offer a comprehensive summary of the greenhouse's single-day climate trajectories. The support system provides growers with a brief and easy-to-understand report that highlights any major changes in the greenhouse's climate, thus facilitating the integration of advanced control strategies into real-world farming practices. In this work, MPC is used to generate the control input and climate trajectories tailored to the operation of a greenhouse.
The language-based support system as a first step, dynamically segments the generated time-series reference data using the Change Point Detection (CPD) method to identify the significant slope change. The evaluation and comparison of the goodness of the fit to the ground truth are conducted among various CPD methods, eventually leading to the selection of the Pruned Exact Linear Time (PELT) algorithm. Secondly, the Natural Language Generation (NLG) method generates meaningful and coherent long texts from the identified change points and non-linguistical data. The detailed long texts are finally condensed into user-friendly information using a pre-trained Large Language Model (LLM) by formulating an output-focused prompt.
The presented work will assist the growers in receiving a clear and concise summary of the greenhouse climate without delving into the intricate details. Correspondingly, the tool can also be used to compare the operation of the greenhouse on different days with the help of automatic summary generation. This research offers a potential future method for generating practical insights into greenhouse management by combining MPC and NLG, which could improve efficiency and accuracy in agricultural practices.

Keywords: Natural language generation, predictive control, change point detection, time-series to text, machine learning

OP34-6 | SSL-NBV: A self-supervised learning-based NBV algorithm for efficient plant reconstruction by robot

Jianchao Ci[1], Gert Kootstra[1], Xin Wang[1], Eldert J. van Henten[1]
[1]Wageningen University & Research, Wageningen, Netherlands

For robots to deal with plants, the 3D reconstruction of these plants by the robot's vision system is crucial to perform downstream tasks like harvesting and phenotyping. However, efficient reconstruction of the plants is challenging due to the complex morphology of plants, which creates high levels of occlusion. To solve this problem, next-best-view (NBV) methods actively reposition the camera to the viewpoint that is expected to achieve the highest information gain (IG). Voxel-based NBV methods use 3D occupancy maps and ray-casting for IG calculation. They have been shown to efficiently gather information from multiple viewpoints, but the ray-casting procedure is slow. Deep-learning-based NBV (DL-NBV) methods, do not explicitly calculate IG but instead learn to predict IG from examples. However, a big challenge of DL-NBV methods is the substantial amount of IG-annotated data required for training. Moreover, existing methods require ground-truth information about the morphology of the object to calculate the ground-truth IG, which obviously is not available for real plants in a real environment.

We propose self-supervised learning-based NBV (SSL-NBV), enabling a robot to autonomously gather its own training data allowing it to continuously learn and improve during the execution of the task. The method consists of a deep neural network that predicts the information gain of potential next viewpoints based on the current point-cloud reconstruction and past viewpoints. It utilizes an enhanced IG calculation metric, weakly supervised learning, and experience replay.

We tested the method in simulation and real-world environments, showing a reconstruction performance on par with a voxel-based method but with a 818 times faster computation time. Additionally, our method significantly reduced training data annotations by 92.60% compared to a baseline DL-NBV method. Most importantly, our method does not need a separate training and execution phase, but instead continuously learns, allowing to adapt to novel situations.

OP35-1 | SmartIrrigation cropfit – A decision support tool for scheduling irrigation in cotton, maize, peanut, and soybean

George Vellidis[1]
[1]University Of Georgia, Tifton, United States of America

SmartIrrigation CropFit (SI CropFit) is a decision support tool (DST) for scheduling irrigation in cotton, maize, peanut, and soybean that operates on a smartphone platform. It utilizes the FAO-56 method coupled with a soil water balance model to provide irrigation recommendations to users. The FAO-56 method uses reference evapotranspiration (ETo) calculated from meteorological data multiplied by a crop coefficient (Kc) to estimate daily crop water use, also referred to as crop evapotranspiration (ETc). ETo accounts for varying weather conditions and Kc changes with crop growth stage. The DST operates by maintaining a root-zone soil–water balance. Daily ETc is subtracted from the balance, and precipitation and irrigation are added to the balance. If the balance decreases below a pre-set threshold, the user receives a notification that irrigation is required. Users delineate the perimeter of their field. The field's geographic coordinates are used to pull meteorological data via application programming interfaces (APIs) from state-operated weather station networks in the United States, world-wide gridded weather data sets, and on-farm automated rain gauges to calculate ETo. The DST estimates crop growth using accumulated heat units or growing degree days (GDDs) associated with crop-specific phenological stages. The DST uses the perimeter of the field to extract soil properties from the USDA NRCS Web Soil Survey which are in turn used to estimate the root zone's plant-available water holding capacity. Plot-scale and on-farm research conducted at the University of Georgia, the University of Florida, Auburn University, and Mississippi State University has shown that scheduling irrigation with SI CropFit results in 5–15% greater yields and up to 40% greater irrigation water use efficiency (IWUE) when compared to traditional calendar-based irrigation scheduling tools recommended by many Extension services in the United States. The DST has similar results to scheduling with soil moisture sensors. SI CropFIT has 851 users who have applied the DST to 3,598 irrigated fields, most located in the southeastern United States. This paper will describe how the DST operates, compare its performance to traditional and other advanced irrigation scheduling methods, and discuss functionalities under development that will further improve the performance of the model.

OP35-2 | Irrigation water management in rice fields to sustain environmental flow requirements in Axios river basin

Charalampos Doulgeris[1], Evangelos Hatzigiannakis[1], Nikoleta Papastamkou[1]
[1]Soil & Water Resources Institute, Hellenic Agricultural Organisation, Sindos, Greece

In Greece, irrigated agriculture is the largest consumer of water, potentially causing significant environmental impacts. Given the pressure that the water bodies are under, the proper management of irrigation water is necessary to improve the ecological conditions in the river estuaries. The need for irrigation management practices that safeguard sustainability becomes even more imperative due to the expected increase of temperature, and thus the increase of evapotranspiration, in the coming decades, due to climate change.
This work aims to mitigate the reduction of the flow regime in the estuary of River Axios and to contribute to the improvement of the water flow conditions in the riverbed, through irrigation water saving, considering that the yield and quality of agricultural products are kept at a similar level.
To achieve the above goal, this research includes: i) Application of reduced irrigation relative to common local practice in a rice field of 8,2 ha. The field is divided into three experimental layouts; in the first one, irrigation is applied according to the local agricultural practice, while in the other two, the annual applied water is reduced to 75% and 50%, respectively. ii) Evaluation of irrigation scenarios to crop yield, considering rice quality. iii) Assessment of water flow that ends up in the estuary of River Axios, using a water resources management model, and examine the fulfillment of the environmentally minimum flow (ecological discharge) in the river's estuary for each irrigation scenario.
Preliminary results from the first year of the field experiment show that the rice yield and quality are almost identical in the three layouts, indicating a significant saving of irrigation water in the Axios river basin without any loss of agricultural income.
This work is implemented in the framework of the ongoing RicEnviFlow project (https://ricenviflow.gr) funded by the Greek Rural Development Programme 2014-2020 (M16ΣYN2-0035). The project's key objective is to improve irrigation efficiency in rice crop, and to promote a new – environmentally sustainable, economically efficient, and socially equitable – culture in agronomic practices that will ensure the protection of the environment without compromising rural development, through integrated water resources management.

Keywords: irrigation scenarios, rice crop, environmental flow, reduced irrigation

OP35-3 | Application of the soil and water assessment tool (SWAT) model to assess mitigation strategies for diffuse nutrient pollution in Iowa, United States

Philip Gassman[1], Tássia Brighenti[1], Yongjie Ji[1], Janette Thompson[1]
[1]Center For Agricultural And Rural Development, Iowa State University, Ames, United States of America

The State of Iowa is located in the western part of the U.S. Corn Belt Region and is characterized by intensive row crop (corn and soybean) and livestock production. This intensive agricultural production manifests pervasive nutrient export from cropland landscapes, resulting in elevated in-stream nutrient levels that also contribute to a seasonal hypoxic zone in the northern Gulf of Mexico via Mississippi River discharge. A modeling system has been developed using the Soil and Water Assessment Tool (SWAT) ecohydrological model (https://swat.tamu.edu/) to assess alternative management strategies to mitigate diffuse nutrient pollution for the Des Moines River Basin (DMRB), which drains an area of nearly 32,000 km2 in north central and central Iowa. Funding support for the modeling system has been provided from three different projects: (1) Iowa UrbanFEWS (https://iowa-urbanfews.cber.iastate.edu/), (2) Diverse CornBelt (https://diversecornbelt.org/), and (3) Iowa Nutrient Research Center (https://www.cals.iastate.edu/inrc/projects).

Detailed representation of cropland and other land use are incorporated in the modeling system, along with baseline tillage, nutrient applications, subsurface tile drainage and other management practices. Soil, topographic and climate data are other key inputs included in the model structure. Extensive hydrologic and other testing has been conducted with SWAT, to ensure robust scenario results. The SWAT-based modeling system thus provides a flexible platform to evaluate alternative cropping systems, tillage management and other practices that can be introduced to mitigate diffuse nutrient losses. Overviews of the extensive nutrient management problems occurring in Iowa and the structure of the modeling system will first be presented, followed by a summary of the DMRB hydrologic and other testing that has been performed with SWAT. Background information regarding specific scenarios will be presented next including the following mitigation strategies: (1) replacement of row crops with multiple horticultural (fruit and vegetable) crops), (2) introduction of a winter cereal rye cover crop between corn and soybean growing seasons, (3) installation of field buffers downslope of row crop landscapes, and (4) expansion of no-tillage on row cropped areas. Results of the different cropping system and management strategies will anchor the presentation with an emphasis on the expected reductions in nutrient losses that would occur.

OP35-4 | Use of NIR regional scale calibrations to map soil characteristics for PA: A case study in 5 fields

Andrea Lazzari[1], Nicolò Pricca[1], Andrea Gasparini[1], Giovanni Cabassi[1]
[1]Council For Agricultural Research And Economics - Research Centre Animal Production and Aquaculture, Via Antonio Lombardo, 11, 26900, Lodi (LO), Italy

In Italy, the adoption of precision agriculture is escalating. However, the operational costs pose a significant impediment to its adoption. Near-infrared spectroscopy (NIR) is out-well established low-cost technique used in northern Italy for soil analysis; this research presents the result of the application of this technology at a sub-field scale for PA mapping purposes of soil texture and organic carbon content across five fields in diverse locations within the Po Valley. The selected trial fields exhibit varied soil types and have undergone different tillage and fertilization practices, which could affect soil attributes.

Soil samples were collected according to a 50-meter regular grid at a depth of 30 cm. These samples were both analysed by an external laboratory employing standard wet reference methods and analysed utilizing a FOSS NIRSystem 5000 spectrometer.

The NIR analysis, conducted on spectra obtained in diffuse reflectance within the 1100-2500 nm range, employed the LOCAL calibration technique (US Patent # 5,798,526). This method, a locally weighted calibration approach, selects samples from a vast database with spectra similar to those under examination. It utilizes principal component analysis (PCA) on soil spectral data, creating models from a reference dataset of topsoils (0-30 cm) from arable fields in Northern Italy, encompassing 1500 samples.

The NIR-based estimations for clay content, clay+silt, and organic carbon content were evaluated using Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and bias metrics. Specifically, the analysis focused on bias (the systematic error component) and the coefficient of determination (R^2) correlating the actual, laboratory-measured values with the NIR-predicted values (0.70, 0.62, 0.68 respectively). The bias evaluation identified a low value for the soil components under analysis in all the fields, except for one in clay+silt (bias > ±100) and two in organic carbon (bias > ± 0.4).

Results showed good skill of the NIR calibrations to estimate field averages of the parameters under analysis. The Range/MAE allowed the identification of in-field variation gradients. For clay the ratios ranged from 2.4 to 9.9, for clay+silt from 1.4 to 8.4; for organic carbon, the ratio ranged from 3.4 to 5.9, depending on the variability of the field.

The findings indicate that, after adjusting for bias, NIR LOCAL calibration data can be used not only for mean field values determination but also for effectively identifying trends in soil texture variation and, to some extent, organic carbon gradients.

Keywords: Precision agriculture, NIR spectroscopy, soil characterisation, soil mapping.

OP35-5 | CultiSensor – Smart subsoiler for automatic generation of soil resistance maps, and its correlation with soil compaction

Fran Garcia-Ruiz[1], Ramon Salcedo Cidoncha[1], Francisco Fonseca[2], Emilio Gil Moya[1]
[1]Universitat Politècnica de Catalunya (UPC), Castelldefels, Spain, [2]AKIS international, Lleida, Spain

Precision agriculture relies on data that is translated into management prescriptions . Soil mapping allows fields to be managed as homogeneous zones, or considered as heterogeneous and variable parcels, allowing then to implement variable management procedures. Soil compaction is an important factor to consider, as it affects several soil and crop processes, including water infiltration rates, root development, and water availability to crops. In this study, a new prototype of a fully digitised commercial subsoiler (Jympa, Castellserà, Spain) has been developed in the framework of the CULTISENSOR project. The implement has been equipped with a GNSS system and several independent oil pressure sensors (one for each hydraulic cylinder of every arm), as well as an ultrasonic sensor to monitor the working height. A control unit developed by Waatic (Abrera, Spain) is capable of storing the data read at each point of the plot, allowing the oil pressure of the cylinders to be traced in real time, generating the corresponding soil resistance maps (MPa). In this context, an evaluation of the system's performance was carried out on selected plots. The sensor's capability was validated in terms of accuracy, repeatability, and consistency of the data. The prototype was compared with physical soil characterization in the different zones identified in the maps. The EM38-MK2 electromagnetic soil sensor (Geonics, Canada) was also used to produce maps of apparent electrical conductivity (ECa). These maps were used to assess the spatial variability of the soil and to compare its distribution with that generated by the prototype subsoiler. This study has served to carry out a first validation of the prototype developed in the CULTISENSOR project and to propose new adjustments to be carried out to improve the validity and reliability of the soil maps. This work highlights the potential of taking benefit of current operations in the field to acquire complementary information for a more informed management of agricultural operations.

OP35-6 | Soil tillage quality measurement: A methodical approach

Marina Graf[1,2], Franz Fuchshumer[1], Marcus Geimer[2]
[1]AGCO GmbH, Marktoberdorf, Germany, [2]Karlsruhe Institute of Technology , Karlsruhe, Germany

This paper presents a methodical approach for systematically measuring the process quality of the agricultural task soil tillage, with a special focus on the cultivating process. This is an essential step in the development of automation towards the vision of fully automated agricultural field work. The proposed approach for measuring process quality for autonomous tillage involves three basic steps. Firstly, the relevant parameters that define the process quality are identified. These parameters depend on the agricultural task, such as primary tillage, stubble cultivation or seedbed preparation and are based on the farmer's expertise. The quality parameters are the identified set of parameters for each task that indicate the quality of the process. Secondly, the measurement method presented in this paper is applied to these quality parameters. The method involves the implementation of different algorithms to characterize the quality parameter. The algorithms can be based, for example, on 3D point cloud data or image data. As there is no reference measurement method available to verify the developed algorithms, the proposed strategy is a two-step process. In a first step, the different implementations are evaluated by cross-correlation. The second step is to verify the plausibility of the best rated algorithms in a deterministic environment, such as a simulation environment. The measurement method is validated by testing the implementation in reality, considering challenging cases and anomalies, and taking into account factors such as speed and soil dependency. Finally, the measurement method for the quality parameter is used to derive a model that describes the variation of the parameters with respect to the degrees of freedom of the agricultural task, e.g. the working speed for the cultivation process. With this model, a multi-criterial optimization can be performed with respect to the quality parameters to obtain the best settings for tractor and implement.

OP36-1 | Key technologies for fully intelligent production of kiwifruit

Leilei He[1], Longsheng Fu[1]
[1]Northwest A&F University, Yangling , China

Traditional kiwifruit production relies heavily on manual labor, resulting in inefficiency and inconsistent yields. Automation of bud thinning, flower pollination, yield estimation, fruit picking and branch pruning is critical to solving these problems.
As bud thinning is crucial for nutrient management, a robotic system based on bud classification and laser was developed to detect and destroy redundant side buds. Multi-classification bud detection strategy based on the latest YOLO model is proposed. A laser end-effector removes redundant buds under the control of a robotic arm.
Automated flower pollination system based on optimal flower targeting and electrostatic spray was proposed to overcome the limitations of natural and manual pollination. An optimal flower targeting strategy using new YOLO for multi-class flower detection and Euclidean distance matching was proposed. An air-assisted liquid pollination method operated by a robotic arm enables precise pollination by controlling the spray duration, and an electrostatic generator provides better pollen adsorption.
Yield estimation is critical for resource allocation. A multi-target tracking and counting algorithm based on new YOLO model and ByteTrack was proposed, ensuring accurate fruit counting for yield estimation.
Fruit picking robot was designed based on multiple categories detection and bending of fruit-stem. Multiple categories detection based on occlusion degree is proposed to minimize branch interference during robotic harvesting. An end-effector has been designed with bending of fruit-stem, complemented by a separation test to guarantee the nondestructive detachment and preservation of fruit quality. To improve harvesting efficiency, dual-arm harvesting robot and strategy are proposed.
Automated branch pruning system based on optimal pruning point localization and pulse-control actuator was proposed to cope with the need for high expertise in traditional manual pruning. An algorithm based on branch distribution is proposed for optimal pruning point localization, which can identify and classify branches based on bud morphology. A pulse-control based pruning actuator is designed to maintain high shear force and applicability for branches of different diameters.
Key technologies for intelligent kiwifruit production have improved efficiency and accuracy in agricultural process. Yield estimations reach 90% accuracy. A versatile robot, capable of switching between tasks with different end-effectors and image detection modules, achieves task times of 1.5s for thinning, 1s for pollination, 2s for picking, and 5s for pruning. Future research can continue to explore more economically practical intelligent equipment, strengthen the training and awareness of farmers on the new technology, and promote the application of intelligent agricultural technologies in a wider range.

OP36-2 | Localization of metal piles in grapevine rows by means of LiDAR based 3D reconstruction

Andreas Heiss[1], Joseph Bleser[1], Nikos Tsoulias[1], Björn Poss[1], Dimitrios S. Paraforos[1]
[1]Geisenheim University, Geisenheim, Germany

In trellis training systems of grapvines, the removal of pruned wood from the supporting material is one of the most time-consuming work steps. Pre-pruners can ease this work but operating them requires constant attention to make adjustments and avoid harmful collision with the piles of the supporting material. Automated avoidance systems using mechanical, optical or inductive sensors are commercially available but still error-prone, limited either by the material, shape or circumference of the piles, or the vines' growth characteristics.
In various research related to specialty crops like fruit trees and grapevines, Light Detection and Ranging (LiDAR) systems have proven to be a promising and robust tool to generate highly accurate phenotypic 3D reconstructions. The aim of this work was to develop and validate a methodology for the absolute localization of metal piles from 3D point clouds of grapvine rows by means of a LiDAR system embedded in a multi-sensor framework.
A sensor frame for attachment to the front of a tractor was designed, which comprised a LiDAR as well as an RTK-GNSS and an Inertial Measurement Unit (IMU). Ground-based measurements were conducted at a speed of 0.5 km h-1 in four rows with different varieties of vitis berlandieri in low cordon training during the dormant phase, comprising an approximate row length of 100 m and 163 piles in total. After a sequence of transformation steps, the single LiDAR scans were composed to georeferenced point clouds representing a 3D reconstruction of the rows. From this, the lower part of the trellis was extracted based on the height above the ground. Then, an incremental analysis of the point density was conducted to identify the piles and trunks as single objects. The piles were segmented using the reflectivity values provided by the LiDAR and reconstructed with the aid of Principal Component Analysis.
The validation has shown promising results with a 100% true-true detection of piles within the measured rows. A comparison with ground truth measurements conducted with RTK-GNSS at the piles has resulted RMSE values below 10 cm in the horizontal plane, which was considered as an acceptable accuracy for using this information in automated pile avoidance systems of pre-pruners. Further investigations should deal with assessing the suitability of reflectivity values for other pile materials. Beyond that, the developed method shows a high potential also for other applications like e.g. trunk inventory.
Keywords: Grapevine pruning, pre-pruner, LiDAR-based 3D reconstruction, multi-sensor fusion

OP36-3 | Continuous monitoring of an Agri-PV-covered pear orchard with autonomous solar-powered UGVs

Nicolas Congouleris[1], Athanasios T. Balafoutis[1], Nikos Mylonas[2], Giorgos Bokouzis[2], Stefan Hol[3], Hellen Elissen[3], Cláudia Fernandes[4], Filipe Serra[4], Bruno Barrionuevo[1], Thanasis Tzimourtas[5], Emmanouil Christakis[5]
[1]iBO - CERTH, Volos, Greece, [2]Edencore Technologies, Athens, Greece, [3]Stichting Wageningen Research, Wageningen, The Netherlands, [4]EDP NEW, , Portugal, [5]Agricultural University of Athens, Athens, Greece

Making solar energy more affordable and reliable requires new methods for Operation and Maintenance (O&M) of photovoltaic (PV) farms. Robots are increasingly being used but still rely heavily on human intervention for operation and data interpretation. Consequently, these methods are prone to human error, scale poorly, and may still expose workers to dangerous, dull and dirty jobs. These factors considerably increase the cost of O&M, limiting the frequency of activities to a minimum. This prevents the early detection of problems, which can result in deterioration of the PV system, decreased energy yield and high economic losses.

To alleviate this, the project TALOS (roboTics and Artificial intelligence Living labs improving Operations in PV Scenarios), proposed and funded by the EU Horizon programme, was launched in October 2023. It aims to deploy a fully autonomous robotic fleet for unmanned monitoring, inspection and O&M in three PV scenarios: land-based, floating and agrivoltaics.

The envisioned system emphasises robot-robot and human-robot collaboration. At its core lies the TALOS platform, which will coordinate operations, process data from all robots, host digital twins of the PV systems, recommend actions, and present intelligible information to human operators. UAVs will inspect the PV panels, gathering visual and thermographic data to assess their health. Additional robots will be integrated into each scenario, adapted to their challenges: in the particular case of agrivoltaics, autonomous crop inspection will be implemented using the EdenCore Viewer, a commercial perception system designed for this purpose, mounted on a Clearpath Husky UGV.

The agrivoltaics site is a facility of Stichting Wageningen Research located in Randwijk, the Netherlands, and consists of a pear tree orchard partly covered by PV panels. It is composed of four fields: one control and three covered by bi-facial panels with different transparencies (5%, 40%, 70%) to study how the shelter they provide affects crop yield.

The Husky will navigate the orchard, capturing images of each tree and, when needed, using wireless charging stations placed in the field and powered by the PV installation. Collected data from all the embarked sensors will be used for balancing energy production and crop yield, recognising cultivated plants, and detecting anomalies at an early stage. The TALOS platform will then be able to predict yield, based on crop status and treatments of the farmer, and propose supportive actions, precisely adapting water and chemical use to the actual needs, thus reducing their consumption.

Agrivoltaics, robotics, AI, monitoring, automation

OP36-4 | Potential challenges encountered when adopting new technologies such as proximal sensing to realize VRA applications in cotton

Nikolaos Georgiadis[1], Konstantinos Papachristos[1], Vlasios Mangidis[1], Evangelia-Maria Giatsiou[1], Evangelos Adamopoulos[1], Christina Vogiatzi[1]
[1]CNH Industrial, Athens, Greece

Increased public awareness along with the rising new technologies are key driving forces towards sustainable productivity. Precision agriculture -based on data-driven decisions- is a valuable asset, the utilization of which might contribute to achieving this goal. The scope of this study was to evaluate the efficiency of Variable Rate Applications (VRA) in cotton, an input intensive crop, when utilizing proximal sensing technologies compared to conventional farming techniques. Large scale pilots have been set up, where split-plot applications have been performed. The different treatments include VRA's of multiple inputs typically applied in-season including Plant Growth Regulators, Boll Openers and Defoliants as well as flat rate applications of each agrochemical respectively. For the realization of the VRA treatments a multispectral camera-based system (Augmenta TM), has been used. This system gathering data regarding the field's condition generates a Vegetation Index (NDVI based) upon which different, proprietary, agronomic algorithms are utilized for each of the agrochemicals applied enabling VRAs in real-time, while the farmer is driving on the field without further need for additional calibration. For the evaluation of the efficiency of the VRA treatments each plot was harvested separately at the end of the growing season and yield was determined gravimetrically. In all VRA treatments, 5.5% and 7.5% of savings were realized regarding PGR and HA respectively. Despite the positive outcome, several challenging points are to be considered, if high adoption of such an approach is to be expected. Farm size can be an inhibiting factor, especially in countries such as Greece, where the pilot was set, since the expected time for the Return Of Investment (ROI) is extended compared to larger agroholdings. The farmers' demographic profile might have a high impact as well since elder people of lower education are less willing to test new approaches. Likewise, existing farming techniques eg fertigation and planting distances, and low-tech machinery might also affect the adoption rates. Finally, existing infrastructure such as wi-fi coverage could have an impact as well. Plug and Play solutions as well as alternative options are to be considered since global trends and regulations appoint sustainable productivity as an inevitable one-way.

OP36-5 | Utilization of an on-line dual sensor system for soil property measurement and mapping

Rukayat Oladipupo[1], Muhammad Abdul Munnaf[1], Ajit Borundia[1], Abdul Mouazen[1]
[1]Ghent University, Gent, Belgium

Real-time assessment of within-field soil fertility variation is crucial for making informed and sustainable decisions, like crop nitrogen (N) fertilization. Two commonly used soil sensors i.e., visible-near-infrared (vis-NIR) spectroscopy and ion-selective electrodes (ISE) have been reported to successfully estimate various soil macronutrients and nitrate N, respectively. However, their integrated use for mapping a full-scale soil fertility variation has not been taken into consideration to date. The objective of this study is to utilize an on-line dual-sensor system of vis-NIRS and ISE to estimate key soil fertility indicators including mineral nitrate-N, and map within-field soil fertility variations. An ISE sensing system was first developed and integrated with an available on-line vis-NIR sensing system. The sensing system was mounted to the three-point linkage of a tractor and surveyed two arable fields in Belgium. A total of 10 soil samples were collected for laboratory analyses of pH, organic carbon (OC), extractable-phosphorus (P), potassium (K), calcium (Ca), moisture content (MC). These samples were augmented with 146 soil samples from the spectral library to develop and validate partial least squares regression models for the vis-NIRS sensor. A linear regression model was established for validation of the ISE sensor. Maps for on-line measured soil attributes were generated using the inverse distance weighting and ordinary kriging methods for ISE data and vis NIR, respectively. The linear correlation confirms a very high similarity between ISE-measured nitrate-N and laboratory-analyzed nitrate-N (0.93). Besides, vis-NIRS demonstrates very good prediction accuracies for all the fertility attributes concerning the coefficient of determination ($R2$ = 0.70-0.78), root mean square error (RMSE =0.52-2.46 %) and residual of prediction deviation (RPD = 1.89 to 2.13). Validation between laboratory and on-line measured soil maps also shows quite comparable spatial distribution patterns. Therefore, the proposed dual on-line sensor system likely has a high potential to estimate and map within-field spatial fertility distributions including nitrate-N, offering a basis for sustainable management decisions for precision soil and crop production.

OP36-6 | Evaluation of supercontinuum laser line illumination for imaging spectroscopy in agriculture

Gerrit Polder[1], Selwin Hageraats[1], Junior de Vries[2]
[1]Wageningen University & Research, Wageningen, Netherlands, [2]The Hague University of Applied Sciences, The Hague, Netherlands

Imaging spectroscopy (hyperspectral imaging) is an imaging technique that provides a light spectrum for each pixel in an image. This technique allows spatial resolved chemometrics, such as calculating the water, nutrient or sugar concentration in fruits and leaves. For illumination in imaging spectroscopy, a broad spectral range with a smooth spectrum, and high intensity are required. Traditionally tungsten halogen incandescent sources are used. More recently also LED sources entered the market. These light sources have disadvantages, such as low intensity, the projection angle differs from the camera's field of view and heat emission.

A new technique based on supercontinuum laser technology, combined with a line light generator is recently being developed. The optical power of this system is much larger than for the existing illumination sources, furthermore the optical line light generator can be placed in line with the field of view of the camera, which compared to the current setup results in constant illumination at all distances from the camera.

In our research a supercontinuum laser light source (NKT Photonics, SUPERK FIANIUM) emitting the full spectrum between 400 and 2400 nm is used as illumination source in an imaging spectroscopy setup consisting of spectrograph-based line scan cameras in VNIR (400-100nm) and SWIR (900-1700nm) range (Specim FX10, FX17). Special optics, that project a line exactly in the camera field of view, are used. The nature of this light source makes it also possible to measure light interactance by positioning the laser line parallel at an offset to the camera field of view.

The performance of the system illuminated by the supercontinuum laser is compared in terms of sensitivity, noise, and stability, to the performance when using LED (VNIR) and halogen (SWIR) illumination standard calibration objects. Fruit, leaves, and plants differing in water content are imaged with both light sources and classification and regression performance is compared. Furthermore, tomato fruits are recorded in reflection and interaction mode and performance difference in prediction of soluble solids (sugars) is evaluated.

OP37-1 | Automation systems in management of remote bee apiaries

Vasileios Kilimpas[1], Efthymios Rodias[2]
[1]National And Kapodistrian University of Athens, Department of Agricultural Development, Agri-Food and Natural Resources Management, Psachna, Evia, Greece, [2] Institute for Bio-Economy and Agri-Technology (iBO), Centre for Research and Technology-Hellas (CERTH), Thermi, Thessaloniki, Greece

Apiculture presents significant growth the latest decades in Europe and worldwide. According to FAO, the bee colonies in Europe in 2021 were 25.1 million with most of them to be located in the Southern-Eastern countries. Smart technologies have invaded in almost every pillar of agriculture, including apiculture. Modern apiculture is rather nomadic than sedentary. Nomadism in beekeeping implies the settlement of bee colonies in more than one place per year in order to select more honey, pollen and contribute to the overall growth of the bees. To this scope, it is efficient to monitor and have a wide control of them remotely in parallel with other smart applications. This paper outlines a series of automation systems in apiculture used in optimization of bee apiaries management processes. Sensors and communication means may transfer multiple bee-related data from various locations where the beekeeper has settled his bee apiaries. The beekeeper is able to optimize the whole management operational and strategic planning throughout the year. Reduced cost, increased honey production and minimum CO2 emissions are only a few of the advantages of such automation systems.

Keywords: apiculture, beekeeping, smart farming, automation control.

OP37-2 | Effectiveness of using drone-based thermal /infrared in enhancing the performance of controlled environment agriculture

Rwan Al Najadi[1], Yaseen Al-Mulla[2], Abdullah Al-Saadi[3], Ibtisam Al-Abri[4]
[1]Department of Soils, Water and Agricultural Engineering, Sultan Qaboos University, Al Khod, Oman, [2]Remote Sensing and GIS Research Center, Sultan Qaboos University, Al Khod, Oman, [3]Department of Plant Sciences, Sultan Qaboos University, Al Khod, Oman, [4]Department of Natural Resources Economics, Sultan Qaboos University, Al Khod, Oman

One of the requirements that must be met in greenhouse production is the continuous monitoring of the plant's physiological properties and internal environmental parameters. Greenhouses (GH) with the Internet of Things (IoT) and wireless network sensors (WNS) technologies provide hi-tech tools for automatic monitoring and detection of the GH microclimate and plants' health/stress. Also, it helps to increase yield and improve productivity. Additionally, remote sensing (RS) technology, including drone application, is considered a highly important technology that can be adapted to controlled environment agriculture (CEA). Applications and adaptation of such technologies still are with limited applications, especially in developing countries, which can hinder the development of agriculture and the enhancement of food security in general. Since canopy temperature estimation is an important process for plant water status monitoring, this research aimed to investigate the effectiveness of remote sensing via a drone-based thermal infrared camera in enhancing the performance of CEA and monitoring plant health. In this study, we developed a method to measure canopy temperature via thermocouple and thermal imaging for pepper plants in a greenhouse to identify plants with water stress and verify its potential to be used as a technology to assess sweet pepper water status using thermal imaging. We evaluated the influence of four levels of irrigation ranging from 50%ETc, 100%ETc, 150% ETc to 175% ETc. The results indicated a positive relationship between the plant's water stress and its canopy temperature. The developed thermal imaging technique was able to detect plants that were subjected to water restrictions. Hence, this technique can improve irrigation scheduling and so provide precise crop water requirements at precise spatial and temporal aspects.

Keywords: Greenhouses, CEA, WSN, IoT, Drone, Remotes Sensing, Thermal images, canopy temperature

OP37-3 | Utilization of multi-crop plant biomass for production of biofuel pellets and analysis of biofuel properties and life cycle assessment

Algirdas Jasinskas[1], Rita Petlickaitė[2], Marius Praspaliauskas[2], Egidijus Lemanas[2]
[1]Department of Agricultural Engineering and Safety, Faculty of Engineering, Agriculture Academy, , Lithuania, [2]b Laboratory of Heat Equipment Research and Testing, Lithuanian Energy Institute, , Lithuania

Wood biomass is mostly used to produce solid biofuel pellets in many European countries, but also it is important to evaluate the possibilities of using other types of biomass as well. This our work presents an evaluation of the quality characteristics of biofuel pellets produced from multi-crop plants (fibrous hemp, maize, and field beans). According to the plot from which the biomass was taken, 7 types of pellets were produced: pellets from maize biomass (abbreviation S-Mz), fiber hemp biomass (S-FH), faba bean biomass (S-FB), maize and fiber hemp (MIX2-1), maize and faba bean (MIX2-2), fibrous hemp and faba bean (MIX2-3), maize, fibrous hemp and faba bean biomass (MIX3-1). The physical mechanical, chemical, thermal and energy properties of investigated pellets were determined according to international standards. Analysis showed that in most cases the produced biofuel pellets met the requirements of standard ISO 17225-6:2021, which defines the quality requirements for non-wood biofuels. Determined bulk density in dry mass (DM) of pellets ranged from 643.43±9.37 kg m-3 (field beans) to 507.80±6.93 kg m-3 (maize). After testing of pellet lower heating value (LHV) it was determined, that it was sufficiently high and was very close to pine sawdust pellets, it varied from 16.72±0.18 MJ kg-1 to 16.99±0.34 MJ kg-1. The ash content of burned pellets ranged from 5.75±0.07% (maize) to 8.57±0.14% (fibrous hemp). Determined harmful emissions to the environment – CO2, CO, NOx and unburnt hydrocarbons (CxHy) did not exceed the maximum permissible levels. Summarizing the results of investigated properties, burning and emissions of multi-crop plant pellets, it can be concluded that this biofuel is characterized by sufficient high quality, efficient combustion and permissible harmful emissions.

Keywords: multi-crop plants, biomass, biofuel pellets, properties, harmful emissions.

OP37-4 | Mapping the best sites for inland aquaponics using multi-criteria analysis powered by geospatial technologies

Andrea Zaniboni[1], Alberto Barbaresi[1], Enrica Santolini[1], Patrizia Tassinari[1], Daniele Torreggiani[1]
[1]University Of Bologna, Bologna, Italy

The identification of suitable sites for implementing integrated inland aquaponics poses a current and intricate research challenge, with remarkable impacts for advancing sustainable fish and crop production and enhancing food security. This research focuses on proposing a multi-criteria land suitability assessment model, implemented in a GIS environment, aimed at considering resources and infrastructure availability and environmental conditions, as well as potential access to market. Field-tested in an Italian case study, the model is based on a participatory approach that has allowed the reclassification and integration of many specific criteria, to map the various suitability level of the region of interest. While being tailored to the specific needs of the sector under study and testes on an Italian case study, the structure of the proposed model allows for its application in various regions and countries, being designed to accomodate adaptations in the range and importance weights of the various decision factors. The research, conducted within an international research project focused on the demonstration of groundbreaking integrated multi-trophic aquaponic system, represents a crucial building block in facilitating their effective implementation.

Acknowledgments: this study has been carried out within the international project “SIMTAP – Self-sufficient Integrated Multi-Trophic AquaPonic systems for improving food production sustainability and brackish water use and recycling, funded by the PRIMA program (Partnership for research and innovation in the Mediterranean area).

OP37-5 | Temporal stability of soil electrical conductivity patterns: Case study with contact and non-contact sensors in dryland pastures

João Serrano[1], Shakib Shahidian[1], J. Marques da Silva[1], Luís Paniágua[2], Francisco Rebollo[3], Francisco Moral[3]
[1]Med- University Of Évora, Évora, Portugal, [2]Departamento de Expresión Gráfica, Escuela de Ingenierías Industriales, Universidad de Extremadura, Badajoz, Spain, [3]Departamento de Expresión Gráfica, Escuela de Ingenierías Industriales, Universidad de Extremadura, Badajoz, Spain

Precision agriculture intents to validate technological tools that allow for capturing soil and crop spatial variability, which constitutes the basis for the establishment of differentiated management zones (MZ). Soil apparent electrical conductivity (ECa) sensors are commonly used to survey soil spatial variability. Temporal stability of this survey is essential to ensure medium and long-term decisions. In this study, an ECa contact-type sensor (Veris 2000 XA) and an electromagnetic induction sensor (EM-38) were used in four fields of dryland pastures in Alentejo region of Portugal. The first survey was carried out between October 2018 and February 2019, and the second was carried out in October 2021. Data processing involved synchronizing geographic coordinates obtained by the two types of ECa sensors in each location and establishing MZ based on geostatistical analysis. Although the basic technologies have different principles (contact versus non-contact sensors), the surveys were carried out at different soil moisture conditions and were temporarily separated, ECa measurements showed statistically significant correlation in all experimental fields, with clear spatial stability patterns of MZ maps. These results provide perspectives for future developments, which will need to occur in the creation of algorithms that allow validating the spatial variability and temporal stability of ECa through smart soil sampling and analysis to allow recommendations for sustained soil correction or fertilization.

Keywords: pastures, soil variability, sensors, electrical conductivity, management zones.

OP38-1 | Bacterial contamination detection in water and milk samples with porous si immunosensor coupled with a rapid catalytic signal amplification

Divagar Muthukumar[1], Giorgi Shtenberg[1]
[1]ARO- Volcani Institute, Rishon Lezion, Israel

Rapid, facile and sensitive detection of water-borne pollutants is crucial to safeguard public health. Herein, a miniaturized biosensing platform based on a porous silicon (p-Si) interferometer was designed to detect Escherichia coli (E. coli) contamination in a rapid and reliable manner. An indirect immunoassay followed by a simple syringe filtration was adapted to exclude the unreacted antibodies tagged with horseradish peroxidase (HRP) from the bacterial suspension while assessing the residual immuno-entities by the optical transducer. The quantification of minute E. coli concentrations was achieved by HRP moieties' biochemical activation and real-time monitoring of the reaction products infiltration into the porous nanostructure by alternating reflectance spectra. The developed bioassay depicted high sensitivity against target microorganism detection, as low as 2 CFU mL-1 and a linear response of 101 -105 CFU mL-1. Furthermore, the selectivity was tested using common interfering pathogens, i.e., Listeria monocytogenes, Salmonella enterica serovar Typhimurium, Staphylococcus aureus, Staphylococcus epidermidis and Bacillus cereus, which resulted in satisfying output. Finally, the potential applicability of the developed platform for real-life scenarios was interpreted with respect to the standard culture plate approach while depicting recovery values of 92-114% in ground, irrigation and river water, as well as staple food samples (raw and pasteurized milk). Overall, the miniaturized p-Si scaffold can be utilized for various emerging applications with pathogenesis relevance assessment conducted at on-site conditions.

Keywords: biochemical immunoassay, biosensor, Escherichia coli, porous silicon, rapid assay

OP38-2 | Multispectral imaging application for food safety and quality evaluation

Chrysanthos Maraveas[1], Marianna Kotzabasaki[1], Dimitrios Giannopoulos[1], Thomas Bartzanas[1]
[1]Agricultural University of Athens, Athens, Greece

Farmers must ensure the quality of their products at all stages of production. Food contamination can occur at several stages of the processing chain, posing a health risk. Control is necessary to assure quality. Many use machine vision for this task, but only a few employ multispectral cameras. Multispectral imaging is a non-destructive sensing technique that can be used to evaluate the quality and safety of agricultural products. It involves capturing images of fruits or vegetable at different optical wavelengths, which can reveal information about the chemical composition, structure, and other properties of the food. This technique can be used to detect defects, such as bruises or insect damage, in fruits and vegetables.
Emerging a new generation of sensing technology, by utilizing spectral imaging, machine vision systems can reveal much more about food products than traditional vision methods, like RGB and X-ray sensors. These systems integrate the major features of imaging and spectroscopy, thus enabling the acquisition of both spectral and spatial information from an object simultaneously. Hyperspectral cameras produce images where each pixel contains full spectral information. This allows the detection of contaminants e.g., plastics, wood, and bones and the quantification of chemical and nutritive properties (e.g., pH, sugar, fat, water, and salt content).
In this study we will collect multispectral images of food products under different conditions, such as different wavelengths, illumination sources, and viewing angles. The images will be then analyzed using image processing algorithms to extract relevant information about the food product. The data collected from the food imaging analysis will be evaluated with trained AI algorithms like Convolution Neural Networks and Genetic Algorithms (CNN-GE) in order to result useful output to potential customers. One example of experimental research in this field will be the use of visible to short-wavelength infrared (SWIR) hyperspectral imaging for safety and quality evaluation. This technique will be used to identify defects in apples and other fruits by analyzing their spectral characteristics. This innovative hyperspectral imaging-based technique, which will be implemented and evaluated through a participatory approach with the costumer, will focus on property and quality evaluation of fruits and vegetables. In this way, our data-driven solution will provide valuable insights for policymakers, farmers, and other stakeholders in making informed decisions related to agriculture and food security.

OP38-3 | Tracing irrigation treatments and geographical origin in pistachio nuts using hyperspectral imaging

Raquel Martínez Peña[1], Salvador Castillo Gironés[2], Sara Álvarez[3], Sergio Vélez[4]
[1]Woody Crops Department, Regional Institute of Agri-Food and Forestry Research and Development of Castilla-La Mancha (IRIAF), Ciudad Real, Spain, [2]Agroenineering department, Valencian Institute for Agricultural Research (IVIA), , Spain, [3]Woody Crops Department, Agro-Technological Institute of Castilla y León (ITACyL), Valladolid, Spain, [4]Group Agrivoltaics, Fraunhofer Institute for Solar Energy Systems ISE, , Germany

The commercialisation of pistachio nuts often faces issues of adulteration or misrepresentation concerning their cultivation practices and geographical origins. In this investigative study, we harnessed the capabilities of Hyperspectral Imaging (HSI) employing a SPECIM IQ camera to discern the irrigation treatments and geographical variations in pistachio nuts harvested from two distinct orchards in Spain, namely "La Seca" and "La Moraleja". Two experimental plots were designated as control and high irrigation within each orchard. Hyperspectral data, covering the spectral range of 400-1000 nm, were meticulously captured and analyzed to unravel the contrasts in water management practices and their implications on pistachios' commercial quality and yield.

The ensuing image analysis encompassed a broad spectrum of parameters, including water supplied (m^3/ha) and yield (Kg/tree), along with an assessment of percentage distribution among split, non-split, and blank nuts. Additionally, the origin and commercial calibre were evaluated to gauge the commercial viability of the yield. Three different Machine Learning (ML) models were used: Partial Least Squares-Discriminant Analysis (PLS-DA) or regression (PLS-R), Support Vector Machine (SVM) and XGBoost, which robust models were conceived. The results show that pistachio origin and water treatment predictions showed high accuracy with F1 scores of 0.99 and 0.92, respectively, and a combined prediction achieving 0.97, indicating the significant impact of location and irrigation. In contrast, quality predictions like yield and dry matter were strong (R2 scores of 0.88 and 0.89), but shell split and caliber predictions were less accurate, highlighting the potential of advanced modeling to enhance pistachio quality predictability.

Our analysis accentuates the profound potential of HSI, especially when deployed with a SPECIM IQ camera, in delineating the irrigation treatment and tracing the geographical origin of pistachio nuts. This endeavour not only paves the way for ensuring authenticity and commercial quality in the pistachio trade but also augments our understanding of the interplay between irrigation practices and nut commercial quality, fostering a sustainable and informed agricultural paradigm.

Keywords: Geographical location, Hyperspectral imaging, Irrigation treatments, Origin tracing, Pistachio.

OP38-4 | The aquaphotomic approach in the discrimination of the metabolic condition of dairy cows

Simone Giovinazzo[1], Laura Marinoni[2], Tiziana Maria Piera Cattaneo[2], Carlo Bisaglia[1], Massimo Brambilla[1]
[1]Crea - Research Centre for Engineering and Agro-Food Processing. Via Milano, 43, 24047 Treviglio (Bergamo), Italy, [2]Crea - Research Centre for Engineering and Agro-Food Processing. Via Giacomo Venezian, 26, 20133, Milan, Italy

Modern dairy farming has intensified considerably due to heightened food demand and economic pressures. This intensified production model has led to an increase in milk production per cow; however, it has also been associated with an elevated incidence of nutrition-related metabolic disorders, such as ketosis. Such condition frequently goes undetected by farmers because it is often not severe enough to show symptoms, but it still impacts animal welfare and productivity. Hence, the significant challenge lies in the timely detection by the farmers.
In-line milk monitoring systems based on NIR spectroscopy offer insights into cows' metabolic conditions through milk composition analysis (e.g. highlighting the fat-protein ratio). However, although reliable and affordable, such instruments may struggle to distinguish between ketotic and healthy animals, especially during subclinical metabolic conditions. In contrast, Aquaphotomics can constitute an innovative approach to detecting subtle biochemical changes at the onset of the disease. This novel discipline considers the molecular spectrum of water as a biomarker to point out any biological system's behaviour and functionality. This chemometric approach, in particular, leverages water's ubiquitous presence as a mirror that reflects any perturbation of the system, representing a promising avenue for enhancing the sustainability of modern dairy production.
A study was conducted on 621 milk samples from three Italian dairy farms. These samples underwent NIR spectroscopy analysis in the 908 – 1676 nm range of the spectrum, and the collected data underwent processing using the open-source software Gnu Octave (version 8.4.0). The developed script enabled the identification of the most significant absorption wavelengths of water for distinguishing between healthy and ketotic cows. This result was achieved through multivariate spectral analysis and the application of chemometrics methods such as PCA, Quadratic Discriminant Analysis (QDA), and Partial Least Squares Regression (PLSR). On the one hand, the QDA, utilizing only three water wavelengths, has preliminarily resulted in a 72,6% correct classification rate (the validation process demonstrated a 71.5% accurate classification rate). On the other hand, the results of the PLSR analysis suggest that there is a significant opportunity for improvement. The aim is to expand the number of samples and farms analyzed to create a more robust mathematical model to increase the classification accuracy.

OP38-5 | Development of an oyster (Pleurotus spp.) mushroom substrate compactor-bagger in the Philippines

Jordan Abad[1], Helen Gavino[1], Romeo Gavino[1], Melba Denson[1], Rosalinda Abad[1]
[1]Department Of Science And Technology, Vigan City, Philippines

The low supply of mushroom in the Philippines evident to its 90% importation is ironic to the abundant biomass resource it could offer. The low biomass utilization rate affected by the lack of appropriate technologies also applies to the low productivity in bagging of substrate in the mushroom industry using manual labor with a capacity of 25 bags/hr. These problems enthuse the study to design, fabricate and evaluate a mushroom substrate compactor-bagger adoptable to local practices and mushroom production technologies in the country.

The 1432 mm x 741 mm x 2040 mm (l x w x h) 140 kg machine was designed using 152 x 305 mm, 0.02 mil polypropylene plastic bags with compaction height of 203 mm and 95 mm diameter. A weight of 750 grams of substrate per bag was determined as setting using the CLSU formulation (70-30 RS-S) and the BSU (80-15-5 S-RB-L) formulation.

Performance evaluation of the machine using the two formulations was tested with different loading weights of 10kg, 15kg and 20kg per batch. It was evaluated using simple CRD and means were compared using LSD test. Results of the study revealed that CLSU formulation at 15kg loading gained 71.67% bagging efficiency, 70.78% filling efficiency, 204 bags/hr bagging capacity and with an average of 740.90 grams/bag. Using BSU formulation, the machine loaded with 20kg produced the highest bagging and compacting efficiencies of 88% and 83.48%. It had a capacity of 307 bags/hr with an average of 759 grams/bag. The average weight per bag was within the acceptable weight of 750 ±50 grams.

The cost analysis of the machine for a year of operation at six hours per day, three times a week with a custom rate of PhP1.5/bag could generate an income of PhP96,736.00-PhP191,749.00 per year and a payback period of 0.30-0.60 years for the BSU and CLSU formulations, respectively.

With the developed machine, there would be increased biomass waste utilization, more production of oyster mushroom at lower cost and hence, more benefits to the farmers and the mushroom industry.

OP38-6 | Insertion of carbon-rich exogenous materials with bio-stimulants into subsoil for promoting maize growth

Dewen Qiao[1], Ajit Borundia[1], Cristina Cruz[2]
[1]Ghent University, Gent, Belgium, [2]University of Lisbon, Lisbon, Portugal

Recent research suggests that soil microorganisms (fungi and bacterial) might be an important component of the soil organic carbon (SOC) pool, in addition to facilitating carbon sequestration by providing biophysical protection. The present study evaluated the influences of inserting available carbon-rich exogenous material with and without microorganisms incorporation in enhancing carbon capture within top-to-subsoil depth (down to 75 cm) in order to improve soil health and productivity, and consequently maize growth. The materials (including two carbon-rich exogenous materials, i.e., liquid digestate and humic acid, plus with three microorganisms, i.e., bacteria, mycorrhizal fungi as well as Trichoderma) were injected into the soil down to 75 cm depth using a novel drilling machine 45 days after maize seeding in two fields. A total of 12 treatments were established, each with three replicates. The growing states of maize were monitored throughout the entire growing season. The greenhouse gas (GHG) emissions (e.g., $CO2$, $CH4$, $N2O$) as well as yield were also measured. The results showed that the combined application of humic acid and mycorrhizal fungi (HM) led to the highest NDVI (0.77 ± 0.05) and chlorophyl content (3.43 ± 1.06) among other treatments. The treatment of the liquid digestate incorporating mycorrhizal fungi (LM) presented the highest corn cob mass (0.30 ± 0.04 kg) and total plant mass (0.68 ± 0.16 kg), while HM treatment led to the highest crop height of 210.47 ± 9.91 cm. The corn cob mass is significantly and positively associated with total plant mass, but shows weak positive correlation with diameter and negatively correlated with the height. As for GHG emissions, HM treatment showed the minimal emission rate of $N2O$ and $CO2$. Therefore, it is recommended to apply humic acid as well as mycorrhizal fungi in the subsoil, as a means of increasing the growth of maize and indirectly promoting the photosynthesis process, thus helping mitigate the $CO2$ to the atmosphere.
Key words: soil organic carbon, exogenous material, greenhouse gas, subsoil, maize growth

OP39-1 | Optimisation of individual nutrient supply in a closed-loop soilless tomato crop using ion selective electrodes and a novel decision support system

Dimitrios Savvas[1], Evangelos Giannothanasis[1], Angelos Peppes[1], Konstantina Terzi[1], Juan Cedeño[2], Georgia Ntatsi[1], Rodney Thompson[2]
[1]Agricultural University Of Athens, Athens, Greece, [2]University of Almeria, Almeria, Spain

Recycling of fertigation effluents in closed-loop soilless culture systems (CLS) is an environment-friendly cultivation technique that can eliminate nitrogen and phosphorus emissions, while reducing water and fertilizer consumption. However, the unknown mineral composition of recycled fertigation effluents, also referred to as drainage solution (DS), is a significant challenge to optimal nutrient management of CLS. To addresses this challenge, a new strategy, based on daily measurement of the concentrations of selected macronutrients and sodium in the DS using ion-selective electrodes (ISE) was examined. The ISE-determined nutrient concentrations are introduced to a new DSS, named NUTRISENSE, which automatically calculates appropriate injection rates of single fertiliser stock solutions to a mix of DS and raw water. This approach aims to accurately maintain target nutrient concentrations in the crop root zone of the plants. The fertiliser injection rates calculated by NUTRISENSE are transmitted on-line to the fertigation system and applied automatically in real time. To test the concept and to validate the algorithms of NUTRISENSE, a tomato crop was grown using CLS with daily measurement of NO_3-N, K, Ca, Na and Mg concentrations in the DS using ISE. The accuracy of the ISE measurements was confirmed. The tested concept and the algorithms used in NUTRISENSE maintained the target nutrient concentrations in the root zone of the plants, as indicated by the measured concentrations in the DS. The proposed strategy represents a breakthrough innovation that can optimise nutrition management and increase the adoption of CLS, thereby improving the economic and environmental sustainability of greenhouse production.

OP39-2 | Automatic generation of shrub and tree crop datasets for use in deep learning detection algorithms on agricultural vehicles

Klaus Müller[1], Jan Kunze[2], Klaus-Dieter Kuhnert[2], Michael Möller[1]
[1]University of Siegen - Computer Vision, Siegen, Germany, [2]University of Siegen - Institute for Realtime Learning Systems, Siegen, Germany

Deep learning-based object detection algorithms are increasingly finding their way into agricultural technology. These promise high recognition rates under real-time conditions. However, a large data set is required to train the appropriate model. This is no problem for everyday objects, where large datasets are available. The situation is different in agriculture and, in particular, in special crops. Datasets are rare here and manual generation is very time-consuming and therefore costly. In this paper we present a system for the automatic annotation of tree and shrub crops in RGBD data recorded by vehicle-mounted cameras.
The system is based on the assumption that the images are taken on a plantation where only one plant species grows and the plants stand out geometrically from their surroundings.
Data recording: A camera (RGB-D) is mounted on a carrier vehicle. The recording is started manually when the vehicle is in the crop.
Data analysis: In a first step, the depth data of the RGB-D stream is converted into a point cloud. An algorithm searches for the local maxima in the point cloud, which usually represent the top of the tree or shrub. Starting from these points, the point clusters of the individual plants are segmented using a min-cut-based segmentation algorithm. The clusters obtained this way are filtered on the basis of their size and position in relation to each other.
The point cloud clusters are then projected into the RGB image and the congruent pixels are assigned to a plant. The image including the plant labels is added to the dataset.
We tested the system on plantations for Christmas trees. The data was recorded with Intel Realsense D455 and D435i cameras. Over 50.000 trees were automatically annotated on a total of 7.000 images.
For testing, a pre-trained model (YOLOV8) was trained with the dataset.
While training YOLOV8 on the generated dataset saturates with a Mean Average Precision (mAP) of 0.69, qualitative results suggest that the resulting model outperforms the noisy model-based process for generating training data.
The model was able to deliver significantly better results than the detection system used to generate the training data, particularly at the edge of the field.
Compared to manual annotation, our system makes work much more efficent while at the same time offering a high recognition rate. It can be used to quickly generate a recognition model even for less common special crops.

Keywords: plant detection, automated data labeling

OP39-3 | Automated needle-based trunk injection system for Hlb-affected citrus trees

Yiannis Ampatzidis[1], Israel Ojo[1], Antonio de Oliveira Costa Neto[1], Ozgur Batuman[1]
[1]University Of Florida, Gainesville, United States of America

Citrus Huanglongbing (HLB) is the most significant threat to the citrus industry worldwide, resulting in substantial economic losses in global citrus production. Currently, no cure exists for HLB-affected trees. The fastidious HLB-causing bacteria (CLas) resides in the phloem of the plant tissue. Although several control methods have been applied, the most effective method currently to control CLas is the trunk injection of oxytetracycline (OTC), which has shown remarkable success in improving tree health, yield, and fruit quality. However, existing trunk injection methods are labor-intensive and time-consuming and, hence, have a high application cost, posing implementation challenges. For example, the most commonly used devices for the injection of OTC in citrus trees in Florida are drill-based and pressurized. OTC injection via these devices is very labor-intensive and requires that the device remain attached to the tree for a prolonged period (from 20 min to 24 hours). Another major concern with these drill-based systems is the possibility of tree injury because they make relatively large holes, which serve as entry points for pathogens or insects. The estimated cost for OTC injection using these devices is $1.34 to $2.70 per tree, not including labor and injection devices. The cost of each device is ~$17, and growers in Florida usually buy 2,000 to 3,000 devices.
An urgent need for the development of efficient automated trunk injection systems applicable on a large scale in commercial agricultural settings has been emphasized by several studies and growers. In response, we have developed a drill-free, non-passive, automated trunk injection device that can be mounted on existing farm vehicles to control HLB and potentially other tree diseases. This automated system consists of a retractable positioning arm that controls the movement of an end effector (EE) that forces injection needles (of 3.81 mm diameter to reduce wounding) into the tree and supplies therapeutic material from both sides of the tree trunk. A metering pump with adjustable pressure and flow rate, allowing for user-defined injection rate and pressure. In field experiments, we could apply 100 ml OTC in less than 1 min. To the best of our knowledge, this is the first automated trunk injection system developed for tree crops.

OP39-4 | Hyperspectral imaging as a novel early detection method of aphid infestation on faba bean (Vicia faba L.)

Ian Fisk[1], Ali Saeidan[1], John Caulfield[2], Jozsef Vuts[2], Ni Yang[1]
[1]University of Nottingham, Nottingham, United Kingdom , [2]Rothamsted Research, ,

Faba bean (Vicia faba L.) is a widely cultivated winter-sown leguminous crop known for its nutritional value, with a steadily growing global market demand. However, its productivity is threatened by black bean aphid which causes direct phloem damage, impaired growth and reduced yield. We have developed a novel approach for aphid detection utilizing hyperspectral imaging, multivariate classification and spectral information divergence analysis. Aphid-infested and healthy plants had subtle spectral differences that could only be observed using hyperspectral imaging. Machine learning algorithms were optimised, and temporal analysis unexpectedly revealed early distinctions between infected and healthy leaves, challenging initial assumptions. The resultant ML models could predict infection earlier than other best-in-class tools with a 99.20% accuracy. This research advances hyperspectral image analysis for pest detection in agriculture.

Hyperspectral imaging; faba bean; machine vision; machine learning

OP39-5 | Autonomous greenhouse cultivation control through deep reinforcement learning with recurrent neural networks

Qingzhuo (George) Qi[1], Bart Van Laatum[1], Sjoerd Boersma[2]
[1]Agricultural Biosystems Engineering, Wageningen, The Netherlands, [2]Agricultural Biosystems Engineering, Wageningen, The Netherlands, [3]Biometris, Wageningen, The Netherlands

Greenhouse cultivation is recognized as a sustainable and reliable food production system, offering a promising solution to feed the increasing global population. However, with the increasing scale of facilities and labor shortage in the greenhouse industry, the lack of experienced greenhouse growers to control the greenhouse crop production system has become a pressing problem. Autonomous control aiming at optimizing crop production and energy consumption has become a promising solution to aid growers in decision-making. Reinforcement learning (RL), a sub-field of artificial intelligence (AI), has demonstrated its ability to address long-term continuous control task. Unlike model-based methods that learn decision-making based on an explicit model, RL learns directly from data. This data-driven nature reduces its dependency on accurate models and enhances adaptability to unseen circumstances. These strengths have been amplified with the advancement of deep RL, leveraging deep neural networks (DNNs) as function approximators within an actor-critic structure. While several studies have employed deep RL to address the greenhouse control problem, none have explored the use of recurrent neural networks (RNNs) instead of feed-forward neural networks (FNNs). This paper employs proximal policy optimization algorithm to train the agent using only FNNs as the baseline method (PPO), and compares its overall performance with an alternative method (RecurrentPPO) with RNNs implemented. Through sensitivity analysis on hyperparameters of the algorithm, RecurrentPPO obtains significantly higher return (19.05%) and net profit (4.29%) than PPO when comparing the resepctive best performance. Moreover, it demonstrates less sensitivity to hyperparameters and maintains an overall higher performance than PPO. However, RecurrentPPO exhibits a higher likelihood of violating the system constraints, which could pose safety concerns in real-world scenarios. In general, RNNs could benefit the design and training process of the RL agent to address the greenhouse control problem by providing additional temporal information. The results illustrate that RNNs could be a promising solution to improve control performance of RL agents in greenhouse control problems.

Keywords: Autonomous greenhouse control, deep reinforcement learning, recurrent neural networks

OP39-6 | Gerbera temperature monitoring over time using thermal imaging and deep learning-based segmentation

Roel Klein[1], Gerrit Polder[1], Frank Kempkes[1]
[1]Wageningen University And Research, Wageningen, Netherlands

In greenhouse climate control flower temperature is an important parameter, since condensation, caused by low flower temperatures, increases the risk of fungal diseases. In this study, we investigate the use of thermal imaging for measuring gerbera flower temperature in greenhouses.

For this purpose, two high-resolution infrared cameras (FLIR-A655sc) are placed one meter above the flowers, recording one image every five minutes. The raw detector signal is converted to a temperature reading using the emissivity, distance, ambient temperature, reflected temperature and relative humidity. Ambient temperature and humidity come from climate control sensors at the top and bottom of the crop. Emissivity of flowers is estimated at 0.98, and reflected temperature is assumed equal to ambient temperature. With this setup, temperature differences of <50mK can be measured with an accuracy of ±2K.

To precisely determine the dewpoint, an accuracy of ±2K is insufficient. To improve accuracy, reference objects with known temperatures are placed in the camera field of view for calibration. A per-timestep calibration is needed due to environmental influences like radiation. Reference objects consist of a wet and a dry sock, wrapped around a PT100 thermometer (accuracy = ±0.2K), similar to measuring Wet Bulb Temperature (WBT) and Dry Bulb Temperature (DBT). A reliable calibration can be performed, since the reference temperatures correspond to the minimum and maximum possible flower temperatures. A linear calibration curve, fitted between the reference temperatures, is then used to correct temperatures in the entire image. Under the linearity assumption, the accuracy in the corrected image is improved from ±2K up to ±0.2K.

Finally, an automatic flower segmentation step is used to measure the average temperature of flower pixels. Due to the high thermal and spatial resolution of the cameras, this could directly be done on the thermal images and no additional registered RGB images were needed. Instance segmentation is performed using the deep learning framework YOLOv8. With 73 training images and 24 validation images, a mAP50 of 0.948 is obtained on the test set of 25 images. Segmentations can still be temporally inconsistent, with detections that flicker between frames. We can assume that flowers hardly move, so tracking is performed using ByteTrack and gaps in flower detections are filled using the last known flower segmentation. Unreliable detections that are tracked for less than 12 frames are removed.

By combining corrected infrared images with flower segmentations, we were able to accurately and automatically measure flower temperature over time.

OP40-1 | Delineation of soil management zones using unsupervised machine learning methods in olive orchards

Ioannis Nikolaos Bougiouklis[1], Panagiotis Petropoulos[1], Panagiotis Paraskevopoulos[2,3], Georgios Kalantzopoulos[3], Pantelis Barouchas[1]
[1]University of Patras, Department of Agriculture, Soil Science Laboratory, Messolonghi, Greece, [2]Agricultural University of Athens, Department of Natural Resources and Agricultural Engineering, Soil Science Laboratory, Athens, Greece, [3]Region of Western Greece, Directorate of Agricultural Economy, Patras, Greece

Decreasing inputs (fertilization, irrigation, pesticides, etc.) while maintaining the productivity of cultivated areas is one of the biggest challenges in the agricultural sector. The delineation of soil management zones is one of the most commonly used practices to achieve it. This study evaluates three unsupervised machine-learning methods for delineating management zones. For this study, a field of 6 acres in Geraki, Ilia, in the Region of Western Greece, where olive trees and a variety of Koroneiki are cultivated, was selected. Sixty soil samples were collected at depths 0-30 cm and a density of 21x21. The samples were then analyzed for their physicochemical properties. In particular, the particle size distribution, texture class, apparent electrical conductivity, organic matter, pH, and the content of available macroelements (N-NO_3, N-NH_4, P, K, Ca, and Mg) and microelements (B, Fe, Zn, Mn, and Cu) were determined. All three machine learning methods used, namely K-Means, Hierarchical Clustering, and DBSCAN, delineated two soil management zones. The soil properties used to delineate the zones were CEC, K, and Ca. The properties were selected based on PCA (Principal Component Analysis). Based on ANOVA analysis, statistically significant differences in the properties were identified among the management zones. DBSCAN is the most suitable method based on the silhouette score. In conclusion, soil management zones can be delineated by using unsupervised machine learning methods. CEC, K, and Ca are soil properties that can be used to delineate management zones.

OP40-2 | Isotherms and desorption patterns of various natural zeolites during the removal of ammonium from wastewaters

Silvia Balzan[1], Giacomo Ferretti[1], Giulio Galamini[2], Barbara Faccini[3], Massimo Coltorti[3]
[1]University Of Ferrara, Department of Chemical, Pharmaceutical and Agricultural Sciences, Ferrara, Italy, [2]University of Modena and Reggio Emilia, Department of Chemical and Geological Sciences, Modena, Italy, [3]University of Ferrara, Department of Environmental and Prevention Sciences, Ferrara, Italy

Even though livestock effluents (LE) are valuable nutrient source for crops, improper management can lead to contamination processes. Thus, it is recommended to treat LE before spreading them into the environment. Among the many methods available for the treatment of LE, the adsorption of ammonium using zeolite-rich tuff is a promising technology. Due to their high cation-exchange capacity and molecular sieve properties, zeolites are strategic materials both for treating livestock effluents and as slow-release soil amendments, zeolites are known since decades as alternatives to synthesized fertilizers. Nevertheless, among the numerous species of natural zeolites available on the market, it is crucial to select the most suitable for the treatment process, taking into consideration their exchange capacities.
This study aims to evaluate the potential application in treating livestock effluents of three zeolite collected from different geographical location but having a similar selling price in the market. The selected materials are represented by: Rumenian clinoptilolite (CLP_RU), Turkish clinoptilolite (CLP_TR), and Italian chabasite (CHA_IT).
The NH_4+ adsorption process under equilibrium conditions at 25°C was investigated by performing adsorption isotherms, considering the interaction among zeolites and a solution of NH_4Cl (1500 mg N-NH4/L), to create ideal conditions, neglecting potential ionic competition phenomena. For each zeolite, two particle sizes were studied, coarse-sized and micro-sized. The initial and equilibrium NH_4+ content was measured with the Kjeldahl method, and the major cation release during the ion exchange process was determined by Inductively Coupled Plasma Mass Spectrometry analysis. Isotherm model fitting was performed with R, testing various models available in the scientific literature.
The Non-Linear Langmuir Model was considered the most representative for all the treated materials, with R^2 ranging from 0.898 to 0.998. With the same zeolite, an inverse relationship was observed between grain size and the calculated maximum adsorption capacity (Qmax). Qmax ranges from 19.39 to 14.83 in CLP, from 26.91 to 19.26 in CHA_IT and 28.09 to 16.00 g/Kg in CLP_TR, representing increases of 24%, 28%, and up to 40%, respectively. While all the zeolite showed satisfactory NH_4+ removal efficiencies, the desorption study highlighted that high sodium levels were released in the solution treated with CLP_RU. This makes CLP_RU potentially unsuitable for LE treatment, since elevated quantities of Na+, if discharged into the environment, can be toxic to crops. This work provides valuable insights into the potential use of zeolites for nitrogen removal and the importance of considering specific application requirements to ensure effective treatment.

OP40-3 | FlobondTM CCAMS50 enhances emergence, stand establishment and yield in salad onions

Robert Simmons[1]
[1]Cranfield University, Cranfield, Bedford, United Kingdom

Light erodible soils are well suited for salad onions. However, these soils are highly susceptible to capping. This can result in significant reductions in seedling emergence, stand establishment, crop uniformity and final yield. The efficacy of synthetic polymers to prevent aggregate breakdown and capping has been documented for over 40yrs. To date however practical adoption has been limited due to issues of polymer viscocity. FlobondTM CCAMS50 can be applied via conventional spray machinery to the immediate soil surface.

During June-Oct 2023, three replicated trials were conducted in Kent, UK in collaboration with Jon Maynard (TLC Farm Manager, Kent). FlobondTM CCAMS50 was sprayed using an 18 m Hardi Spayer (Hardi Flat Fan Nozzle Part No. 755630) on the 28th of June, 12th of July and 19th of July 2023, respectively 1 Day after Drilling (DAD) at forward speeds of 2.0 and 4.0 km hr to achieve application rates of 40 and 80 kg ha-1. All treatments were replicated in quintuplicate. Treatment performance was evaluated in terms of emergence per linear meter, stand establishment and final yield. Repeated measurements of emergence and stand establishment were taken from 5 randomly selected locations (1.0m length) from two drill lines from each experimental plot. Within each 20.0 m experimental plot, a representative 5.0 m long section of 2.0m wide bed (10 m2) was harvested. These salad onions were subdivided into 'In Spec' and Out of Spec' onions and total number of salad onions per harvested area determined. The mass of 'In Spec' onions per harvested area (kg) was then divided by 0.150 kg to obtain the number of 150 g bunches per plot.

Results indicate that for Trial 1 and 2 FLOBONDTM CCAMS 50 application resulted in 70-95% and 36-41% increase in emergence and uniform salad onion crop growth 14-16 DAD as compared with untreated Control. Across all three trials, FLOBONDTM CCAMS 50 application resulted in earlier and more uniform emergence and >20% uplift in stand establishment >30 DAD compared with the untreated Control. Due to issues with mildew, Trial 1 was not harvested. As a consequence to meet customer orders, Trial 2 was harvested early. Yield was captured on 9th October 2023 from Trial 3 only. FLOBONDTM CCAMS 50 application at 80 kg ha-1 resulted in ~20% uplift in yield in Trial 3 as compared with the untreated Control.

OP40-4 | Pesticide management: modeling agricultural practices for sustainable soil and groundwater quality in Nabatyeh Governorate - South Lebanon

Farah Kanj[1], Dany El-Obeid[1], Kady Saleh, Hussein Yazbeck
[1]Lebanese University - Faculty Of Agronomy, Dekweneh , Lebanon

Pollution of groundwater by leaching of pesticide active ingredients has become a relevant issue worldwide. The Lebanese agriculture has experienced excessive use of pesticide and chemical fertilizers for decades. From there, the pollution of groundwater by the leaching of these active ingredients has experienced an extension and is progressively causing worrying effects.
Studies dealing with these issues of pesticide pollution are very rare in Lebanon. In this study, the impact of pesticide use on soil and groundwater contamination in Al Nabatieh Govenorate (South Lebanon) was assessed. This region is characterized by diverse production systems and agricultural practices. PEARL model and Geographic Information System were used by the study to acquire new understanding and to visualize the spatial distribution of vulnerable areas by introducing the treatment frequency indicator. The validation of this model was performed by comparing the concentration of an active material (in our case Nitrate) in four groundwater samples analyzed in the laboratory and the values predicted by the model.
The results of the analysis allowed us to identify areas of high phytosanitary pressure and the most used substances in the study area (alfa cypermethrin, mancozeb, emamectin benzoate, methomyl and chlorpyrifos-ethyl). Results also allowed for the evaluation of the quality of groundwater based on the predictions of the concentrations of active ingredients leached at the level of the study area. Four active ingredients were identified as the most leached to groundwater: methomyl, chlorpyrifos-ethyl, mancozeb, and alfa cypermethrin. Our results of forecasting the concentrations of these pesticides annually allowed us to identify vulnerable zones in terms of a risk of contamination. The areas cultivated with citrus and eggplant on sandy and sandy clay soils were found to be sensitive to the active ingredient ethyl-chlorpyrifos (> 0.1µg / l) and alfa-cypermethrin (> 1µg / l). Areas cultivated with lettuce on sandy and sandy clay soils were found to be sensitive to the active ingredient methomyl (> 1µg / l); and finally area cultivated with cucumber on sandy soils were found to be sensitive to the active ingredient mancozeb with a concentration ranging between 0.1 and 1 µg / l.
Keywords: pesticides, active material, modeling, PEARL model, soil, groundwater, agricultural practices.

PP01-001 | Experimental facility to study climate-house-animal-manure interactions

Mélynda Hassouna[1], Marcel Lecomte[1], Philippe Le Roy[1], Paul Robin[1]
[1]Inrae, Institut Agro Rennes-Angers, UMR SAS, Rennes, France

Sustainable improvement of animal housing requires simultaneous control of animal performances, gaseous emissions and manure production. We considered that for long-term use of datasets, minimal stoichiometry data should include knowledge of mass and speciation of carbon, nitrogen, hydrogen and oxygen: optimal feed index; optimal carbon output as CO2 and soil storage; optimal nitrogen output as N2 and plant fertilizer; optimal hydrogen output for energy production; optimal oxygen output as H2O and CO2. A pilot-scale laboratory was designed and built to measure accurately the mass budget, the energy consumption and gaseous emissions of animals reared in commercial conditions with repeatable climate, animal housing, breeding equipment, rearing practices, manure management. Six “houses” with 5 m² rearing area were installed in a controlled climate environment. Temperature outside the houses can be chosen between -10 °C and +40 °C. Hygrometry outside the houses can be chosen between 30% and 80% when temperature is above 12°C. Houses are naturally ventilated depending on opening size and air density difference between inside and outside climate (pressure differences less than 5 Pa). Therefore, house fluxes only result from animal and manure sensible heat and water vapour production to minimize house energy input. A small heating can be required to compensate for wall heat losses (e.g. for 50 g chicks). Ventilation can vary between 3 and 200 m3 h-1 m-2. Energy flux detection level and measuring accuracy was around 1 W per house (0.2 W m-2). Measurement variability of water content in manure was above 3% because of difficulties to get representative samples and because of non-water volatile compounds lost during sample drying. Mass budget of CHON including the gaseous emissions showed the oxygen input. Energy budget showed the importance of taking into account separately the specific heat of dry air and water vapour in inlet and outlet air.

PP01-002 | AI4PHENO - Digital phenology platform for precision agriculture and bioclimatology

Tomasz Wojciechowski[1], Monika Różańska[1], Gniewko Niedbała[1], Bogdan Chojnicki[1], Jarosław Kurek[2], Bartosz Świderski[2], Krzysztof Bobran[3]
[1]Poznań Univeristy Of Life Science, Poznań, Poland, [2]Warsaw University of Life Sciences, Warsaw, Poland, [3]Seth Software, Głogów Małopolski, Poland

Phenology, the study of how vegetation changes over time, traditionally focuses on seasonal events like budding, flowering, fruiting, and aging. This scientific field is gaining attention not only from the public and scientists but also from the agri-food and forestry sectors. Various methods, such as individual observations, near-surface measurements, and satellite remote sensing, are used to detect phenological stages. Digital phenological imaging with time-lapse cameras is employed in scientific and engineering projects for near-surface observations.

Stationary digital phenology faces challenges like the heterogeneity of camera types, the need for multiple methods to detect phenological parameters, and the absence of open tools for digital phenological imagery collection and analysis using machine learning (ML).

With the increasing availability of high-performance commercial CCTV cameras and the popularity of machine learning, phenological cameras have emerged in agronomy. These cameras enable continuous observations of vegetation at the field level, providing valuable information for yield forecasting. Seasonal changes captured in images necessitate the use of machine learning algorithms to assess characteristics like the number of apples in a given plot.

To address these needs, the AI4Pheno platform was developed through a collaboration between EOSC for Future, Poznan University of Life Sciences, and Seth Software. The platform focuses on linden and apples, with flexibility for additional species. Key functionalities include automatic image retrieval from field cameras, manual creation of user-specific data sources, integration with nearby weather stations, utilization of AI algorithms for classification and segmentation of linden and apples, and statistical analysis of AI model outputs for phenological assessment. AI classification and segmentation models were specifically developed for apple trees and linden within the platform. The AI4Pheno platform serves as a comprehensive solution for both the scientific community and practitioners involved in phenological research and applications.

Keywords: digital phenology, artificial inteligance, yield, apple,

PP01-004 | Optimizing sustainable buildings: A two-step approach with genetic algorithms and computer simulations for energy efficiency and bio-based material selection

Alberto Barbaresi[1], Marco Bovo[1], Enrica Santolini, Daniele Torreggiani[1], Patrizia Tassinari[1]
[1]University Of Bologna, Bologna, Italy

The pursuit of nearly-Zero Energy Buildings has imposed more stringent constraints on construction design while encouraging exploration of innovative architectural approaches in residential, industrial and food processing sectors. The integration of energy simulations with machine learning enables researchers and practitioners to explore new strategies for energy saving. In this context, we introduce a two-step methodology leveraging genetic algorithms coupled with energy simulations, with the objective of minimizing energy consumption for indoor heating and cooling. Simultaneously, it aims to assess and rank bio-based materials derived for byproducts and waste of agricultural sector, identifying optimal commercial solutions for external wall and roof constructions. Specifically, the methodology will return bio-based materials ranked according to their energy-saing efficiency.

PP01-005 | A dynamic energy model for investigating the integration of heat pumps and photovoltaic systems in poultry facilities

Andrea Costantino[1], Dimitrios Tyris[2], Pantelis Bakalis[3], Dimitris Manolakos[2]
[1]Universitat Politècnica De València, València, Spain, [2]Agricultural University of Athens, Athens, Greece, [3]Thermodraft IKE, Piraeus, Greece

Intensive livestock farming is an energy-intensive sector that heavily depends on non-renewable energy sources, a matter that contributes to increase its greenhouse gas (GHG) emissions. In this context, poultry houses stand out for their substantial energy consumption, primarily driven by climate control. In conventional poultry facilities, heating is usually provided through gas air heaters or infrared heating lamps, while cooling is provided through mechanical ventilation -which also controls the indoor air relative humidity and air quality- and evaporative systems. A paradigm shift from this conventional system is represented by the combined integration of a reversible heat pump and a photovoltaic (HP-PV) system into poultry houses, with a dual advantage. On the one hand, the HP-PV system improves climate control by maintaining adequate indoor climate conditions, even during extreme weather events, such as heat waves. On the other hand, the adoption of renewable energy technologies contributes to the decrease of GHG emissions from the facility. These advantages make the solution promising and worthy of investigations aimed at understanding its potential impacts and practical applications in commercial facilities. This work aims to contribute to investigating the integration of HP-PV systems in poultry houses by developing a numerical model able to perform long-term simulations and estimating different indicators, such as the Renewable Energy Ratio (RER), Temperature-Humidity index (THI), and GHG emissions. For this purpose, the experimental facility of the Agricultural University of Athens campus (Greece) is selected as a case study and numerically modeled. The facility is a laying hen house that consists of two rooms of 45 m2 and accommodates up to 400 animals per production batch. The building has been recently refurbished, in the framework of the RES4LIVE Project, by integrating an HP-PV system. The developed model dynamically simulates the indoor climate conditions and the energy consumption of the building with an hourly time step. Moreover, the model estimates the power generation from the PV system, enhancing analysis of the system self-consumption and self-sufficiency. The reliability of the model was evaluated against the real data acquired in the same experimental facility. The increase model enhances the evaluation of the system performance from both the energy and indoor climate conditions point of view, contributing to increasing the body of knowledge regarding the integration of HP-PV systems in livestock houses. Moreover, it represents a valuable tool for industry to facilitate the scalability of the analyzed system in commercial facilities.

PP01-006 | Modelling enteric methane production of dairy cows: A hierarchical bayesian stochastic approach

Cécile Levrault[1], Peter Groot Koerkamp, Carel Peeters, Peter Groot Koerkamp, Kelly Nichols, Nico Ogink, Carel Peeters, Jan Dijkstra[1]
[1]Wageningen University & Research, Wageningen, Netherlands

Monitoring methane production from individual cows is required for evaluating the success of greenhouse gas reduction strategies. However, converting non-continuous measurements of methane production into daily methane production rates (MPR) remains challenging due to the general non-linearity of the methane production curve. In this paper, we propose a Bayesian hierarchical stochastic kinetic equation approach to this challenge. Modelling was used to fit a non-linear curve on climate respiration chamber (CRC) data of twenty-eight individual dairy cows before computing an area under the curve, thereby providing an estimate of MPR from individual cows. The shape parameters of this model were pooled across cows (population-level), while the scale parameter varied between individuals. This allowed for the characterization of variation in MPR within as well as between cows. Model fit was thoroughly investigated through posterior predictive checking, which showed that the model could reproduce the CRC data of twenty-eight cows well. Comparison with a fully pooled model (all parameters constant across cows) was evaluated through cross-validation, where the Hierarchical Methane Rate (HMR) model proved to perform better. Concordance between the values observed in the CRC and the ones predicted by the HMR model was assessed with R2 (0.995), r (0.997), root mean square error (10.0 g/d), and Lin's concordance correlation coefficient (0.961). Overall, the predictions made by the HMR model appeared to reflect individual MPR levels and variation between cows as well as the standard approach taken by scientists with CRC data.

PP01-007 | Vegetation indices generated by images captured with RPAS in the prediction of common bean biophysical parameters

Henrique Fonseca Elias De Oliveira[1], Bac Lucas Eduardo Vieira de Castro[1], Cleiton Mateus Sousa[1], Me Josef Augusto Oberdan Souza Silva[1], Marcio Mesquita[2], Me Vilson Soares de Siqueira[1], Jhon Lennon Bezerra da Silva[1], Marcos Vinícius da Silva[3]
[1]Goiano Federal Institute, Ceres, Brazil, [2]University of Goiás, Goiânia, Brazil, [3]University of Alagoas, Maceió, Brazil

With the advent of photogrammetry, widely used in precision agriculture, it is currently possible to predict the nutritional, phytosanitary, and productive condition of different crops quickly, non-destructively, and with greater efficiency compared to conventional techniques, using for this purpose, specific sensors, onboard unmanned aerial vehicles or satellites. In this context, the objective of this study was to evaluate, in common bean (Phaseolus vulgaris L.) cultivation, the performance of eight vegetation indices, six (06) Multispectral: Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Normalized Difference Red Edge Index (NDRE), Modified Chlorophyll Absorption in Reflective Index (MCARI), Leaf Chlorophyll Index (LCI) and Structure Insensitive Pigment Index 2 (SIPI2); and two (02) RGB (red, green, blue): Visible Atmospherically Resistant Index (VARI) and Triangular Greenness Index (TGI)). Correlations were established between these indices and the biophysical characteristics of the crop analyzed “in loco” as a function of the foliar application of 4 doses of magnesium in two different phenological stages. Data were submitted to regression analysis and the interaction between variables was analyzed by statistical significance, correlation coefficient (r), coefficient of determination (R^2), and root mean square error (RMSE). The NDVI and MCARI vegetation indices stood out for productivity prediction, both with r = 0.82 and RMSE of 330 and 329 kg/ha, respectively. TGI had the best performance about plant height (r = 0.73 and RMSE = 7.4 cm). The best index for detecting the relative content of chlorophyll SPAD was MCARI (r = 0.81; R^2 = 0.66 and RMSE = 10.14 SPAD), followed by NDVI (r = 0.81; R^2 = 0.65 and RMSE = 10.19 SPAD). The phenological stage with the highest accuracy in estimating the productive variables was R9 (Physiological maturation) at the beginning. GNDVI in phases R6 and R9 and VARI in phase R9 were significant at 5% for magnesium doses, with quadratic regression adjustments and a maximum point at 500 g/ha.
Keywords: Remote sensing; Multispectral; RGB; Reflectance; Phaseolus vulgaris L.

PP01-008 | Crop reflectance measurements for water deficiency detection in Valerianella locusta plants

Dafni Avgoustaki[1], Giorgos Varras[1], Eirini Xeilaki[1], Pavlina Skouriali[1], Andreas Giakoumatos[1], Thomas Bartzanas[1]
[1]Agricultural University Of Athens, Athens, Greece

Early detection of water stress is essential in order to effectively and precisely manage crop production in a greenhouse facility. This research demonstrates the use of multispectral vision as a non-contact and non-destructive method for detecting crop water deficit in a hydroponic lamp lettuce crop. Two different irrigation programs, control with normal water dose and stress with limited water dose, were applied to lamp lettuce plants grown in a hydroponic greenhouse facility based in the Laboratory of Farm Structures of the Agricultural University of Athens. The growing conditions were semi-controlled, meaning with controlled temperature and humidity but not controlled lighting conditions as the only light source was the sun. Crop reflectance measurements were conducted using a multispectral camera that was measuring the radiation reflected by the crop at eight different wavelengths (542, 582, 619, 661, 700, 742, 780, and 822 nm) with 10 nm bandwidth according to the selected spectral indices. The results showed that crop reflectance was significantly increased during the experimental period, although the researchers never observed it visually until the end of the experiment and the harvest of the crops. More specifically, the Normalized Difference Vegetation Index (NDVI) and the Photochemical Reflectance Index (PRI) showed statistically significant differences between the control treatment and the stress treatment with limited water dose. The research provides insights into analyzing data from sensors and techniques used to measure how the crops reflect solar light as well as spectral indices for remote water detection. Finally, the results provide a feasibility analysis, suggesting that multispectral images could be used as a rapid and reliable tool to estimate the physiological status of plants, which is indicative of the spatial variation in greenhouses.

PP01-009 | Micro-Near-Infrared (Micro-NIR) sensor for predicting organic carbon and clay contents in agricultural soil

Jiang Liu[1], Abdul Mounem Mouazen[1], Muhammad Abdul Munnaf
[1]Gent University, Gent, Belgium

Micro-Near-Infrared (Micro-NIR) sensor for predicting organic carbon and clay contents in agricultural soil

Jiang Liu1, Abdul Mounem Mouazen1*, Muhammad Abdul Munnaf,
1Department of Environment, Ghent University, Belgium

Abstract

Micro-near-infrared (Micro-NIR) spectroscopy has emerged as a promising technique for cost-effective estimation of key soil attributes when compared to the traditional wet chemistry methods and conventional NIR spectroscopy. Despite its potential, the full extent of its capabilities and applications remains unexplored. This study has evaluated the performance of a low-cost micro-NIR sensor for predicting soil organic carbon (SOC) and clay content. 92 samples (Randwijk, Netherlands) was scanned using a micro-NIR of 2000 ~ 2450 nm with 18 ~ 28 nm sampling resolution (NIRONE D2.5, Spectral Engine, Germany) in fresh and air-dried conditions. Partial least squares regression (PLSR) models were developed with and without feature selection by competitive adaptive reweighted sampling (CARS), successive projections algorithm (SPA), and slime mould algorithm (SMA). The best accuracy achieved for SOC prediction for the fresh samples (coefficient of determination in prediction (RP2) = 0.76; root mean square errors in prediction (RMSEP) = 0.27 %) was improved for the dry samples (RP2 = 0.81; RMSEP = 0.27 %). The predictive performance for clay content was found relatively poor (RP2 = 0.48; RMSEP = 5.00 %). With the implementation of feature selection, SMA improved SOC prediction for fresh soil (Rp2 = 0.79; RMSEP = 0.25 %) and CARS improved that of dry soil (Rp2 = 0.84; RMSEP = 0.25 %). Using CARS also improved the results of clay prediction for dry soil (Rp2 = 0.56; RMSEP = 4.62 %). Therefore, this study indicates that a micro-NIR sensor is a potential innovation that can accurately predict SOC, and clay content (to a smaller degree of accuracy) for a normally distributed dataset.

Keywords: micro-NIR spectroscopy, soil analyses, feature selection, organic carbon, clay.

PP01-010 | AgrOassis - Regenerative approaches for building climate change resilience into EU agricultural regions prone to desertification

Chris Cavalaris[1], Persefoni Maletsika[1], Georgios Nanos[1], Aris Kyparissis[1], Christos Karamoutis[1], Vasilis Giouvanis[1], Panagiotis Dalias[2], Skevi Stylianou[2], Giorgos Theofanous[3], Filippos Filippou[4], Areti Christodoulou[5], Dimitris Sarris[6], Antonia Stelikou[6], Androulla Miliotou[6], Ioannis N. Vogiatzakis[7], Savvas Zotos[7], Paraskevi Manolaki[7], Elli Tzirkalli[7], Chariton Kalaitzidis[8], Panikos Hambas[9], Pavlos Paradisiotis[10], Vaggelis Perakis[11], Athanasios Markinos[12], Kostas Kiourtsis[12], Artemis Yiordamli[13], Costas Orountiotis[13]
[1]University of Thessaly, Department of Agriculture, Crop Production & Rural Environment, Volos, Greece, [2]Agricultural Research Institute, Department of Natural Resources and Environment, Ministry of Agriculture, Rural Development, and the Environment, Nicosia, Cyprus, [3]Department of Agriculture, Ministry of Agriculture, Rural Development, and the Environment , Latsia, Cyprus, [4]Department of Environment Ministry of Agriculture, Rural Development, and the Environment , Nicosia, Cyprus, [5]Department of Forests Ministry of Agriculture, Rural Development, and the Environment , Nicosia, Cyprus, [6]KES Research Center Limited, Nicosia, Cyprus, [7]Faculty of Pure & Applied Sciences, Open University of Cyprus, Nicosia, Cyprus, [8]Mediterranean Agronomic Institute of Chania, , Greece, [9]Union of Cypriot Farmers, Nicosia, Cyprus, [10]Paradisiotis Ltd, Ypsonas, Limassol, Cyprus, [11]Sitia UNESCO Global Geopark, Sitia, Crete, Greece, [12]Land Reclamation Organization of Tavropos, Karditsa, Greece, [13]Laona Foundation, Limassil, Cyprus

The current work presents the main concept and some preliminary findings from the LIFE AgrOassis project. The project proposes nature-based solutions and circular economy approaches for combating desertification within degraded agroecosystems of Cyprus and Greece (Thessaly and Crete). Co-funded by the European Union LIFE program, AgrOassis project started in 2023 and will continue until 2026. The main land management interventions focus on changing soil management by promoting minimum tillage, no-tillage, mulching and compost application as well as introducing hedgerow structures on the most vulnerable parts of the fields. The action plan includes the implementation of reduced tillage in 100ha of arable land in Cyprus and 85ha in the region of Thessaly. In addition, 15ha of arable land in Thessaly will be devoted to permanent no-tillage management. Mulching will be introduced in 350ha of orchards in Cyprus and 50ha in the region of Crete. At least 10ha of land will be treated with compost every two years in Cyprus. For that scope, two pilot composting plants will be established for processing municipality green waste and chicken poultry. Finally, 30km of hedgerows consisting of 6000 trees and 12000 shrubs will be established in Cyprus and another 3km (600 trees and 1200 shrubs) in Thessaly and Crete. Through the above soil management interventions, the AgrOassis project aims to revert soil degradation and upgrade soil quality by improving the soil structure, preventing soil erosion, enriching soil carbon, preserving soil water, enhancing soil fertility, and promoting soil biodiversity. Combined with the hedgerow's beneficial impacts on microclimate, windborne erosion, and local biodiversity, the interventions are expected to support the ecosystem services within the prone to desertification farmlands. On the other hand, the incorporation of CO_2 into soil carbon pools, the CO_2 fixation into woody tissues on the hedgerows, along with the avoidance of carbon losses from uncontrolled green waste disposal and the reduction of GHGs emissions through fossil fuel savings from reduced and no-tillage are expected to contribute towards climate change mitigation. Finally, the use of compost is expected to promote the circular economy concept within the agro-sector community. Through the exploitation of a multi partner, multi actor approach, the AgrOassis project aims to mobilize the primary food production sector towards close-to-market solutions on sustainable solutions and seeks to identify and remove obstacles related to inappropriate governance and policies, that obstruct the implementation of the EU's Green Deal Agenda.

PP01-011 | Effect of installing organic photovoltaic panels on the environmental performance of greenhouse tomato in Greece

Andreas Giakoumatos[1], Vasileios Anestis[1], Thomas Bartzanas[1], Nikolaos Katsoulas[2]
[1]Agricultural University of Athens, Athens, Greece, [2]University of Thessaly , Volos, Greece

The objective of this study was to assess the potential environmental benefits of installing Organic Photovoltaic (OPV) panels on the roof of a 200m2 plastic greenhouse for tomato production in Greece while using different types of roofs. The study employs a cradle-to-greenhouse gate approach, with 1 kg of fresh tomatoes at the greenhouse gate as the functional unit and a temporal boundary of 1 year. Comparative assessments were conducted to estimate the environmental performance of the greenhouse tomato supply chain after the installation of OPV panels. The results were compared to the respective performance before the installation of OPV panels. Four systems were defined: B-OPV, which represents the situation before the installation of OPV, and A-OPV-PR, A-OPV-AR, and A-OPV-GR, which represent the situation after the installation of OPV on a pitched roof, arched roof, and gothic roof greenhouse, respectively. Various environmental impact categories were addressed, using indicators in accordance with the EU – Environmental Footprint method. The highest weighted environmental impact category indicators (EICI) regarding the total environmental score were GWP-100 (Climate change), ADP-fossil (Abiotic resource depletion - fossil fuels), and PEFE (Freshwater Eutrophication). An inversely proportional relationship was observed between the electricity produced from the OPVs and the value of the EICI for these EICIs. This indicates that the higher the electricity production of the OPVs, the lower the values of the EICIs per kg of fresh tomato at the greenhouse gate. The A-OPV-PR and B-OPV systems showed the largest difference in environmental impact, with potential average variations of 15% for GWP-100, 73% for PEFE, and 14% for ADP-fossils over a 25-year period. Additionally, installing OPV panels on the greenhouse roof improved the overall environmental performance of the tomato supply chain and most environmental impact indicators. Furthermore, the type of greenhouse roof was found to affect the amount of electricity generated by the OPV panels that can be fed back into the grid, thereby potentially affecting the overall annual environmental performance per kilogram of greenhouse tomatoes. These results demonstrate the potential for on-farm installation of OPV panels to decrease the environmental impact of fresh horticultural products.

Keywords: Organic Photovoltaic Panels, Environmental Performance, LCA, Greenhouse tomato supply chains, Greece

PP01-012 | Innovative hybrid dairy waste water system assisted by an intelligent information algorithm tool for quality prediction of the outlet water and support in decision making for sustainable practice

George Spyrou[1], George Papadakis[1], Evangelos Dimitriou[1], Anastasios Aktypis[1], Alexandros Zolotas[2], Dimitra Dimitrakopoulou[3], Dimitris Vagenas[4]
[1]Agricultural University of Athens, Athens, Greece, [2]Watera Hellas , Athens, Greece, [3]NAMA Consulting Engineers and Planners , Athens, Greece, [4]University of Patras, Patras, Greece

The rapid increase in industrial activity and the overconsumption of goods, has led to environmental degradation caused by the discharge of untreated wastewater. The introduction of strict laws and restrictions in the industrial sector, in combination with environmental awareness makes water treatment an inevitable requirement for sustainability. The project focuses on the design, construction, implementation and demonstration of an advanced automated, energy efficient, environmentally friendly, hybrid waste treatment system in a model dairy processing unit, with the aim of maximizing the recovery of clean water for use in agriculture. In addition, the process supports the recovery of useful by products to be used as fertilizers. The project will also conclude integration of a “smart” information tool on the wastewater treatment system, for outlet water quality monitoring and prediction. The proposed system treats the dairy effluent as a resource rather than waste and includes a combination of mature technological solutions, such as adsorption processes, biofiltration, electrochemical oxidation, precipitation and final carbon filtration. The final product of the system is high-efficient ‘clean’ water to be used for irrigation through the construction of a pipeline from the industrial unit to the greenhouse while the intermediate by-products will be used as fertilizers. The hybrid character of the system (combination of processing technologies) and the advanced design of the electrocoagulation reactor are system’s innovations. Additionally, research for the use of a 'smart' information tool, through high-tech sensors combined with a software system of algorithms, to control and predict the quality of water produced, will reveal new entrepreneurial horizons in the agricultural industry. The project will prove that industrial coexistence is possible on a small or larger scale, while it will increase synergies between different industries by adopting targeted actions to reveal possible alliances between parties of mutual interest. The advantages of the proposed scheme are: the advanced technology that is applied, its sustainability, better output quality compared to conventional systems, almost zero environmental footprint, enhancement of the circular economy model and the development of business intelligence.

PP01-013 | Evaluation of machine learning-driven sensor networks for observing separation processes in combine harvesters for estimating separation efficiency

Kevin Penner[1], Marvin Barther[1], Felix Wittenfeld[1], Marc Hesse[1], Michael Thies[1]
[1]Bielefeld University, Bielefeld, Germany

Accurate measurement of combine harvester separation process efficiency - the amount of grain separated from straw and material other than grain (MOG) - is crucial to process automation and economic efficiency in agriculture. Traditional methods rely on structure-borne noise sensors for grain counting. In most combines of leading harvester manufactures there is a single sensor line at the end of the separation unit to measure the amount of grain within the straw fraction, some manufactures are already using multiple sensors. The signal processing underlies disturbance variables like varying grain, field and weather conditions, which interferes with predictions for the separation process.

This study introduces a novel approach utilizing a large grid aligned sensor network within the combine harvester's separation unit, in conjunction with a suite of machine learning regression models. The models used to predict the separation efficiency are k-nearest neighbors (k-NN), support vector machines (SVM), decision trees (DT), fully-connected neural networks (FCNN), convolutional neural networks (CNN), and recurrent convolutional neural networks (RNN). Data has been collected across different grain harvests in European summers, which presented contrasting grain, field and weather conditions. Through the analysis of sensor and combine setting data represented in one-, two-, and three-dimensional spatial tensor formats, we demonstrate that CNNs, especially with three-dimensional data representations, yield the highest prediction accuracy.

The models achieved validation accuracy, evidenced by an average R^2 score of up to 0.79 with k-fold cross-validation on the limited recorded data, thereby proving their reliability across varying conditions. Machine learning models like k-NN, SVM or DT with an R^2 score of up to 0.69 could not achieve such validation results. A major difference between CNNs and most other machine learning models is the inherent focus on location-dependent data due to the convolutional calculations, which indicates to be the main benefit in analysing separation processes.

Keywords: separation process; separation efficiency; sensor network; machine learning; neural networks

PP01-014 | Implementation of a smart monitoring system for data collection in dairy cattle farms

Marco Bovo[1], Stefano Benni[1], Alberto Barbaresi[1], Enrica Santolini[1], Daniele Torreggiani[1], Patrizia Tassinari[1]
[1]University of Bologna, Dep. of Agricultural and Food Sciences, Bologna, Italy

The study outlines the aims, methodologies, and technical aspects of a monitoring system developed within a national research project focused on innovative solutions for smart dairy farming, aimed at enhancing herd productivity. The primary objective was to improve environmental conditions and animal welfare for dairy cows, ultimately leading to increased reproduction and production rates. Over recent years, advancements in animal control techniques and farm environmental monitoring have evolved significantly, driven by the integration of Information Communication Technology systems and data analysis models. A Smart Monitoring System (SMS) was conceived and realized in two study cases of commercial farms. This system plays a crucial role in facilitating more efficient herd and housing management, and it stands as a promising tool for enhancing both animal welfare and production efficiency. Its effectiveness lies in the integration of diverse sensors, data types, and analytical models, reflecting modern approaches to herd management and sustainability in the dairy sector.
The system employs specially designed sensor networks within a tailored architecture, enabling the collection of comprehensive time series data on the physical and environmental conditions of cow housing facilities. This encompasses both indoor and outdoor environmental factors, facilitating intelligent facility control, operational diagnostics, and timely anomaly detection.
Developed to function across various environmental settings, the system offers real-time remote access to data via cloud-based infrastructure. By leveraging a combination of sensor data and advanced analytics, it enables proactive management strategies to optimize herd conditions and productivity, while ensuring that animal welfare standards are upheld.
The data supplied by the SMS play a pivotal role in bolstering the sustainability and efficiency of the dairy sector, as this system enables:

- Monitoring and gathering data to decrease the need for constant human oversight of the facility;
- Establishing both local and remote databases;
- Enhancing operational precision by furnishing data for assessing reductions in environmental impact and potential benefits.

Acknowledgments
The activity presented in the paper is part of the research project PRIN 2017 “Smart dairy farming: innovative solutions to improve herd productivity” funded by the Italian Ministry of Education, University and Research [20178AN8NC].

PP01-015 | An economic analysis of bolus-sensor technology for precision dairy cattle management

Elias Maritan[1], Gundula Hoffmann[2], Friederike Schwierz[2], Mark Rutter[1], Andreas Meyer-Aurich[2], James Lowenberg-DeBoer[1], Karl Behrendt[1]
[1]Harper Adams University, Newport,, United Kingdom , [2]Leibniz Institute of Agricultural Engineering and Bio-economy e.V., Potsdam,, Germany

Bolus-sensors are a precision livestock farming tool measuring physiological, behavioural, and production indicators of individual animals to improve herd productivity. Bolus-sensors collect data such as animal activity, rumination, and body temperature. On dairy farms, these data may be used to assess general cattle health, detect oestrus, and monitor presence of disease.
This study focuses on oestrus detection and clinical mastitis (CM) monitoring via bolus-sensors on two dairy farms in northeastern Germany. The two farms use an automatic (AMS) and a conventional milking system (CMS), respectively. A Monte Carlo partial budgeting analysis is performed to quantify the probability of positive net economic outcomes after bolus-sensor adoption. Following previous economic research, the bolus-sensor is assumed to affect milk production and herd growth rates. Annual net economic outcomes are calculated for the two target functions and combined to assess the overall outcome when the bolus-sensor is utilised as a multi-functional tool.
Analysis results show that economic outcomes differ across farm types and functions considered. For CM monitoring, the probability of bolus-sensor adoption leading to increased profits is 58% on AMS farms and 99% on CMS farms. Conversely, the probabilities for oestrus detection on AMS and CMS farms are 80% and 59%, respectively. When the two functions are combined, the likelihood of increased profit is 75% on AMS farms and 93% on CMS farms. Annual economic benefits span from €26,470 to €110,301 on the AMS farm, and from €27,420 to €197,763 on the CMS farm. The mean economic advantage for both target applications is €126,257 year-1 on the AMS farm and €214,670 year-1 on the CMS farm. However, these outcomes are highly variable and more data on the effects of bolus-sensors on herd productivity are required. Additionally, further research is needed to identify potential trade-offs among economic benefits, animal welfare, and other non-economic aspects.

PP01-016 | Effect of maltogenic-amylase and tamarind paste mixture on the nutritional composition of bread

Musliu Olushola Sunmonu[1], Mayowa Saheed Sanusi[1], AbdulKareem Bamidele Bello[1], Aishat Teni Ahman[1], Islamiyat Dolapo Jimoh[1], Omoniyi Friday Akinnusi[1]
[1]University Of Ilorin, Ilorin, Nigeria

The incorporation of blends of maltogenic-amylase and tamarind paste in dough could serve a possible potential for improving bread quality. This study aimed to evaluate the effect of varying proportions of maltogenic-amylase and tamarind paste on the nutritional quality of bread. The proximate composition, minerals (calcium, magnesium, potassium and phosphorus), vitamin C and total phenolic content were determined using standard procedures. Maltogenic amylase and tamarind paste at varying proportions were interacted using a central composite design of response surface methodology while Pareto plot was used to identify the most significant factor. The moisture content of the bread ranged from 26.83 to 34.58%, fat (2.29 – 3.49%), fibre (0.42-0.64%), ash (2.47-3.53%), protein (12.02-18.56%) and carbohydrate (45.24 – 50.13%). The calcium content ranged from 135.63 to 164.25 mg/100g, magnesium (112.38 – 128.42 mg/100g), potassium (210.22 – 228.55 mg/100g), phosphorus (60.15 – 75.25 mg/100g). The total phenolic content of the bread ranged from 120.64 – 145.18 mg GAE/g and Vitamin C from 11.56 to 16.55 mg/100g. The linear effect of maltogenic-amylase exerted a more significant influence on the nutritional composition of the bread compared to tamarind paste. The findings from this study underscore the potential for optimizing bread quality through the strategic incorporation of maltogenic-amylase and tamarind paste.
Keywords: Bread, Maltogenic amylase, Tamarind, Nutritional composition

PP01-017 | Assessment of instance segmentation methods for amodal apple detection in challenging environments

Tito Arevalo-Ramirez[1], Juan Villacrés[2], Michelle Viscaino[3], Francisco Yandun[4], Oswaldo Menéndez[5]
[1]Facultad de Ingeniería, Pontificia Universidiad Católica De Chile , Santiago, Chile, [2]Department of Biological and Agricultural Engineering, University of California, Davis, USA, [3]Department of Radiology, School of Medicine & DataLab: Data Science and Informatics, University of California, Davis, USA, [4]Robotics Institute, Carnegie Mellon University, Pittsburgh, Pittsburgh, USA, [5]Departamento de Ingeniería de Sistemas y Computación, Universidad Católica del Norte, Antofagasta, Chile

Recent developments in sensor technologies and deep learning algorithms have played a vital role in continuously monitoring crops and vegetation in agricultural fields. Specifically, several researchers have widely explored the identification and characterization of fruits on farms. The physical characteristics of fruits can provide relevant knowledge about the orchard's status. In addition to yield estimation, parameters related to the health and quality of the fruits can be estimated using visual sensors. Furthermore, robotic systems can use the location of the fruits to automate picking and harvesting tasks. While there is plenty of related work for detecting and segmenting fruits in images, a robust and reliable application in real conditions is an open challenge. Research works aimed to address this challenge using different sensing modalities, such as active sensing, sensor fusion, and various data processing techniques, mainly based on deep learning. However, changing illumination, blurring, and total or partial occlusion of the fruits within the canopy often limit field deployment. We precisely aim to address the problem of fruit occlusion using semantic amodal segmentation approaches. Amodal segmentation refers to recognizing visible and occluded parts of an object of interest in an image, allowing one to infer information beyond the visible features in the scene. This work comprehensively evaluates the application of three state-of-the-art instance segmentation algorithms for the amodal semantic segmentation of apples in dense trees.
We evaluated and benchmarked three state-of-the-art instance segmentation algorithms for this task: cascade-RCNN, mask-RCNN, and rf-RCNN. The training, validation, and testing sets correspond to 2304, 814, and 807 images from a Fuji and Elstar apple orchard. Images were captured using a handheld EOS 60D DSLR camera at two different growth stages: apples at 70% of their final size and the ripening stage. Results show a mAP_75 value of approximately 0.71, 0.71, and 0.67 for the cascade-RCNN, mask-RCNN, and rf-RCNN, respectively. Furthermore, based on a qualitative evaluation, we observed that all the networks are prone to misclassify apples when their skin color mimics the leaves, which is expected to some extent. In general, all the evaluated architectures showed good potential for detecting and segmenting occluded apples, with the best qualitative and quantitative performance corresponding to cascade-RCNN and mask-RCNN. These promising results will lead us to study and generate new architectures that use prior knowledge of the task (e.g., the expected shape of the fruit) to improve the performance and deploy the system in the field.

PP01-018 | Impact of orientation and height on grain quality in pistachio cultivation: A multivariate analysis

Raquel Martínez Peña[1], Sergio Vélez[2], Salvador Castillo Gironés[3], Hugo Martín[4], Sara Álvarez[4]
[1]Woody Crops Department, Regional Institute of Agri-Food and Forestry Research and Development of Castilla-La Mancha (IRIAF), Ciudad Real, Spain, [2]Group Agrivoltaics, Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany, [3]Agroenineering department, Valencian Institute for Agricultural Research (IVIA), Valencia, Spain, [4]Woody Crops Department, Agro-Technological Institute of Castilla y León (ITACyL), Valladolid, Spain

Pistachios are a crop that is significant to the world economy and nutrition, and their demand is rising in several foreign markets. Pistachios are one of the nuts with the highest nutritional content in the world; they have a considerable quantity of dietary fibre, protein, vitamins, and important minerals, among other nutrients, indicating their potential health advantages. Owing to these advantageous characteristics, pistachios show promise as a component for the food industry in the creation of several novel products. Agronomically speaking, hedgerow orientation can be expected to modify nut composition because of differences in temperature and irradiation patterns.

In an extensive analysis of pistachio nuts, this work investigates a spectrum of nutritional and biochemical parameters, inclusive of macroelements and microelements, and their lipid profile. Key constituents including fats, carbohydrates and proteins were also meticulously quantified. The study specifically explored how variables such as orientation and height influence the nutritional makeup of the pistachio crop, including the use of Hyperspectral imaging to infer the localisation of these nuts in the tree.

Findings reveal significant disparities in some parameters based on the orientation and height of growth. For instance, fat content showed notable variation concerning tree orientation, while some fatty acids analysed were affected by the crop's height. These results underscore the substantial impact of environmental factors on the nutrient profile of pistachios, suggesting that the directional planting and elevation of the land are critical considerations in cultivating pistachios. In addition, three different Machine Learning models were conceived to analyse the hyperspectral images: Partial Least Squares-Discriminant Analysis (PLS-DA), Support Vector Machine (SVM) and XGBoost. The results showed that predicting the tree height and orientation was challenging, obtaining low F1 scores for tree orientation (0.35 (SVM) and 0.36 (PLS and XGBoost)), but better results for height location (F1 scores: 0.61 (PLS) and 0.59 (XGBoost and SVM)).

This investigation substantiates that the orientation and height at which pistachio trees are planted have a discernible effect on the quality of the nuts produced. Therefore, these characteristics should be carefully considered in agricultural practices to enhance the quality of pistachio crops, aligning with industry demands for premium nuts and supporting the nutritional expectations of the end consumer.

Keywords: Grain quality, Hyperspectral imaging, Orientation, Pistachio, Tree Height.

PP01-019 | Advanced UAV edge computing ML solutions for livestock management

Aristotelis C. Tagarakis[1], Costas Davarakis[2], Alexander Loos[3], Dimitrios Kateris[1], Dionysis Bochtis[1]
[1]Institute for Bio-Economy and Agri-Technology (iBO), Centre for Research and Technology Hellas (CERTH), Volos, Greece, [2]Nydor System Technologies, Athens, Greece, [3]Fraunhofer Institute for Digital Media Technology (IDMT), Ilmenau, Germany

The role of Unmanned Aerial Systems (UAS) in different application areas in the agricultural sector is increasing rapidly. Following the current trends, the focus of SPADE EU Project (HE 101060778) is to investigate the potential benefits of UAS contributing to multiple field operations and processes and promote sustainable digital services in the sectors of agriculture, forestry, and livestock. Part of the developments within the SPADE ecosystem involves deployment of UAV formations (single UAV, collaborating UAVs, UAV swarms) equipped with edge-computing devices (AI/ML) for direct applications in livestock management such as detecting focused risks. These developments are being evaluated in real field conditions through the dedicated pilot activities.
The current work presents the preliminary results of SPADE livestock use cases undergone two trials to evaluate the performance of UAS-enabled edge-computing AI tools, for ML modelling & data assimilation. The scope is to enable the flying systems for real time monitoring of sheep in open field grazing environments. Within this framework, the SPADE Livestock setup utilized state-of-the-art object detectors and edge computing devices. The Models being investigated included Faster R-CNN, YOLO, and SSD as backbone object detection in aerial images captured by the UAS. The acquired dataset was used to train selected Tiny Object Detection algorithms.
The trials included flights at varying altitudes for capturing objects at different scales and evaluate the motion blur due to high-speed at low-altitude flights. The analysis proposed the utilization of TPH-YOLOv5 model, an enhanced version of YOLOv5, where an additional prediction head is introduced to detect objects at different scales. Furthermore, the original prediction heads are replaced with Transformer Prediction Heads (TPH), which leverage a self-attention mechanism to enhance object detection capabilities. Moreover, the convolutional block attention model (CBAM) was integrated into the model to identify attention regions in scenarios with dense objects. The results showed that TPH-YOLOv5 exhibits excellent performance when applied to drone-captured scenarios and thus outperformed competing methods. Specifically, on the DET-test-challenge dataset, TPH-YOLOv5 achieved an average precision (AP) of 39.18%, surpassing the previous state-of-the-art method by 1.81%. Plans for future work include the implementation of further in-situ pilot trials, to evaluate the real-time response of the system.

Keywords: Digital Agriculture, Unmanned Aerial Systems, Edge-computing, Machine learning, Livestock management

Acknowledgement: This work has been supported by the SPADE project, funded by the European Union’s Horizon Europe Research and Innovation programme within HORIZON-CL6-2021-GOVERNANCE-01 under Grant Agreement no. 101060778.

PP01-020 | Optimizing maize crop productivity: A variable rate approach from over-density trials with different inter-row spacing and sowing densities

Luís Conceição[1,2,3], Luís Silva[1,2,4], Tiago Silva Pinto[5], Susana Dias[1,2], Constantino Valero[6]
[1]Polytechnic Institute of Portalegre, 7300-110 Portalegre, Portugal, [2]Research Center for Endogenous Resource Valorization, Polytechnic Institute of Portalegre, 7300-110 Portalegre, Portugal, [3]InovTechAgro—National Skills Center for Technological Innovation in the Agroforestry Sector, 7300-110 Portalegre, Portugal, [4]Earth Sciences Department, NOVA School of Science & Technology, Campus of Caparica, NOVA University Lisbon, 2829-516 Caparica, Portugal, [5]INOVMILHO—National Skills Center for Maize and Shorgum, António Teixeira Experimental Station, 2100-127 Coruche, Portugal, [6]LPF-TAGRALIA, School of Agricultural, Food and Biosystems Engineering (ETSIAAB), Technical University of Madrid, Avenida Puerta de Hierro 2-4, 28040 Madrid, Spain

The implementation of drip irrigation in maize crops with a 0.75 cm inter-row spacing faces recurring challenges, particularly regarding the optimal emergence of sown maize. To address this, an experimental trial was conducted on a 1.3-hectare plot at the António Teixeira Experimental Station in Coruche (38.941844, -8.512472). The trial aimed to assess the impact of widening inter-row distances while adjusting sowing doses and plant populations per hectare. By increasing row spacing to 1.50 meters, an over-density of plants within the rows was created, especially when augmenting the sowing dose. The primary objective of the experiment was to measure the emergence rate of over-density trials with a row spacing of 1.50 meters and sowing densities of 80,000 and 160,000 plants per hectare. A comparison was made with traditional row spacing of 0.75 meters and a density of 80,000 plants per hectare. Parameters evaluated included the number of plants reaching the end of the crop cycle, the number of ears, specific grain weight, and yield (t ha-1) for two maize varieties (DKC 6092 and Ixabele). Remarkably, the yield in trials with a 1.50-meter inter-row spacing remained consistent with the control trial (14.2 t ha-1 of grain maize at 14% humidity). The 80,000-plant trial achieved a yield of 14.7 t ha-1, and the 160,000-plant trial yielded 15.3 t ha-1. This suggests that widening inter-row spacing does not directly impact yield compared to traditional spacing. Trials with a planting density of 80,000 plants closely resembled the control, while those with 160,000 plants deviated slightly. Further investigation into intermediate densities is recommended to understand their influence on plant emergence and completing the crop cycle. The DKC 6092 variety demonstrated yields at super-density comparable to the control, while the Ixabele variety produced slightly less but consistently across densities. The study suggests that maize variety is a factor influencing productivity, prompting the exploration of other varieties in this system in future research. Crucial aspects to analyze include sowing density and maize variety, both of which could significantly impact desired objectives.

PP01-021 | Classification model using cluster analysis with corn silage yield maps

Javier Bueno Lema[1], Jorge Dafonte Dafonte[1], José Miguel Edreira Sanjurjo[1], Miguel Ángel Vilar Rivas[2]
[1]Department of Agroforestry Engineering, University of Santiago de Compostela, Lugo, Spain,
[2]Department of Applied Mathematics, University of Santiago de Compostela, Lugo, Spain

Precision Agriculture (PA) is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. In northwest Spain, agricultural contractor companies that work with self-propelled (SP) forage harvesters equipped with yield mapping systems, usually harvest lots of small fields in every season. For example, the contractor company that has obtained the yield files used in this work harvests around 700 fields each season, of which 50% have an area of less than 1 ha. In this scenario, working with between-field variability may be more advisable for optimizing the management of each field (seeding rate, corn variety, fertilizer rate…). Between-field variability implies the variability among fields, where each field can be considered as a unit.

This article presents a methodology used to analyze the variability of inter-field and intra-annual production. For that purpose, data from yield maps obtained in 67 different fields in northwest Spain were used. In all the fields a corn silage crop was harvested through four seasons (2019-2022) with a SP forage harvester equipped with a yield mapping system. The Principal Component Analysis (PCA) method was used, which is a multivariate analysis technique that allows identifying the variables that represent most of the total variance in the datasets. When PCA is used, a new set of synthetic variables called principal components (PCs), which are uncorrelated with each other and commonly denoted as linear combinations of the original variables, are obtained from the original variables through some transformations.

Once the principal components were calculated, the parameters were grouped based on these components. Both variable groups and field groups were also defined using PCA to grade the importance of the variables considered in the field on dry and wet yield.

Keywords: Precision Agriculture, Yield Maps, Cluster Analysis, Corn Silage

PP01-022 | Estimation of the water footprint using a life cycle assessment approach

Alexandros Liapis[1], Pantazis Georgiou[1], Dimitrios karpouzos[1]
[1]Aristotle University of Thessaloniki, School of Agriculture, Department of Hydraulics, Soil Science and Agricultural Engineering, Thessaloniki, Greece

The Water Footprint is widely used in water management of agricultural activities, mainly due to its straightforward concept and efficiency in assessing the water consumption of goods' production. However, environmental impacts such as regional water scarcity dictate the need to consider the distinct characteristics of a crop area in irrigation water management. The aim of this paper is to showcase, through the study of the hydrological and agricultural profile of the river Nestos plain in Northern Greece, that the Life Cycle Assessment principles can be a methodological updated approach of the conventional Water Footprint framework towards the sustainability of water resources management in a specific region. To conduct the Assessment of Water Footprint for this paper, the methodology of Ridoutt and Pfister was implemented, which is based on the framework and principles of Life Cycle Assessment (LCA), in compliance with ISO 14046. The net irrigation water requirements (IWRn) of the crops were calculated using the software CROPWAT. The environmental impact category chosen is the eutrophication of freshwater in the study area, and the calculations were conducted using the LCA software SimaPro. The results have shown that the Water Footprint calculation, according to the Life Cycle Assessment methodology, is a comprehensive tool for assessing the environmental impacts of water use for irrigation purposes. Due to the correlation of water use with the local water supplies, the results are directly comparable with those of other regions, facilitating water resources management at local and global levels.

PP01-023 | An AI-based approach to animal welfare modelling

Chao Zhang[1], Ricardo da Silva Torres[1,3], Lars Christian Gansel[4], Marc Bracke[2]
[1]Department of Plant Sciences, Agricultural Biosystems Engineering Group, Wageningen University & Research, Wageningen, the Netherlands, [2]Department of Animal Health and Welfare, Wageningen Livestock Research, Wageningen University & Research, Wageningen, the Netherlands, [3]Wageningen Data Competence Center, Wageningen University and Research, Wageningen, the Netherlands, [4]Norwegian University of Science and Technology, Ålesund, Norway

Animal welfare is a sustainability issue that is receiving increasing attention in society as well as in the scientific community. However, assessing animal welfare is a complex concept that is difficult to quantify directly. Semantic Modeling (SM) defines welfare as the quality of life as perceived by the animals themselves, utilizing scientific insights into animal behavior and health. Despite its efficacy, constructing a semantic model demands substantial expertise and is time consuming. To overcome this challenge, we will analyze and decompose the process of semantic modelling process and explore potential solutions of an artificial intelligence (AI)-based approach to semantic modelling. The envisioned AI-based semantic analysis comprises three key components. Initially, Natural Language Processing (NLP) is proposed to extract information from voluminous, unstructured text data, transforming it into a concise, structured format. Subsequently, Knowledge Graphs (KGs) can be explored to establish connections between relevant indicators of animal welfare. Finally, a model inference approach can be used to calculate the weights of indicators, facilitating the construction of comprehensive animal welfare models. This approach aims to streamline and expedite the intricate process of building animal welfare models. By incorporating NLP, KGs, and model inference, our proposed methodology may present a promising avenue to contribute to the sustainable development of the livestock industry.

PP01-024 | Revolutionizing livestock management: synthesizing advanced sensor data with genAI for cattle behavior recognition

Regina Eckhardt[1], Reza Arablouei[2], Kieren McCosker[3], Heinz Bernhardt[1]
[1]Technical University Of Munich, Freising, Germany, [2]CSIRO, Pullenvale, Australia, [3]University of Queensland, Brisbane, Australia

In precision livestock agriculture, the utilization of sensor data plays a vital role in understanding animal behavior and welfare. As farms and herds expand, the complexity of collecting and interpreting this data increases. Typically, existing datasets represent only the specific conditions under which they are collected, limiting their broader applicability. For advanced analysis, particularly when employing artificial intelligence (AI) models, there is a critical demand for comprehensive datasets that can facilitate effective modeling and deriving insightful conclusions.

This study proposes the employment of generative artificial intelligence (genAI) to generate extensive sensor datasets in livestock agriculture. This method aims to overcome the limitations inherent in conventional data collection methods, allowing for the representation of a broader range of scenarios within the datasets, encompassing diverse climatic conditions and nutritional variations.

The methodology of our study includes two main steps: The first step involves generating synthetic accelerometer sensor data using genAI, specifically leveraging transformer architecture. In an initial application this approach has already demonstrated promising results, particularly with the Informer and Reformer models - both of which are sophisticated implementations of the transformer architecture. These models exhibited low root mean squared error (RMSE) and median absolute error (MedAE), indicative of their potential for accurate behavior prediction in diverse conditions. This enables the coverage of a wider array of scenarios beyond the capabilities of traditional data collection methods, thus leading to the creation of a more diversified dataset. The second step focuses on refining an AI model capable of interpreting and predicting cattle behavior leveraging this comprehensive dataset. This model is essential for understanding various conditions, such as environmental and dietary changes, and devising appropriate responses.

Our study emphasizes the pivotal role of genAI in augmenting data resources for effective livestock management. The enhancement of data breadth and quality through genAI is a key to crafting sophisticated predictive models tailored for livestock management and developing sustainable strategies. This approach not only expands the utility of AI in agricultural systems engineering, but also empowers farmers with the tools to effectively adapt to evolving environmental and managerial conditions, representing a substantial leap forward in the domain of precision agriculture.

Keywords: GenAI, artificial intelligence, sensor data, cattle

PP01-025 | Strategies for mitigating heat stress in pig farming: Safeguarding animal welfare in a warming climate

Erika Yukari Nakanishi[1], Dalila Larios[1], Joahnn Palacios[1], Valerie Letourneau[2], Caroline Duchaîne[2], Martine Boulianne[3], François-Xavier Philippe[4], Naceur Mhamdi[5], Stephane Godbout[1]
[1]Irda, Quebec, Canada, [2]Laval University, Quebec, Canada, [3]University of Montreal, St-Hyacinthe, Canada, [4]Université de Liège, Liège, Belgium, [5]INAT, Tunis, Tunisia

Climate change and global warming pose challenges for livestock production, especially in Europe and North America, notably in Canada, where hotter and more humid summers are expected. This climate shift increases the risk of heat stress in animals, particularly in pig farming. Pigs in hot conditions face a challenge because they lack sweat glands, i.e., they do not sweat, making it difficult for them to easily lose heat and maintain thermal comfort. In addition, heat stress can lead to reduced productivity, resulting in economic losses. Annually, $299 to $316 million is lost in the swine industry in the US livestock industry due to heat stress. With ongoing global warming, it is expected that the adverse effects of heat stress on livestock production will become more pronounced in the future4. This literature review aims to list and discuss key management strategies used worldwide to mitigate thermal stress in pig production, for promoting sustainable and resilient farming systems in the face of hotter and more humid climate during the summer. Four main strategies have emerged from this review: livestock management, cooling methods, feeding adjustments, and genetic approaches. Livestock management and feeding strategies offer straightforward solutions to mitigate heat stress that can be implemented in the short term. The incorporation of feed supplements improves animal performance and the immune system, aiding in managing heat stress. Cooling methods are categorized into passive and active cooling systems. Passive systems are considered cost-effective; however, in regions with hot and prolonged climates, the adoption of active cooling systems becomes necessary as passive cooling alone may not suffice. Active cooling systems have been demonstrated to be more effective. However, during elevated temperatures and humidity, some techniques or systems such as direct evaporative cooling, fogging, and spray cooling increase indoor humidity, consequently diminishing their efficiency and affecting thermal comfort and air quality. In this case, other techniques or systems like dew-point indirect evaporative cooling, desiccant-evaporative cooling, surfaces cooling, forced-air cooling could be more advantageous, reducing the inlet air temperature without humidification. In conclusion, managing heat stress will become more restricted and less efficient as global warming intensifies. Decisions and actions will need to be carefully considered for the new climatic scenarios.

PP01-026 | Bacillus subtilis and Burkholderia seminalis in promoting the growth of Solanum lycopersicum l

Henrique Fonseca Elias De Oliveira[1], Thiago Dias Silva[1], Priscila Jane Romano Gonçalves Selari[1], Wesley de Melo Rangel[1], Jhon Lennon Bezerra da Silva[1], Marcio Mesquita[2], Marcos Vinícius da Silva[3]
[1]Goiano Federal Institute, Ceres, Brazil, [2]University of Goiás, Goiânia, Brazil, [3]University of Alagoas, Maceió, Brazil

The use of microorganisms has proven to be a promising technique in agriculture, providing greater efficiency in the use of water and nutrients by crops. The study focused on the use of microorganisms Bacillus subtilis (strain ATCC 23858) and Burkholderia seminalis (strain TC3.4.2R3) and the evaluation of the effects of inoculation on the growth and productivity of cherry tomato (Solanum lycopersicum var. cerasiforme) in a protected environment. Adopted a randomized block design (DBC) with three treatments: i) Bacillus subtilis ATCC 23858, ii) Burkholderia seminalis TC3.4.2R3, and iii) without inoculation (SI). Eight blocks were used in the experiment. Morphometric parameters and yields were measured at 15 and 30 days after sowing (DAS) and at 135 days after transplanting (DAT). Parameters evaluated included germination rate, emergency germination speed, chlorophyll and carotenoid content, water content foliar, productivity, and fruit quality. At 15 DAS Burkholderia seminalis showed higher germination rates compared to the non-inoculated treatment and Bacillus subtilis resulted in greater plant and root height compared to the non-inoculated treatment. AT 30 DAS Bacillus subtilis and Burkholderia seminalis inoculations led to statistically significant differences in emergence speed index (IVE), fresh mass (MFPA), dry mass (MSPA), and root length (CR). AT 135 DAT both Bacillus subtilis and Burkholderia seminalis increased productivity compared to the non-inoculated treatment, soluble solids content of fruits increased due to inoculation with both microorganisms and Inoculation also enhanced mechanical resistance of the fruits. Inoculation with Bacillus subtilis and Burkholderia seminalis demonstrated the potential to promote plant growth, increase productivity, and improve the quality of fruits. The study suggests that these bioinoculants can be used in sustainable agricultural management.
Keywords: bioinoculant, BPCP, solanaceae, Tomato, main component analysis.

PP01-027 | Improving dairy cow feed intake monitoring: Insights from depth camera imaging

Marjaneh Taghavi[1], Tomas Izquierdo[1], István Fodor[1]
[1]Wageningen University & Research, Wageningen , Netherlands

Monitoring individual dairy cow feed intake is crucial for optimizing feed efficiency and detecting health events. Established methods for measuring feed quantity and intake are too costly for implementation on commercial farms. Therefore, increasing attention is paid to computer vision-based solutions such as 3D cameras, which offer a more affordable alternative. In this study, we investigated the effect of camera-to-feed distance and time of day on the relationship between estimated feed volume and measured feed weight.
An Intel® RealSense D455 depth camera was set up at the Dairy Campus of Wageningen University and Research (Leeuwarden, the Netherlands). Positioned above a heap of feed (Total Mixed Ration), the camera was paired with a digital scale accurate to 0.1 kg to measure feed weight. RGB-depth images of the feed were taken across a range of 0.5-20 kg, with increments of 0.5 kg, at two different heights (1 m and 2.6 m), and under varying light conditions (morning and afternoon) within the barn. Each setup captured five different shapes for every feed weight, resulting in a total collection of 800 RGB-depth images.
A deep learning image segmentation model called Segment Anything was utilized to segment the feed on each RGB image and applied resulting masks to depth images. A point cloud of the segmented food was generated from RGB-depth data. Subsequently, a Delaunay 2.5D algorithm was employed to create a mesh from the point cloud, and feed volume was calculated by summing triangle volumes within the mesh.
A linear model was fitted to the data with log-transformed feed volume as the dependent variable, log-transformed feed weight, camera-to-feed distance, light condition, and all two-way interactions as explanatory variables. Non-significant terms ($P > 0.05$) were removed from the final model.
We observed an interaction between the light condition and weight effect ($P = 0.003$), with estimated feed volume increasing by 0.85% and 0.68% with each % increase in feed weight in the morning and afternoon, respectively. The distance of the camera from the feed was significantly related to the estimated feed volume ($P < 0.001$). When fitted separately by distance, the model explained 66.5% of volume variance at 1 m distance and 38.1% at 2.6 m. Outliers occurred more frequently at 2.6 m (6.6%) compared to 1 m (1.8%).
Overall, distance and light conditions need to be taken into account when using RGB-depth imaging to estimate feed volume.

PP01-028 | Implementation of a proximal optical sensor for real-time characterization of extensive rainfed crops and targeted fertilizer applications

María Videgain[1,2], Sergio Artero[1], Alba Vigo-Morancho[1], Mariano Vidal[1], F. Javier García-Ramos[1,2]
[1]Escuela Politécnica Superior - Universidad De Zaragoza, Huesca, Spain, [2]Instituto Agroalimentario de Aragón - IA2, Huesca, Spain

In recent decades, the advancement of Precision Agriculture (PA) technologies has facilitated a detailed analysis of spatial and temporal variability in agricultural fields, enabling site-specific management of input applications. Variable-rate bottom fertilizer application in extensive crops often relies on a prescriptive map that delineates management zones based on previously collected information. Similarly, variable nitrogen fertilizer application can be based on prescriptive maps derived from vegetation indices at the time or in real-time, based on measurements taken by onboard sensors. The capability of optical sensors, specifically proximal sensors, to collect real-time data and provide detailed information about crops represents a technological advancement that aids decision-making and translates into direct prescriptions for machinery. This study implements the CropSpec active proximal optical sensor (Topcon Positioning, Spain) for real-time characterization of the vegetative state of extensive rainfed crops, aiming to conduct targeted fertilizer applications based on sensor measurements. The implemented sensor measures crop reflectance using near-infrared and red edge bands, calculating its own vegetation index. The selected configuration comprised two sensors mounted on the top of a John Deere 6155 R tractor cabin, connected through an independent Isobus line. These sensors are linked to an AGM1 GNSS receiver for geolocating recorded data. The approximate measurement footprint width of each sensor is 3.81 m. Measurements were taken with the sensor across a total of 60 hectares of crop (cereal and pea under rainfed conditions) in the 2023/2024 agricultural season. The data were correlated with apparent electrical conductivity (ECa) information, acquired by means of Veris 3100 ECa Surveyor, and Normalized Difference Vegetation Index (NDVI) calculated from satellite images from the Planet Scope constellation. High levels of correlation between the three variables were observed across all plots. Additionally, a real-time fertilizer application based on sensor measurements was conducted in a specific plot (5 ha), correlating sensor measurements with crop vegetation index and SPAD index. The results of this application allowed for observing the difference in application accuracy when applying with the sensor compared to NDVI-based prescription maps. The results demonstrate the feasibility of using optical proximity sensors for real-time characterization of extensive rainfed crops and for implementing targeted fertilizer applications based on sensor data. This approach enhances PA practices by providing timely and accurate information for decision-making, ultimately leading to optimized resource management and improved crop yields.
Key words: precision agriculture, satellite images, apparent electrical conductivity, variable rate application, cereal management

PP01-029 | Developing a plant for processing PGI 'Cipolla Rossa di Tropea Calabria' onions using compressed air

Matteo Sbaglia[1], Lorenzo M. Abenavoli[1], Bruno Bernardi[1]
[1]Dipartimento di Agraria, Università Mediterranea di Reggio Calabria, Reggio Calabria, Italy

One of the best-known Italian products is 'Cipolla Rossa di Tropea Calabria PGI', which refers to the Allium cepa L. onion, limited to the local ecotypes of Tondo Piatta (early), Mezza Campana (medium) and Allungata (late). A mark identifying red onion bulbs in Cipollotto (spring onion), Cipolla da Consumo Fresco (fresh onion) and Cipolla da serbo (onion for preserving) that meet the conditions and requirements of this specification, following Regulation (EC) No 510/2006. Depending on the stage and type of product being processed, the mechanical plant plays a key role in the processing chain. In post-harvest operation, plants based on the use of large quantities of water are widely used for processing spring onions, allowing them to be washed, rooted, and peeled at the same time. They generally consist of cutting, peeling, and cleaning equipment. Both root and leaf-cutting are usually carried out by 2 pairs of shearing blades. Peeling is carried out by 2 pairs of rotating rollers, usually of the brush type, and during the peeling phase, washing is also carried out through a series of special sprayers. However, a problem with this type of system is that the water stagnating in the cut onions tends to spoil them, reducing their shelf life. A processing line that uses compressed air to clean the onions was developed to solve this problem. This research reports on the functional structure of the realised plant.

PP01-030 | Improving energy-efficiency and indoor climate of livestock buildings for pigs through passive and active adaptation measures- a PhD-project

Therese Malm[1], Marie-Claude Dubois[1,2]
[1]Department of Biosystems and Technology, Swedish University of Agricultural Sciences, Alnarp, Sweden, [2]Department of Building and Environmental Technology, Lund University, Lund, Sweden

Climate change causes warmer and more humid climates as well as increasing the frequency and duration of heat stress for pigs housed in confined buildings. This elevated heat stress not only compromises the welfare and health of the animals but also increases economic risks for farmers due to impacts on growth and mortality rates and potentially increased energy demand.
To address these challenges, this PhD-project aim to assess potential adaptation measures in livestock buildings for pigs to mitigate the adverse impacts of climate change while promoting energy efficiency. The objective is to identify cost-effective solutions for pig livestock buildings that ensure optimal indoor conditions, particularly as external temperatures and humidity levels rise due to climate change. A literature review has been conducted, focusing on energy use and indoor climate conditions in these buildings, with a separate abstract submitted to EurAg2024.
In this project, the indoor climate and energy use in a section for fattening pigs is investigated using the dynamic simulation software programme IDA ICE 4.8. The private company Equa Simulation AB developed IDA ICE 4.8. In Sweden, the software is widely used in the building design process for offices, residential buildings, schools etc. The building studied is located at the Swedish livestock research centre (59°49'59.9"N 17°49'02.2"E).
The simulation will undergo validation using measurements obtained from one section for fattening pigs at the research centre. The measurements for the validation include monitoring electricity use and air flow of the exhaust air fan, as well as monitoring energy use for heating by flow and temperature readings from floors and wall-heating systems. Additionally, temperature and humidity loggers have been deployed in the section above six out of 14 boxes, close to the exhaust air fan as well as above two pairs of supply air devices situated in the ceiling, and outdoors by the air intake. Weather and solar radiation data are sourced from the nearby Lövsta field research station.
The validated model will be used to assess the impact on energy use and indoor climate conditions of various passive and active adaptation measures, in current and in future climate scenarios. Possible adaptation measures are insulation level, sedum roof, cooling, and solar shading.

PP01-031 | VApplications of artificial intelligence in the identification of objects for the analysis of waste in the Segura river

Ana María Codes Alcaraz[1], Carmen Rocamora Osorio[1], Herminia Puerto Molina[1]
[1]Universidad Miguel Hernandez, Alicante, España

Plastic pollution in marine ecosystems presents a significant contemporary challenge due to its pervasive presence in rivers and oceans and its enduring persistence. This research specifically targets the river and traditional irrigation system of Vega Baja del Segura, situated in southeastern Spain, where substantial accumulations of floating waste hinder efficient water distribution in irrigation ditches and azarbes. The primary objective of this study is to develop an algorithm capable of automatically identifying and quantifying various types of debris through image analysis using aerial photographs captured by drones at multiple locations along the river and canals. The YOLOv5 algorithm was employed for training, with mean Average Precision (mAP) serving as the benchmark for evaluation. An mAP of 0.5 yielded an accuracy of 97%, while accuracy ranged at 79% for mAP values between 0.5 and 0.95. This methodology promises to mitigate subjectivity in debris quantification and facilitate swift and secure identification of their sources within the river ecosystem.

Key words: YOLOv5, Python, Plasctic, Waste, Rivers

PP01-032 | Data model for digital twins in smart farming

Annimari Hartikainen[1], Katariina Pussi[1], Taru Palosuo[1], Matti Pastell[1]
[1]Natural Resources Institute Finland (Luke), Helsinki, Finland

Digital twins, i.e. digital representations, of fields are increasingly developed and applied to support decision-making, forecasting and data analysis in agriculture. They combine real-time measurement data with agricultural simulation models or artificial intelligence models and could e.g. guide precision management or provide data for life cycle assessment.

Data models within digital twins describe the data flows between the used models and data sources. A well-documented data model enhances the transparency of the modeling process and allows for smooth integration of new simulation models or data sources. The aim of this study is to define and build a data model for a digital twin of a farm including machinery and management data from fields and basic animal data and milking robot data from the barn. A new data model is required because existing data models are too general for modeling purposes.

The requirements for the data model were 1) measured and modeled data should be included; 2) the uncertainty of both the measurements and the models must be presented; 3) daily crop model data, aggregated event-based machinery data, farm management information system data, yield maps and daily weather data should be included; 4) data should be treated as objects with relations; 5) should be easily applicable to these data sources on different farms; 6) the vocabularies should be as standardized as possible.

Requirements definition led to the selection of NGSI-LD information model. Its suitability for digital twins has been tested and documented previously. NGSI-LD model represents data as objects with relations, as required. Contexts and clear interface documentation make NGSI-LD an easy-to-apply solution for a variety of farms with different data sources. ICASA vocabulary was selected as the vocabulary for field data, while ontologies ATOL and EOL were chosen for animal data to be added in the following use cases.

Prototype of the data model for the digital twin was created. FIWARE software components enabled rapid prototyping of NGSI-LD in the agricultural digital twin. Data from one research farms was mapped to the data model. Simulation models, using cropping system model APSIM, were generated and run using data from the data model and the model results were mapped back to the data model. According to this prototype, the data model seems suitable for smart farming digital twin, and it meets the requirements. The model can be easily extended to include additional data sources and models.

Keywords: Smart Farming, Data Model, NGSI-LD

PP01-033 | Interaction of agroecosystems and aquaculture through engineering: Experiences with small-scale tilapia farms, aquaponics and agroecological systems in South Mexico

Francisco Javier Martinez Cordero[1], Laura Patricia Silva Ledezma[2], Leopoldo Martinez[3]
[1]Research Center For Food And Development Ciad Ac, Mazatlan, Mexico, [2]Research Center For Food And Development Ciad Ac, Mazatlan, Mexico, [3]Research Center for Advanced Technology CIATEQ, Queretaro, Mexico

Agroecological systems integrated with small-scale aquaculture in rural areas, provide not only food for own consumption but the possibilities of generating an extra income by selling excess production in high-poverty households of the South Pacific Mexico. These production systems face similar problems related to water scarcity and droughts as bigger-scale farms, but the consequences are bigger due to their vulnerability. In this paper we are reporting results of incorporating aquaponics in rural, small-scale agroecological systems in order to reduce vulnerability as an adaptation strategy to Climate Change. Engineering is adapted not only to a reduced-cost model for these farmers, but also operating an integrated production model that is easy to learn and respects traditions and cultural habits of farmers. For example, the aquaponics variety or group of vegetables or plants –and their production engineering- are decided by the own farmers according to their needs and traditions, reusing available material and in some cases incorporating models of rain-water collection, low-technique, very practical from the engineering point of view.
Complementing this innovative, small-scale rural model, the agroecological and aquaponics products are offered by the farmers directly to their final clients (usually short-chain markets, or last mile) using digitalization by the platform AUAKAN, in order to improve the usually very small digitalization of rural farmers in Mexico.
Evaluated at multilevel poverty, results prove that these systems reduce it meaing a very desirable impact to increase socioeconomic impacts of engineering adapted and incorporated at small-scale rural farming systems.

PP01-034 | QuantiAGREMI project: On farm quantification of ammonia and greenhouse gas emissions from livestock production

Mélynda Hassouna[1], Sabine Schrade[2], Paola Fisicaro[3]
[1]Inrae, Institut Agro Rennes-Angers, UMR SAS, Rennes, France, [2]Agroscope, Ruminant Nutrition and Emissions, Tänikon, Ettenhausenand, Switzerland, [3]LNE, Paris, France

Many current food production practices still result in air, water and soil pollution, contributing to biodiversity loss, climate change and poor air quality. Increasing global food demand drives ruminant livestock numbers, rapid land use change and nitrogen fertilizer use, accelerating greenhouse gas emissions. The aim of this research is to provide a SI-traceable field measurement infrastructure for accurate determination of animal houses emissions as well as nitrogen footprints.
The specific objectives of the project are:

1. To develop, traceable techniques for quantifying NH_3 and CH_4 emissions from selected livestock housings with a target uncertainty of 10 % (CH_4) to 20 % (NH_3) for mechanically ventilated and 30 % (CH_4) to 40 % (NH_3) for naturally ventilated housing. In addition, to define target applications (e.g. animal category, housing systems) according to stakeholder needs.
2. To develop and characterise CO_2, NH_3 and CH_4 emission monitoring techniques, considering atmospheric conditions, for enhanced spatial and temporal coverage.
3. To identify, using emissions data from objective 2, key-indicators (e.g. milk urea content and manure storage) and to improve emission models (e.g. based on feeding, climate conditions) for increasing the representativeness of the emission estimations and determine their uncertainty. In addition, to develop farm-monitoring systems for evaluating the efficiency of reduction measures and provide management tools to farmers for ensuring reduction performance.
4. To reduce the uncertainty associated with up-scaling GHG emissions and nitrogen loss from soils by improving model parameterisation using field-deployable spectroscopic techniques to determine N_2O isotopic species for different production pathways. To improve methods for quantifying NH_3 deposition from livestock housing and tracing nitrogen isotopes in managed soils.
5. To facilitate the dissemination and uptake of the technology and measurement infrastructure developed in the project by (i) contributing to emissions inventory reports, (ii) providing guidelines to the measurement supply chain and standardisation developing organisations on techniques/modelling approaches, and (iii) providing farmers access to reliable methods for identifying efficient mitigation strategies and provide quantitative GHG emissions at farm level.

The project results will create impact on policy makers by providing them with decision-making tools to adopt efficient measures to reduce emissions. Improved SI-traceable estimations of NH_3 and GHG emissions from agriculture with a defined uncertainty available will create further impact not only on the scientific community, by enhancing emission data comparability across monitoring studies, as well as on agricultural agencies, by contributing to better emission inventories for air pollutants and greenhouse gases

PP01-035 | Improving3D photogrammetry workflow for berry fruit quality assessment

Alessandro Zanchin[1], Aref Sepehr[1], Uxue Encinas Zamora[1], Francesco Marinello[1], Lorenzo Guerrini[1]
[1]Università di Padova, Legnaro, Italy

The assessment of berry fruit morphology and damage estimation is essential for various agricultural applications, including crop management and quality control. Traditional methods for evaluating fruit morphology and damage often rely on manual measurements, which can be time-consuming and subject to human error and variability. In recent years, 3D photogrammetry has emerged as a promising technology for automating and enhancing this process.
This study focuses on optimizing the workflow of 3D photogrammetry for assessing strawberry fruit morphology and estimating damage from impact and frost. By refining the image capture, processing, and analysis steps, we aimed to streamline the process and improve the accuracy of morphological measurements and damage estimation.
Our research involved several experimental trials to evaluate different parameters and techniques for optimizing the workflow. Through iterative testing and refinement, we identified key factors that contribute to the efficiency and reliability of 3D photogrammetry in assessing strawberry fruit morphology and damage.
The results of our study demonstrate significant improvements in workflow efficiency and measurement accuracy compared to traditional methods. By leveraging 3D photogrammetry technology, researchers and practitioners can obtain detailed and precise morphological data and damage estimation in a fraction of the time required by manual methods.
Overall, this research contributes to the advancement of 3D photogrammetry as a valuable tool for strawberry fruit morphology assessment and damage estimation. Further optimization and refinement of the workflow will continue to enhance the capabilities of this technology, opening up new possibilities for research and application in strawberry cultivation and beyond.

PP01-036 | Data-driven solutions for farmer empowerment in smart agriculture: Challenges and opportunities

Havva Uyar[1,2], Clare Sullivan[2], Stamatia Rizou[1], Spyros Fountas[2], Ioannis Karvelas[1], Antonia Vronti[1]
[1] Singular Logic S.A., 14564 Kifisia, Greece, [2]Agricultural University of Athens, 11855 Athens, Greece

In the dynamic landscape of smart agriculture, farmers face multifaceted challenges, including limited resources and barriers to market access. This paper presents initial insights derived from an ongoing study aimed at evaluating the challenges and opportunities for farmers through the application of data-driven solutions.

While data-driven solutions in agriculture are expanding, there is a noticeable gap in understanding the challenges and opportunities specific to farmers when entering the agri-data economy. The existing literature lacks a thorough exploration of the complexities involved in the adoption of data-driven strategies by farmers, which is even more profound in smallholder contexts. This study examines the challenges that hinder the effective use of data-driven approaches among farmers. The methodology involves a PESTLE analysis backed up through literature review and collaborative workshops with stakeholders actively involved in the agri-food chain. This participatory approach ensures a diverse range of perspectives, allowing for a holistic exploration of challenges, opportunities, and potential solutions.

Preliminary results indicate that the main barriers to the adoption of data-driven solutions among farmers revolve around cost and complexity. The workshops highlight the financial implications of technology adoption, with discussions during the sessions indicating a robust demand for training programs aimed at improving technological literacy. Moreover, stakeholders' feedback indicates a shared belief that there is a shortage of technologies designed to meet the varied needs of different farming environments. Additionally, a critical gap still exists in applying data-driven technologies towards climate resilience and mitigation in agriculture. Despite the rising research activities related to the effects of extreme climate events (e.g., flooding, drought), more work is needed on the role of data in predicting and preparing for such events.

The implications of this research are profound for both academia and practitioners in agriculture. By identifying and addressing the specific barriers faced by farmers in adopting data-driven solutions, this study contributes to the development of targeted interventions and strategies. The findings hold significance for policymakers, technology providers, and farmer support organizations, offering insights that can inform the design of inclusive and effective data-driven initiatives tailored to different agricultural contexts.

Keywords: smart agriculture, data-driven solutions, smallholder farmers, technology adoption, climate resilience.

PP01-037 | YOLO-based computer vision technique for identification of individual dairy cows

Claudia Giannone[1], Marco Bovo[1], Mattia Ceccarelli[1], Stefano Benni[1], Daniele Torreggiani[1], Patrizia Tassinari[1]
[1]University Of Bologna, Bologna, Italy

This research paper focuses on the application of a deep learning-based computer vision system in livestock management, specifically for individual cow identification in a dairy farm case study. In the work, a YOLO neural network to train the system to recognize cows based on their unique coat patterns has been adopted. The trained net-work is then tested on a dataset collected from different positions within the barn to assess its recognition capabilities in diverse contexts. The performance of the system is evaluated using precision-recall curves, and data augmentation techniques are applied to enhance the dataset and optimize detection efficiency. The results highlight the system's generalizability and robustness across different real context, emphasizing its ability to recognize cows in various positions. Overall, this research contributes to the advancement of precision livestock farming by enabling real-time recognition of individual cows. The findings also demonstrate the system's potential for monitoring behaviors and movements of cows within a barn, providing valuable insights for livestock management.
Acknowledgments
The activity presented in the paper is part of the research project PRIN 2017 “Smart dairy farming: innovative solutions to improve herd productivity” funded by the Italian Ministry of Education, University and Research [20178AN8NC].

PP01-038 | Exploring feasibility: Low-cost wireless approach for ammonia emissions measurement in German dairy farms

Harsh Sahu[1], Thomas Amon[1,2], Jürgen Zentek[3], Barbara Amon[4,5], David Janke[1]
[1]Department of Sensors and Modelling, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Max-Eyth-Allee 100, 14469, Potsdam, Germany, [2]Department of Veterinary Medicine, Institute of Animal and Environmental Hygiene, Freie University Berlin, Robert-von-Ostertag-Str. 7-13, 14163, Berlin, Germany, [3]Department of Veterinary Medicine, Institute of Animal Nutrition, Freie University Berlin, Königin-Luise-Str. 49, 14195, Berlin, Germany, [4]Department of Technology Assessment, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Max-Eyth-Allee 100, 14469, Potsdam, Potsdam, Germany, [5]Faculty of Civil Engineering, Architecture and Environmental Engineering, University of Zielona Gora, Licealna 9/9, 65-417, Zielona Gora, Poland

In naturally ventilated dairy barns (NVDBs), estimating ammonia (NH3) emissions conventionally relies on multipoint gas analyzers, which are costly and therefore can not be scaled up to multiple barns. Therefore, the goal of this study, in the context of the national joint-project “EmiMod”, was to examine the viability of low-cost sensors as an alternative. In this experiment, several wireless sensor nodes were deployed inside an NVDB in parallel with spatially distributed sampling points of a Cavity Ringdown Spectrometer (CRDS). The low-cost wireless nodes consisted of Electrochemical (EC) sensors for ammonia (NH3) and carbon dioxide (CO2), and climate variables (temperature, relative humidity, and ambient pressure). The low-cost system was calibrated and tested in the laboratory with varying concentrations of CO2 and NH3 and then deployed in an NVDB in Germany. To estimate the accuracy and precision in measuring NH3 emissions, the indirect CO2-balancing technique according to the VERA protocol was considered as a reference method. Preliminary results from lab testing show that CO2 and NH3 measurements are promising and the validation measurements are currently in progress. During the presentation, we will provide detailed results for both laboratory calibration and on-farm validation. Additionally, insights into the system's handling, acquisition costs, and further implementation will be demonstrated.

Keywords
Open-Sided Dairy Barn; Climate Variables; CO2-balancing; Tracer Gas Technique; VERA Protocol; Lab Calibration; On-farm Validation; Cavity Ringdown Spectrometer (CRDS)

PP01-039 | Status of implementation of smart livestock farming tools on German pig farms

Jonas Payerl[1], Barbara Sturm[2], Hannah Graef[1], Jan Adolph[1], Abozar Nasirahmadi[3], Oliver Hensel[1]
[1]University Of Kassel, Section Agricultural and Biosystems Engineering, Witzenhausen, Germany,
[2]Leibniz Institute for Agricultural Engineering and Bioeconomy e.V. (ATB), Potsdam, Germany,
[3]Swedish University of Agricultural Sciences, Department of Energy and Technology, Uppsala, Sweden

Recent trends indicate a growing challenge for pork production. Higher standards of animal husbandry conditions related to animal welfare, a shortage of available qualified personnel and a poor market situation are posing increasingly severe obstacles for the farmers. Smart Livestock Farming (SLF) provides new opportunities to improve animal husbandry and enhance performance and animal health. Various approaches for SLF solutions exist. However, applying these solutions to practice can be challenging because it requires a certain level of commitment and expertise, especially for the pioneering farms. Therefore, this study focused on assessing the implementation status of SLF solutions on commercial pig farms.

To this end, a study on farms of three differently sized German pork value chains was conducted. Semi-structured audits and expert interviews were carried out to get these insights and validate them. Depending on the knowledge and capacities of the farms, selected SLF tools were recommended/implemented.

Our findings show the existence of useful and reliable systems for optimizing and enhancing the on-farm process related to animal welfare and productivity. However, there is significant potential for improvement in real-time process control. The adoption of these systems on practical farms are limited, except for breeding farms, which were notably more advanced in all parameters.

In conclusion, there is a lack of practical implementation of SLF advancements. Furthermore, other limiting factors include a shortage of expertise or dedicated working hours for technology utilization on farms as well as challenges associated with economic feasibility. As of now, the use of technology is economically more feasible on pig breeding farms due to the higher specific value of individual animals.

Keywords: pork production, digitalization, smart livestock

PP01-040 | Design of central fruit drying facilities with the exploitation of geothermal and solar energy towards the efficient process of fruits in Central Macedonia

Vasileios Firfiris[1], S.D. Kalamaras[1], C.A. Tzenos[1], P.N. Kolios[1], T.A. Kotsopoulos[1]
[1]Department of Hydraulics, Soil Science and Agricultural Engineering, School of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

The region of Central Macedonia is one of the main producers of fruits in Europe. The fruits produced are intended either to be marketed directly as fresh produce, some of them are used to produce compost while the lower quality ones are used for juice production. The lowest quality products are sent to waste or biogas plants at a very low price or for free. From the producers' side there is a need to find methods that will lead to the maximization of the profit from all the production quality range, in order to enhance the viability of local agricultural production. Drying of fruits is a method that leads to high quality products with higher market price. Even this is a common method in agriculture there is a need for the designing a more standardized and massive process that will reduce production costs and lead to a more sustainable final product. This could be succeeded with the design and establishment of central drying facilities in the region by considering all the parameters that will lead to an efficient drying process. In this work the design of central drying facilities that are using geothermal and solar energy in order to minimize the production cost are presented. The design includes the sizing of the equipment that should be used in order to cover the drying needs of the required production, with the energy balance and thermodynamic approach. On the other hand, an important part of the research is the definition of the location of the central unit considering the road networks, the areas with the highest production rates, the locations of the geothermal fields, electricity and water grids etc. The location definition will be performed with the use of the multicriteria analysis method that all the above parameters will be graded and a final result will occur in order to pick the optimal location. The results of the research are showing that a great percentage of lower quality fruits could be processed efficiently in such facilities leading to a high quality and market price product that is very important for local production.

Funding
This work has been funded by the European Agricultural Fund for Rural Development and the Greek State in the frame of Sub-Measure 16.1 – 16.2 – Establishment and operation of PES operational teams for agricultural productivity and sustainability (PROJECT CODE: M16ΣΥΝ2-00280).

PP01-041 | Crop reflectance measurements for water deficiency detection in lettuce plants

Dafni Avgoustaki[1], Stavroula Iatropoulou[1], Giorgos Varras[1], Eleni Efstathiou[1], Nikolaos Maras[1], Andreas Giakoumatos[1], Thomas Bartzanas[1]
[1]Agricultural University Of Athens, Athens, Greece

This study demonstrates the potential of using low-altitude multispectral imagery data to assess irrigation and fertilization techniques and the relative degree of plant water stress. This study aims to create a methodology that could be widely used in indoor vertical farming to assist farmers with real-time on-site data on the management and decision-making processes in order to ensure high production and reduced operation costs. The methodology focuses on irrigation, which sets schedules, and automatically updates a decision-making system based on crop reflectance data and simplified reflectance indices. The experimental process took place on the premises of the Laboratory of Farm Structures at AUA in the pilot vertical farm facility. The results showed that crop reflectance increased with increasing water deficit, and the detected reflectance increase was significant during the first week of reduced dosing of irrigation. Based on the reflectance measurements, several crop indices were calculated and correlated with substrate volumetric water content and lettuce's leaf chlorophyll content. Furthermore, a comparison in reflectance performance of plants is performed between lettuce crops grown in an indoor vertical farm and a hydroponic greenhouse, underlining the significance and necessity for controlling and monitoring all the environmental conditions in high-tech facilities in order to provide sufficient and accurate data for autonomous decision-making processes. The results of the present study are promising for the development of a non-contact method for estimating plant water status in lettuce crops grown under controlled environment.

PP01-042 | Online monitoring of crucial anaerobic digestion (AD) parameters

M.A. Tsitsimpikou[1], S.D. Kalamaras[1], C.A. Tzenos[1], P.E. Georgiou[1], Thomas Kotsopoulos[1]
[1]Department of Hydraulics, Soil Science and Agricultural Engineering, School of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

Over the last years, there has been an increasing trend in the installation of biogas plants for the valorisation of organic waste through anaerobic digestion (AD) and the production of a renewable form of energy, biogas (mainly methane). The profitability of biogas plants is an important issue due to the AD instability, which often leads to reduced methane production. To tackle such issues, the modeling of the process could be a valuable tool for the prediction of methane production. Many models have been proposed and implemented, with the latest research interest focusing on the use of neural networks for modelling and process optimisation. To fully exploit the potential of neural networks in this context, enough experimental data is required for model training. The application of neural networks for enhanced methane production becomes particularly robust when Internet of Things (IoT) sensors are used to collect real-time data and provide a rich dataset for the training and the optimisation of the model. In this study, a low-cost system for the monitoring of a pilot-scale AD reactor has been proposed. The critical AD parameters being monitored included the reactor state parameters and production performance indicators. For the monitoring of the state parameters, temperature, pH, redox and NH4+ sensors were placed in the reactor. All sensors were connected to an ESP32 microcontroller, from which the data was sent to an IoT platform. The data from the temperature, pH and redox sensors was uploaded to the platform every 15 minutes, while the ammonia sensor was sampling from the reactor once a day. The monitoring of the production indicators, i.e. biogas and methane production, was carried out through two gas meters, which were equipped with electrodes and operated by displacing a certain amount of water. The biogas counter was connected directly to the reactor and the biogas produced was continuously measured at the counter. To record the methane production, a certain amount of gas was pumped once a day from the reactor and first fed into a gas scrubber to remove CO2 from the biogas and when it was inserted to the methane counter. Finally, all the above sensors and counters operated smoothly in the pilot reactor, which served as an indicator for the possible upgrade of the system to a full-scale reactor.

Funding
This research was carried out as part of the project “SmartMethane - Smart feeding system for biogas plants” (Project code: KMP6-0143289) under the framework of the Action “Investment Plans of Innovation” of the Operational Program “Central Macedonia 2014 2020”, that is co-funded by the European Regional Development Fund and Greece.

PP01-043 | Detection of spectral signature and classification of Alternaria alternata and Alternaria solani diseases in tomato plant by analysis of hyperspectral images and support vector machine

Ahmad Banakar[1], Seyed Mohamad Javidan[1], Keyvan Asefpour Vakilian[2], Yiannis Ampatzidis[3], Kamran Rahnama[2]
[1]Tarbiat Modares University, Tehran, Islamic Republic of Iran, [2]Department of Biosystems Engineering, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran, , , [3]Agricultural and Biological Engineering Department, Southwest Florida Research and Education Center, University of Florida, ,

Detection of spectral signature and classification of Alternaria alternata and Alternaria solani diseases in tomato plant by analysis of hyperspectral images and support vector machine Monitoring plant health during the growth period is essential for ensuring product quality and reducing production costs. Therefore, early diagnosis of plant diseases is crucial. Hyperspectral imaging and artificial intelligence have enabled the diagnosis of plant diseases in their early stages and provide a distinct spectral signature for each disease by analyzing the images. In this study, two tomato diseases, Alternaria alternata and Alternaria solani, were investigated using spectral reflectance analysis in the span of 400-950 nm. To this end, a dataset of images were recorded on days 1 to 7 (every other day) after disease transmission, and color, texture, and shape features were extracted in each band. Finally, two groups of diseased leaves and one group of healthy leaves were classified by support vector machine algorithm. The classification results for days 1, 3, 5, and 7 were 89, 91, 93 and 96%, respectively. Spectral reflectance in the imaging band range of 400 to 950 nm shows the spectral differentiation between the two diseases, indicating their unique spectral signatures compared to healthy leaves. Also, the Relief feature selection algorithm showed that texture features such as energy in bands 550 and 841, entropy in band 600, correlation in band 746, and standard deviation in band 905 are more superior than other features. This study demonstrated the potential of hyperspectral imaging and artificial intelligence for early detection and management of plant diseases.

PP01-044 | Enhancing agriculture correlation model within QA augmented systems and through re-ranking and in-memory computing

Nur Arifin Akbar[1], Domenico Tegolo[1], Biagio Lenzitti
[1]Unipa, Palermo, Italy

In the agricultural sector, as the demand for information becomes bigger and more complicated, the Retrieval-Augmented Generation or RAG technique from Meta offers a good approach. But to achieve their highest performance, these systems need additional improvements. This research explores techniques for enhancing RAG models focused on the agriculture domain.

In our study, we present an introduction to systems by looking at RAG architectures and talk about reasons why it's important to develop solutions that are specifically designed for the needs of agriculture. We include methods like re-ranking techniques and use in-memory computing with the aim to improve how relevant responses are and reduce delay time. We describe a strong platform that uses advanced parts and is trained with a lot of data focused on agriculture, but we do not reveal the basic technologies.

Our solution, which joins together the method of retrieval augmentation and computation within memory, gives precise and relevant answers to many questions about farming. These include methods for farming, managing crops, controlling pests among others. It works instantly without delay; it can grow to support more users or data as needed; our main aim is always to help farmers with their important needs for information about agriculture.

In our paper, we highlight the main advancements and unique features of our approach. We conclude by inviting further investigation into combining recent RAG developments with the changing world of agriculture. Furthermore, the clear summary supports the aim of the paper to develop better informed and more productive agriculture by improving RAG structures.

PP01-045 | A novel rotating device system for improving radio frequency heating uniformity and controlling aspergillus in almond kernels

Rui Li[1], Longsheng Fu[1]
[1]Northwest A&F University, Yangling , China

It is important to improve radio frequency (RF) heating uniformity for developing effective pathogen control protocols before storage of almonds. The purpose of this study was to design a novel rotating device system (NRDS) in the RF cavity for improving sample temperature distributions during pasteurization, drying, and cooling of almond kernels. The results showed that the optimal rotating speed of 15 r/min and loading volume ratio of 60% of NRDS were determined to achieve the required RF pasteurization level. Compared with the five-layer container, the RF heating uniformity of almond kernels was clearly improved and the sample moisture content decreased by only 0.70% w.b. when using NRDS. The pasteurization validation curve using NRDS was closer to the predicted survival one based on the cumulative thermal lethal time model, suggesting that NRDS was suitable for the effective RF pasteurization of almond kernels. The pasteurization protocol was developed based on the selected parameters of NRDS, RF heating/drying, and forced air cooling. The moisture content and color values of almond kernels after RF pasteurization were beneficial for maintaining their long-term storage and stable quality. This NRDS in the RF system may provide a practical and effective technology for pasteurizing almond kernels.

PP01-046 | Prediction of nitrogen-fixing bacteria and phosphorus-solubilising bacteria in the soil using UAV multiespectral images

David Mostaza-Colado[1], Alejandro Alonso-Conde[1], Pedro Muñoz, José Marín[2], Pedro V. Mauri Ablanque[1]
[1]IMIDRA, Alcalá De Henares, Spain, [2]Área Verde MG Projects S.L., Madrid, Spain

As a result of climate change, plants are affected by drought and disease, with biochemical and physiological consequences for commercial crops. These effects affect parameters such as germination, vitality and yield, as well as seed composition and nutrition. The use of plant biostimulants to improve the composition and structure of the soil is becoming increasingly common, as it favours plant development and improves plant health and productivity. Nitrogen-fixing bacteria (NFBs) and phosphorus-solubilising bacteria (PSBs) are key components of sustainable agricultural systems due to their ability to increase the availability of N and P to host plants, thereby increasing the chances of crop adaptation. In addition, the use of new technologies such as UAVs and multi-spectral imagery makes it easier to monitor crops and treatments and assess their effectiveness.
As part of the SOCIAL-AGRI project, IMIDRA has evaluated the microbiological content of a bare soil in which chickpeas were grown, as an approach to remote sensing of the microbial biomass present in it.
We studied the soil of 4 plots where chickpea was grown: 1) seeds sown at 150 kg/ha; 2) seeds sown at 300 kg/ha; 3) seeds sown at 150 kg/ha in intercrop with Camelina sativa at 3 kg/ha and 4) seeds sown at 150 kg/ha and coated with biostimulant. We took soil samples and estimated the number of colony forming units (CFU) for NFB and PSB bacteria in each plot and correlated them with known indices (NDVI, eNDVI, MPRI, GNDVI and OSAVI) calculated from the multispectral images of bare soil collected by drone at an altitude of 45 metres.
The results showed that the intercropped plot had the highest number of CFU and that CFU could be slightly correlated with some of the indices.
Future work aims to assess more soils along with known and newly developed indices to estimate the microbial biomass of NFB and PSB.

PP01-047 | Expectations of machine-to-machine networking in dairy housing rise with experiences of farmers

Jernej Poteko[1], Jan Harms[1]
[1]Bavarian State Research Center For Agriculture, Institute For Agricultural Engineering And Animal Husbandry, Poing, Germany

The integration of robotics in dairy housing systems has led to increased automation and autonomy in tasks such as milking, feeding, and manure removal. These machines enable a high level of autonomy. The intelligence of one machine enables the execution of tasks and work processes automatically, driven by data collected from sensors, mostly embedded within that particular machine. They are uninformed about tasks being carried out by other machines in the same dairy housing. Due to this the autonomy level of these machines must either be limited or manually switched off to avoid that the machines collide with other machines or work processes.
Presently, farmers manually regulate various machines in the dairy housing when multiple machines are performing their tasks simultaneously because the data exchange between the devices is limited. However, to maximize the autonomy of all machines, they should not interfere with each other and should communicate the current task being executed and their own operational mode. To enable devices to coordinate operations based on exchanged data between them, effective Machine-to-Machine (M2M) networking is crucial. Especially, smaller automated machines (for example manure removal robot), which are often overlooked in the consideration of M2M communication, may clash with operations of larger devices if not synchronized. The detailed expectations and experiences of farmers regarding the connectivity of devices in the housing system are underexplored in the literature.
The aim of this study was to capture farmers' expectations and experiences regarding machine networking in the dairy housing systems through online surveys. Insights from Bavarian dairy farmers (n=231) show varying expectations based on different housing systems and devices experience. Farmers with less experience with automated machines or robots anticipate lower benefits such as time savings and greater work flexibility through machine networking compared to those familiar with automated machines. Notably, the highest expectations for machine networking are seen among users of multiple machines in one dairy housing simultaneously.
In conclusion, the integration of robotics in dairy housing offers significant potential, but effective M2M communication is essential for maximizing efficiency and realizing anticipated benefits. Further research and practical implementation are necessary to address current limitations and fully exploit the capabilities of intelligent dairy housing machines.

Keywords: M2M, networking, robots, barn technology, precision livestock farming

PP01-048 | Innovative technologies to eliminate ammonia inhibition in anaerobic digestion in order to enhance methane production: Energy recovery from microalgae production

V. Psachoulia[1], C.A. Tzenos[2], T.A. Kotsopoulos[2], A. Lithourgidis[2], M.A. Tsitsimpikou[2], V. Karayannis[3], Petros Samaras[1]
[1]Department of Food Science and Technology, International Hellenic University, IHU Campus at Sindos, Thessaloniki, Greece, [2]Department of Hydraulics, Soil Science and Agricultural Engineering, School of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece, [3]Department of Chemical Engineering, University of Westen Macedonia, Campus ZEP, Kozani, Greece

The need to address environmental problems arising from the increasing use of fossil fuels to meet modern energy demand and the induced CO2 accumulation in the atmosphere requires the use of innovative methods on clean energy production and waste management. The production of bioenergy utilizing microalgae biomass is promising as a potential alternative energy source. Microalgae can be cultivated alongside various waste treatment systems as a nutrients substrate, and the energy produced from the biomass fulfills the criteria of a renewable energy source, aligning to sustainable development targets: treatment of effluents with high nutrients content and utilization of the cells in an energy efficient path. The aim of this study is the valorization of microalgae cultivated in anaerobic digestate with high ammonia content, towards energy production. Chlorella sorokiniana species were cultivated in a 20 L closed airlift photobioreactor using standard BG11 nutrient substrate and digestate from an anaerobic biogas unit, with varying ammonia nitrogen concentrations. The produced biomass was then subjected to analysis to determine its content in fats, hydrocarbons, and proteins. From the various experimental runs, it was deduced that when excess nitrogen was available in the liquid substrate, the microalgae's content in fats, hydrocarbons, and proteins was almost similar, following a decreasing rank of concentrations: proteins>hydrocarbons>fats. The specific species of Chlorella were able to accumulate a considerable amount of proteins, with concentrations of up to 60%. However, under nitrogen deficient conditions, cell structure changed towards the synthesis of hydrocarbons and fats that could reach concentrations of up to 40%.
The potential of produced biomass valorization for bioenergy production was justified by the composition of microalgae in fatty acids, or in other applications based on the cells' content in chlorophyll a and carotenoids. In addition, biomass presented high biochemical methane production potential, reaching up to 350 mL CH4/g VS. The potential could be enhanced by the prehydrolysis of cells: pretreatment at 40°C for a contact time of 4 to 10 hours increased the methane production potential to 455 mL CH4/g VS. Prehydrolysis at the certain temperature could be achieved by the utilization of flue gases released during biogas use for heat or power generation.
Therefore, the cultivation of microalgae in the digestate, i.e. the anaerobic effluent from a biogas production installation, and their following valorization, represents a viable alternative for a biogas plant, that could contribute to the reduction of its environmental footprint.
Key Words: Microalgae, biogas, ammonia, anaerobic digestion
Topic: Energy and Bioenergy

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor CINEA can be held responsible for them.

PP01-049 | Detection of mushroom browning using hyperspectral imaging and novel machine learning techniques

Kai Yang[1], Ming Zhao[1], Dimitrios Argyropoulos[1]
[1]University College Dublin, Dublin, Ireland

Key words
Fuzzy C-means, k-nearest neighbor, mushroom browning, portable hyperspectral imaging, time-series of post-harvest storage

Abstract
Mushrooms (Agaricus bisporus) have a thin and porous epidermal structure and fresh mushrooms also contain> 90% water, therefore, it's highly sensitive to fluctuations in temperature and humidity at both harvest and post-harvest stages. Color is a vital attribute of mushroom quality parameters as it significantly affects consumers' decision to purchase and the commercial value of mushrooms in the market. With respect to postharvest, mushrooms immediately start to brown due to enzymatic breakdown and loss of moisture through respiration under inappropriate storage and the cold chain regime followed. However, the uneven distribution of discoloration across mushroom caps poses challenges for accurately segmenting pixels to construct calibration datasets for supervised machine learning models. This study developed a novel machine learning pipeline based on Fuzzy C-means (FCM), a soft clustering method known for its color shade quantization capability, in conjunction with principal component analysis (PCA) to classify mushroom hyperspectral image (HSI) pixels into clusters ranging from non-browning to browning. Meanwhile, a portable HSI camera in the visible-near infrared wavelength range (400-1000 nm) was used to determine early-browning effects in time series on white button mushrooms stored at 4 °C while relative humidity kept constant at 60% (G1) and 80% (G2), respectively. Hence, a dual-phase machine learning strategy for accurately detecting the mushroom browning patterns was implemented. Initially, the proposed unsupervised machine learning process selected ROIs to construct calibration data frames of G1 and G2 with 12800 spectral data, including 6400 spectra of browning pixels and 6400 spectra of non-browning pixels. Subsequently, supervised classification models, k-nearest neighbor (k-NN), and partial least squares-discriminant analysis (PLS-DA) were applied to accurately identify browning pixels on mushroom caps. These models demonstrated remarkable efficacy, achieving corrected classification ratios (CCR) of 97.6%-99.8% for k-NN and 94.7%-97.7% for PLS-DA across both groups G1 and G2, respectively. In addition, the best-performed PLS-DA and k-NN models were able to generate clear and intuitive prediction maps of mushrooms for monitoring the discoloration process. Overall, the time-series study demonstrated the feasibility of using a portable HSI camera combined with an end-to-end machine learning pipeline for the nondestructive evaluation of postharvest mushroom browning.

PP01-050 | Preliminary results on the relationship between chemical parameters and gasses emission in a PEC (photo-electrocatalytic) recirculating aquaculture systems for rainbow trout

Eleonora Buoio[1], Gian Luca Chiarello[2], Simone Livolsi[2], Luca Maistrello[2], Alessia Di Giancamillo[3], Daniela Bertotto[4], Giuseppe Radaelli[4], Nadia Cherif[5], Tarek Temraz[6], Katia Parati[7], Annamaria Costa[1]
[1]Department of Veterinary Medicine and Animal Science, University of Milan, Lodi, Via dell'Università 6, 26900, Italy, [2]Department of Chemistry, University of Milan , Milano, via Golgi 19, 20133, Italy, [3]Department of Biomedical Sciences for Health, University of Milan, Milano, Via Mangiagalli 31, 20133 , Italy, [4]Department of Comparative Biomedicine and Food Science, University of Padua, Agripolis, Legnaro, Viale dell'Università 16, 35020, Italy, [5]Aquaculture Laboratory, National Institute of Sea Sciences and Technologies, Salamboo, 28 Rue de 2 Mars 1934, 2025, Tunisia, [6]Department of Marine Sciences, Faculty of Science, Suez Canal University , Ismailia, Egypt, [7]Istituto Sperimentale Italiano Lazzaro Spallanzani, Rivolta d'Adda, Loc. La Quercia, 26027, Italy

The growing aquaculture raises significant environmental concerns. One potential adaptation strategy is recirculating aquaculture systems (RAS), a land-based solution that limits direct interaction with the environment. However, energy consumption and gaseous emissions are the main limiting factors for RAS.
The Fish-photoCAT project (PRIMA), aims to evaluate the efficiency of a traditional RAS setup (mechanical-biofiltration + UV lamp) compared to an innovative solution based on photo-electrocatalysis (PEC). Previous studies showed that PEC avoids ammonia accumulation by converting it into gaseous nitrogen. The project's goals include estimating ammonia and greenhouse gas emissions.
Analysed water samples are related to the second trial of the project, where the two RAS solutions, classical vs PEC, are investigated in Rainbow Trout fry (2g) reared at low density (5 kg/m³).
Gasses emission flux was measured in laboratory conditions, using a static chamber, and the photoacoustic gas detector Innova 1512, was calculated according to the following formula [1]:
F= S V A-1 [1]
Where S is the regression slope (variation of gas concentration in time (mg m² h^{-1}), and V (m³) and A (m²) are respectively the volume and area of the chamber).
Emissions correlations are established with water quality parameters, or nitrogen compounds, temperature, pH and oxygen saturation.
Data were submitted to variance analysis, keeping the treatment as the main effect, and correlation analysis (SAS 9.4, 2023).
During water sampling, tank conditions ranged from 15.7°C to 15.83°C in temperature; 7.65 to 8.03 in pH, and oxygen saturation from 80.7 % to 85 %. NH_3 was 0.18 mg/L vs 0.36 mg/L, NO_2 was 0.12 mg/L vs 0.26 mg/L, NO_3 was 8.9 mg/L vs 6.8 mg/L (P=0.06) respectively for the control and the PEC tanks.
Gas emission factors from the control and the PEC tanks were 0.0716 mg m^{-2} h^{-1} vs 0.111.3 mg m^{-2} h^{-1} for NH_3, 0.0141 mg m^{-2} h^{-1} vs 0.1076 mg m^{-2} h^{-1} for N_2O, 1.98 mg m^{-2} h^{-1} vs 2.35 mg m^{-2} h^{-1} for CH_4 and 6.5 mg m^{-2} h^{-1} vs 13.3 mg m^{-2} h^{-1} for CO_2.
Correlations revealed negative associations between NO_3 content and water temperature (r=-0.91, p<0.01), and N_2O emission flux and pH (r=-0.82; p<0.05), affected by fish number (p<0.001). CH_4 emission flux positively correlated (r=0.97, p<0.01) with CO_2 EF.
Additional analysis is required to determine the effects and the efficiency of the proposed technology, other trials are “in fieri", for fry and adults at different rearing densities.

Keywords: RAS, photo-electrocatalysis, emission factors

PP01-051 | Microclimate conditions in two insect-proof tunnel nethouses with tomato cultivation: Full-scale and CFD analysis

Anastasios Giannoulis[1], Antonis Mistriotis[1], Demetres Briassoulis[1]
[1]Agricultural University Of Athens, Athens, Greece

Nethouses are farm structures covered by plastic agricultural nets. They can be considered as intermediate low-cost technology for protected crops between greenhouse and open-field cultivation. Their inherent properties allow them to provide passively controlled conditions by modifying the exchange rates of mass, momentum, and radiation between the crop and the environment.
Insect-proof nets exhibit a denser mesh as compared to other types of nets. Their lower porosity imposes higher resistance to the airflow leading to decreased ventilation rates. Thus, an adverse microclimate of increased temperatures and relative humidity (RH) may develop at the nethouse interior.
Two single-span small-sized tunnel nethouses with tomato cultivation, each with a different insect-proof net covering (OptiNet 50 mesh, porosity: 53.4%; Biorete 50 Mesh AirPlus, porosity: 38.7%) were utilised for the full-scale experiment. The 50 mesh Airplus net allowed for increased ventilation through its thinner-thread configuration. Temperature and RH levels at the interior of the insect-proof tunnel nethouses were estimated through full-scale experiments and CFD analysis.
For the full-scale experiment three sensors recording both temperature and RH were used simultaneously, one inside each nethouse and one in the field, for a period with fully grown cultivation. The full-scale experiment was simulated by a 3D model using the ANSYS2022R1 software. The net coverings and the tomato plants were simulated as porous domains with specific porosity and aerodynamic coefficients. The insect-proof net was defined as a heat source based on the incoming solar radiation, the plants' canopy as a heat sink (sensible and latent heat difference), and water vapour source and the soil as a heat sink.
Results showed that for high wind velocities the temperatures inside the nethouses are practically equal to the ambient temperatures (convection becomes dominant). For low wind velocities, the highest average daytime temperature increased by 1.1°C for the nethouse covered with the denser mesh OptiNet 50 mesh net and equal to 0.9°C for the 50 mesh Airplus net covered nethouse. RH measurements were similar to the ambient RH values. The highest daytime average RH difference was equal to 2% for the nethouse with the OptiNet 50 mesh net, while most of the indoor RH recordings differed from the ambient ones by less than 1%. CFD results were in good agreement with the full-scale measurements. A detailed CFD analysis of the distribution of the temperature and the RH in the interior of the nethouses is presented.

Insect-proof nethouse, temperature, relative humidity, Full-scale, CFD

PP01-052 | No such thing as free lunch? Four easy optimizations for UAV analytics optimization

Jurrian Doornbos[1], João Valente[1], Önder Babur[2]
[1]Wageningen University, Amsterdam, Netherlands, [2]Eindhoven University of Technology, Eindhoven, Netherlands

Unmanned aerial vehicles (UAVs) have been identified as an important tool supporting a more precise and sustainable food system. The insights the UAV can offer, due to its' flexibility, high precision and sensor variety, are far beyond the previews approaches to measure the health, yield, and status of the agricultural field. Problematically however, is the poor generalization of results to different sensors, different areas, or even a different moment in time. As the flight of the UAV determines the conditions of the imagery, these image conditions in turn influence the modelling approaches. However, for UAV analytics to see wider adoption, modelling approaches need to generalize beyond the single case. Luckily, the data-type is not exclusive to UAVs in agricultural applications, techniques from computer vision, remote sensing, geo-information science and deep learning can be applied to improve generalization.

Taking inspiration from other research fields, four optimizations steps are discussed that require little effort but can have large effects for generalization in all agricultural applications. 1. Dataset normalization, 2. Adding 'free' geometries to extract more variables, 3. Dataset chipping for cross-validation, 4. Down and Up-sample the imagery to other resolutions.

The four techniques are applied to the case of segmenting vineyard-rows in a vineyard from multispectral imagery. The four techniques are applied to the data, after which follows a clustering using both Random Forest, SVM and Deep Learning (U-Net). The generalization is further tested by applying the trained models on the Canyelles vineyard from 2023. The segmented vineyard rows are validated against the true manual segmentation.

The results indicate that whilst the accuracy slightly degrades with some of the techniques on the Bodegas Terras Gauda testing set, however the trained models improve on the Canyelles vineyard significantly with all techniques, increases are evaluated to be between 0.1 and 0.5 increase in mean intersection over union across the whole vineyard. The difference between classical Machine Learning and Deep Learning results are neglible, especially for the generalization accuracies. Furthermore, combining all the techniques show the best increase in performance.

Whilst the shown use-case is simple, we show that these four techniques make the model better at generalizing beyond the Bodegas Terras Gauda vineyard. Furthermore, because all these techniques are applied before the model is fitted, as well as dataset agnostic, they techniques can directly be applied to any agricultural UAV use-case to improve generalization. All methods are available through the uavgeo python package.

PP01-053 | On-site identification of Esca-affected vines using hyperspectral imaging

Sara León-Ecay[1], Jon Ruiz de Gauna[1], Ainara López-Maestresalas[1], Carmen Jarén[1], Silvia Arazuri[1]
[1]Universidad Pública de Navarra, Pamplona, Spain

Today, Esca represents one of the greatest threats to modern viticulture as it represents large annual economic losses. Esca is a disease complex caused by a few ascomycete and basidiomycete fungi. The species mainly involved are Phaeomoniella chlamydospora and Phaeoacremonium aleophilum in the case of ascomycetes, while Fomitiporia mediterranea is the main agent in the case of basidiomycetes. At present, there is a lack of effective strategies and means of disease control, so a technique capable of detecting affected vines would allow annual monitoring of disease incidence in the vineyard and therefore better crop management and decision making. This study evaluates close-range hyperspectral imaging (HSI) for the detection of naturally infected grapevine leaves in a vineyard.
For this, images of 11 vines of the Tempranillo variety grown on plots in Bodegas Otazu, in Etxauri (Navarre) were acquired. All selected plots had a history of esca incidence. A Specim IQ snapshot hyperspectral camera was used to record the images on 21 August 2023. Camera was mounted on a tripod and images were taken on the field in natural light conditions. This hyperspectral system is sensitive in the 400-100 nm range, with a spectral resolution of 7 nm (204 wavelengths) and a spatial resolution of 512 x 512. An individual image was acquired for each of the 11 vines, of which 9 were symptomatic and 2 asymptomatic. Image processing and multivariate analysis was performed in MATLAB using the HYPER-Tools 3.0. Three classes were analysed: asymptomatic leaves of asymptomatic vines (class 1), asymptomatic leaves of symptomatic vines (class 2) and asymptomatic areas of symptomatic leaves of symptomatic vines (class 3). A total of 300 pixels were randomly selected, 100 per class, for further analysis. Partial Least Square Discriminant Analysis (PLSDA) was used to classify the pixels into the three established categories. An accuracy of 86% was achieved in the cross-validation dataset. The PLSDA models were externally validated using an image of an asymptomatic vine as well as an image of a symptomatic vine. The visualisation of the images showed that the majority of the pixels of the asymptomatic vine image were classified as class 1, while most of the pixels of the symptomatic vine image were classified as either class 2 or class 3. This study demonstrated the potential of close-range HSI for the on-site detection of esca.
Keywords: close-range, HSI; PLSDA, accuracy

PP01-054 | Towards a digitalised monitoring of environmental sustainability in arable farms

Silvia Coderoni[1], Michele Mattetti[2]
[1]University of Teramo, Teramo, Italy, [2]University of Bologna, Bologna, Italy

Providing food security and nutrition for a growing global population and contributing to environmental sustainability, while supporting livelihoods for workers along the food supply chain is the threefold challenge to be reached by the global agricultural and food sectors. This complex challenge is established also at the European level, where environmental and climate objectives have become very relevant for agricultural and rural development, as they have been placed at the core of the policy agenda with the European Green Deal (EGD) strategy launch and its subsequent declination in the agricultural sector (the Farm to Fork - F2F).
A key element to attain agricultural sustainability is the proper monitoring of farming activities at the most adequate scale of analysis. In fact, environmental impacts are highly scale dependent and different spatial scales can hinder the real farm performances. In this respect, digitalisation offers plenty of new instruments for sustainability monitoring as it can allow the effective use of data coming from technology compliant with agriculture 4.0, which can provide timely and accurate information.
This information could allow providing feedback not only on the farm level performances, but also on the field level ones, that could be useful in many ways: for farmers for a proper farm management; for operators along the supply chain, to monitor products environmental sustainability performances to meet consumers' demand for more sustainable food; for policymakers to evaluate the progresses towards EGD and F2F goals. The importance of the use of digital tools to improve agricultural statistics is acknowledged also by the European Union to modernize data collection.
Against this background, this study focuses on arable crop farms to: i) highlight the potentiality of data coming from technology compliant with agriculture 4.0 in terms of timeliness, precision and accuracy at the finer farm scale (field level); ii) propose the definition of a protocol for a systemic evaluation of data generated by farms at the field level (with a focus on environmental sustainability aspects); iii) highlight the main pros and cons of such framework with respect to standard approaches for data collection in agriculture.
A multidisciplinary approach, combining agricultural engineering methodologies and political economy analysis, is used to propose a framework for data gathering that could allow reaching the goal to place statistics at the centre of political decision-making by developing an evidence-based process, with high-quality and accessible data, in particular those necessary for the development of agro-environmental indicators.

PP01-055 | Effect of foliar application of silicon on the cultivation of mini watermelon CV. sugar baby in mitigating the effects of water deficit

Marcio Mesquita[1], Viviane Correia dos Santos[2], Henrique Fonseca Elias de Oliveira[3], Rafael Battisti[2], Rilner Alves Flores[2], Moemy Gomes de Moraes[2]
[1]Federal University of Goias, Goiania, Brasil, [2]Postgraduate Program in Agronomy, Federal University of Goiás, Goiania, Brazil, [3]Cerrado Irrigation Graduate Program, Ceres, Brazil

The Plants in ambient conditions are subject to dealing with biotic and abiotic stresses. Water deficit, being an abiotic stress, causes changes in plants that make them respond in several ways, such as reduced growth, leaf senescence and lower fruit growth rate, production of Reactive Oxygen Species (ROS), caused by a deficiency in the dissipation of energy due to impaired photosynthesis. The application of silicon becomes an alternative to mitigate the effects of this stress on plants, being deposited in the cell wall, providing rigidity, and increasing the plant's defense enzymes. The study aimed to understand the morphological, physical, and post-harvest responses of mini watermelon according to different soil humidity associated with the foliar application of silicon. The study was conducted in a greenhouse using the mini watermelon cv. Sugar Baby. The experimental design was in randomized blocks, in a 3x2 factorial scheme, with three water tensions in the soil (-35 kPa without water deficit, -50 kPa moderate water deficit, and -65 KPa severe water deficit) and two doses of foliar Si (0 and 1.5 g L-1), with four repetitions. The variables plant length, stem diameter and shoot dry mass, root dry mass, total soluble carbohydrates, proline, gas exchange, and post-harvest analyses were analyzed. There was a significant difference for the variables ($p>0.05$), but there was no interaction between tension and Si. Proline levels were not statistically significant. The water deficit promoted shorter plant length, aerial part dry mass, root dry mass and Si provided greater stem diameter. For biochemical variables, water deficit caused a higher carbohydrate content in the leaf and lower gas exchange rates. Si influenced skin thickness and average fruit weight. Thus, SI proves to be a strategy for cultivating mini watermelon in conditions of deficient water application.

PP01-056 | Simulation of solar radiation in multi-level hydroponic greenhouse

Helena Vitoshkin[1], Helena Vitoshkin[2]
[1]Azrieli College of Engineering 26 Yaakov Shreibom Street, Jerusalem, Israel, [2]Agricultural Research Organization, The Volcani Center P.O.Box 6, 5025001, 68 Dereh Hamacabim, Rishon lesion, Israel

Multi-level farming is a potential solution to food security risks from soil degradation, limited arable lands, and extreme climate events. Despite its efficient space and resource use, challenges such as high costs, energy usage, and limited cultivation experience persist. To make this growth method more applicable, we propose an approach that incorporates existing greenhouses to grow crops at levels inside them. This method has great potential in Mediterranean regions where many greenhouses are located, and any farm owner can build several growth tiers on a small budget.
This study aims to combine solar radiation modeling (Monte Carlo Ray Tracing model) and computational fluid dynamics (CFD, ANSYS Fluent) to study the distribution of solar light and thermal energy under a two- and three-level cultivation method. The case study model is based on the geometry and meteorological data of a commercial hydroponic growing tunnel (NFT growth method) located in the central region of Israel. The results were validated by experiments conducted in this greenhouse over the last year regarding solar radiation fluxes and inside air temperature within two-level experimental units. Three setups were simulated as a part of the study: a two-level setup with supplemental LED lighting above a lower level, a two-level setup without supplemental light but with 50% shading by the upper level (the upper growth channels were spaced apart to allow sunlight to penetrate to the lower level), three-level setup with supplementing lighting above lower level and spaced growth channels above the second level. The combined solar and LED light distribution, airflow, and heat transfer were investigated from the perspective of structural design, solar motion dynamics, ventilation methods, and external environmental conditions. Simulations were done regarding daily light integral and heat flow reaching the crops grown at the upper and lower levels. The simulation results show that adequate growing conditions can be achieved using a multi-level growing method that provides sufficient lighting and environmental conditions at each growth level. In addition, our growth tests showed successful cultivation of shade-tolerant plants on the lower level and light-demanding crops on the upper level. Thus, low-cost inputs can double or increase crop yields per unit area.

Keywords: Vertical farming, LED supplemental light, Greenhouse microclimate, Shading

PP01-057 | Prediction of starch content in potato varieties using NIR-based deep neural networks

Arman Arefi[1], Thomas Hoffmann[1], Barbara Sturm[1,2]
[1]Leibniz Institut für Agrartechnik und Bioökonomie, Potsdam, Germany, [2]Humboldt-Universität zu Berlin, Berlin, Germany

In line with the emerging concept of Digital Twins, this work intended to build a digital model of starch content, as a pivotal quality criterion, in potato tubers. To achieve this goal, we collected 957 Agria, 942 Charlotte, and 985 Karlena tubers from local farms in Switzerland. Their near-infrared (NIR) spectral information was acquired in the range of 940-1650 nm, followed by the starch content measurements. Later, SpectraNet-32 deep learning architecture was coded using the API Keras. The data was randomly shuffled and split into 75% and 25% for training and test, respectively. To seek whether deep learning models eliminate the need for spectral pre-processing, SpectraNet-32 was trained based on raw and pre-processed NIR spectra. Such pre-processing algorithms were standard normal variate (SNV), first and second derivatives. Each model was trained for 500 epochs with a minimum batch size of 164. The highest prediction accuracy (R-squared = 0.82 and RMSE = 1.39%) was achieved for SNV-preprocessed data followed by raw spectra (R-squared = 0.80 and RMSE = 1.46%) and first derivative (R-squared = 0.78 and RMSE = 1.56%). The model could not learn any pattern from the second derivative of NIR spectra. Our findings indicated successful development of NIR-based 1D deep convolutional neural networks for starch prediction in potato tubers; however, further research is needed to develop a general model, as well as, its expansibility.

Keywords: SpectraNet-32, 1D convolutional neural networks, Postharvest monitoring

PP02-001 | Blockchain for food and beverage supply: Expired buzz word or accelerating trend?

Evangelia Thoukidides[1]
[1]Unito, Grugliasco, Italy

Blockchain's potential for food and beverage (FNB) supply has been widely discussed. However, significant barriers have hindered adoption. Although barriers have been theoretically explored, outcomes of pilots are lacking in the literature. We argue that understanding factors that impact adoption is required as a pre-requisite for real-world impact. A mixed method approach is applied, presenting a comparison of qualitative evidence from semi-structured interviews with FNB managers (n=7) and technology providers (n=9), and the application of the Theoretical Framework of Acceptability. Interviewees fulfilled the criteria of previous participation in the practical implementation of blockchain for FNB supply in the EU/UK. Our findings confirm themes in the literature and draw antithetical parallels with the constructs of the TFA, indicating that adoption is unlikely. Findings indicate that technology providers remain unaware of the operational peculiarities of the industry. We suggest that digitisation of food traceability be viewed holistically to achieve trust.

PP02-002 | Testing the benefits of digital and physical augmentation methods for predicting nutrients in bio-based fertilizers

Khan Wali[1], Haris Ahmad Khan[2], Eldert J. Van Henten[1], Muhammad Abdul Munnaf[1], Erik Meers[3]
[1]Wageningen University and Research, Wageningen, Netherlands, [2]Syngenta, Ede, Netherlands , [3]University of Ghent, Ghent, Belgium

Establishing a robust visible-to-near-infrared reflectance (vis-NIR) spectroscopic model required a large data set, which is often laborious and time-intensive. Spectral data augmentation by random variations i.e., shifting, scaling, noise reduction, smoothing, etc., (DARV) and Digital Spectral Mixing (DSM) methods are reported to increase data size without additional sampling and analyzing, and thus to improve vis-NIR' prediction accuracy. However, these methods are limited to account the non-linear responses of constituents to spectral features. Therefore, this work has proposed a Combinational Physical Data Augmentation (CPDA) method and evaluated the performance of CPDA in predicting nutrients of bio-based fertilizers compared with DSM and DARV methods at both at spectral and prediction levels. Utilizing 44 samples of bio-based material (cow manure), the original spectral dataset undergoes augmentation using DARV, DSM, and CPDA methods. The validation results indicate significant improvements with CPDA and DSM data augmentation, manifesting in substantial reductions in Root Mean Square Error (RMSE) by 2 to 36\%, and the coefficient of determination (R^2) increase by 2.5 to 20\%, excluding their corresponding plant-available forms. DARV, on the other hand, demonstrates marginal improvement in prediction performance. Both CPDA and DSM exhibit similar enhancements in prediction accuracy,as well as result in similar spectra (F-statistic = 1.96 P-value = 0.16) which confirm the absence of non-linear chemical interactions in the samples. Furthermore, DSM and CPDA-based data augmentation balances the data distribution by widening central data density, aiding PLSR in optimal performance. In conclusion, DSM and CPDA-based data augmentation present promising potential in refining vis-NIR-based nutrient estimation accuracy in bio-based fertilizers. If between-sample linear interactions are guaranteed, DSM appears to be a more resource-efficient method compared to CPDA. However, if such interactions cannot be assured, CPDA might offer better performance. Further investigation into this matter could be pursued in future studies.

PP02-003 | Cultivation of golden thistle (Scolymus Hispanicus L.) can support low environmental footprint agriculture and food security

Vassilis Litskas[1,2], Antonios Chrysargyris[1], Nikolaos Tzortzakis[1], Menelaos Stavrinides[1], Spyridon Petropoulos[3]
[1]Biotechnology and Food Science, Department of Agricultural Sciences, Cyprus University of Technology, Limassol, Cyprus, [2]V.L. Sustainability Metrics LTD, Lefkosia, Cyprus, [3]Department of Agriculture Crop Production and Rural Environment, University of Thessaly, Volos, Greece

The integration of wild edible species, such as golden thistle, in commercial farming systems has been suggested as a food security, lower environmental impact and climate change mitigation measure. However, the environmental impact of wild edible species is scarcely investigated. In this study, we employed LCA (Life Cycle Assessment) and a field experiment in Greece (Thesally), to estimate several environmental impact indicators (e.g., Carbon footprint, energy intensity) related to golden thistle cultivation, from cradle to farm gate. We used the data from the field experiment to build a production system model, using the OpenLCA software and the Agribalyse database. We compared the results with commonly cultivated leafy vegetables (e.g., spinach). The results showed that golden thistle could be a valuable alternative, from environmental point of view, compared to conventional leafy vegetables such as spinach, only if cultivated under low inputs (e.g., non-irrigated). Nutritional aspects, if taken into account, further support the low inputs farming of wild edible species. This approach could support the design of zero environmental food production.

PP02-004 | Tracking and behavioural analysis of fattening pigs

Pieter-Jan De Temmerman[1], Jarissa Maselyne[1]
[1]ILVO (Flanders Research Institute for Agriculture, Fisheries and Food), Merelbeke, Belgium

Pig behavioural analysis can reveal upcoming and present disease, welfare and productivity problems. However, for group-housed pigs, individual monitoring of behaviour is challenging. Camera systems provide a promising approach to record a broad set of behaviours, and if combined with tracking algorithms and identification of the pigs, even at the individual level. However, some challenges in applying camera tracking in pig farming are low farm ceilings, sometimes leading to multiple cameras needed to cover one pen, bad image quality and tracks which frequently get interchanged between pigs. To monitor fattening pig behaviour an approach is presented to process camera images, detect and classify objects, track pigs on multiple cameras and validate these tracks using RFID identification data at the feeder and drinker.

During one fattening round 35 fattening pigs were housed in a 4.3 by 9 meter pen equipped with 3 security cameras placed at variable angles on the ceiling at 2m30 above the pigs. Videos were collected for 50 days between 6 am and 10 pm. In a preliminary analysis one video for each camera spanning 3 hours at 25 frames per second was used. From each video, 36 screenshots were selected at minutes ending on 1 and 5. Images were labelled using the “segment anything” approach, labelling 1568 pigs with behaviours: eating, drinking, lying on the side, lying on the belly, sitting with front legs up and standing on 4 legs. The yolov8 segmentation model was trained on a 4 to 1 split train and validation dataset. Animal identification was performed with RFID antennas around the feeding and drinking stations, and this data was used as a ground-truth for the pig track ID.

Preliminary results indicate that for the validation dataset, the segmentation model had a detection accuracy of 77 % and a classification accuracy of 78% with a precision of 1 and 0.87 and recall of 0.5 and 0.97 for drinking and eating classes respectively. The approach succeeded in tracking individual pigs for 3.5 minutes (5324 ± 10434 frames) on average with a maximum of about 1.3 hours (119 000 frames). Final results will be shown of the validation of the individual tracks with the ground truth RFID identifications, comparing methods for connecting track snippets in longer tracks and matching pigs moving from one camera field of view to another camera field of view.

Keywords: Multi-object tracking, RFID identification, Pig Tracking, Multi camera, Pig Behaviour

PP02-005 | Precision spraying under battery constraints and disease severity in vineyards

Maria del Mar Ariza Sentís[1], Gonzalo Mier[1], Sergio Vélez[1,2], João Valente[1,3]
[1]Wageningen University & Research, Wageningen, Netherlands, [2]Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany, [3]Spanish National Research Council , Madrid, Spain

Phytosanitary applications have a significant impact on the environment and biodiversity of agricultural fields. It is therefore important to adopt sustainable farming practices that reduce generalized pesticide usage while targeting its application only to infested plants or weak plants prone to develop diseases. UAVs offer a promising solution to optimize and lower the amount of chemicals utilized. By determining flight paths, UAVs can effectively spray and cover all the infested plants with precision and maximize the effectiveness of pest management strategies. Nevertheless, UAVs have a short battery life that should be taken into account during path planning calculation. This paper aims to propose a two-step approach for enhanced Botrytis Bunch Rot spraying with battery constraints considering the biophysical environment of the vineyard. A first flight is executed with a multispectral camera in order to acquire data about the current field conditions, including terrain and canopy information. The knowledge gained during this first flight is used to compute a heatmap of the areas that have a higher risk of developing Botrytis. Afterwards, the heatmap is divided into cells, where each vine plant is embodied in two cells, one for each lateral of the canopy. The Vehicle Routing Problem is modelled to spray the cells with a higher probability of developing the disease considering the battery limitation and having a big penalization for each non-sprayed cell with high risk. Since many cells with high risk might not be sprayed due to the battery constraint, multiple spraying sessions are also considered to spray all the potentially diseased cells.
Results indicate that the proposed approach significantly reduces the total amount of pesticide applied by as much as 78%, diminishing environmental impact. Additionally, the optimized routes exhibit a reduction of up to 62.9% in travel distance within the field compared to ground robots. Consequently, the proposed approach fosters a more sustainable method through decreased energy expenditure and battery utilization.

Keywords: Pesticide Reduction; Vineyards Management; Precision Spraying; Disease Control; UAV.

PP02-006 | Georeferencing traitseeker field robot data for enhanced spatial analyses

Henk Kramer[1], Stan Los[1], Jan Peter van der Hoeve[2]
[1]Wageningen Environmental Research, Wageningen University & Research, Wageningen, Netherlands, [2]Plant Breeding, Wageningen University & Research, Wageningen, Netherlands

This paper outlines a method for georeferencing TraitSeeker field robot data. The Traitseeker, developed collaboratively by CropTraits and Phenokey and customized for the Netherlands Plant Eco-phenotyping Centre (NPEC), serves as a precise phenotyping platform for measuring plant performance and development through high-resolution imaging. Utilized in field trials by Wageningen University and Research, researchers employ the TraitSeeker to gather data for their experimental plots, augmenting traditional field measurements. An experimental field can contain hundreds of experimental plots with a specific design for a phenotyping experiment. The layout of the plots for the whole field is stored in the TraitSeeker and each plot is captured by driving with the TraitSeeker over the field.

The TraitSeeker captures very-high resolution hyperspectral imagery and LiDAR data at the millimeter level. Despite recording geolocation points when entering and leaving a plot, the recorded data lacks georeferencing and relies solely on basic image coordinates. Although the data can be analyzed or processed per recorded plot, comparison with other geolocated field recordings or Unmanned Aerial Vehicle (UAV) data proves challenging due to the absence of georeferencing in the basic TraitSeeker output.

To address this limitation, a method is developed for georectifying the plot imagery based on the geolocations recorded at the entry and exit points. The four corner points of the collected images are calculated using the recorded geolocations, the sensor's height and the image characteristics. Automation of this process for a complete field recording is achieved through the implementation of Python and the Geospatial Data Abstraction Library (GDAL). The outcome is a georeferenced image for each recorded plot, facilitating automated data processing for Traitseeker field robot data and enhancing data analyses at the sub-plot level.

Results were also compared with UAV imagery acquired on the same day as the TraitSeeker images. Visual comparison already shows small differences in plant/leaf delineation. This gives insights in the acquiring and preprocessing of the TraitSeeker data and is subject of further research for matching TraitSeeker data with other georeferenced data. Georeferenced data allows for precise multi-temporal analysis, crucial for tracking subtle plant development variations in plant breeding.

To conclude, the recorded metadata (geolocation point entry, point exit, sensor height and image characteristics) enables the automated georectification of the TraitSeeker data and makes it possible to the overlay with other high-resolution imagery e.g. UAV imagery. This also simplifies multi-temporal analysis and sub-plot analysis.

Keywords: Georeferencing, hyperspectral imagery, field robot, spatial analysis, scripting

PP02-007 | Analysis of biodegradable mulch films behaviour after a field test

Fabiana Convertino[1], Fabiana Convertino[1], Sabrina Carola Carroccio[2], Maria Cristina Cocca[3], Sandro Dattilo[2], Anna Chiara Dell'Acqua[1], Luca Gargiulo[3], Luca Nizzetto[4,5], Paolo Maria Riccobene[2], Evelia Schettini[1], Domenico Zannini[3], Pier francesco Cerruti[3]
[1]University Of Bari, Bari, Italy, [2]National Research Council, Institute for Polymers, Composites and Biomaterials (CNR-IPCB), Catania, Italy, [3]National Research Council, Institute for Polymers, Composites and Biomaterials (CNR-IPCB), Pozzuoli (Naples), Italy, [4]Norwegian Institute for Water Research, Oslo, Norway, [5]Research Centre for Toxic Compounds in the Environment, Masaryk University, Brno, Czech Republic

Biodegradable mulch films are increasingly being used in agriculture, and this poses the need to understand more about their post-use phase. This research focuses on the fate of a biodegradable mulch film, based on starch and polybutylene succinate, in agricultural soil. The study is based on an experimental field test carried out for 16 months at the experimental farm of the University of Bari (Southern Italy), consisting in burial and periodic retrieval of pristine and UV-aged biodegradable mulch film. The soil and the films were physically and chemically characterized before and after the burial period. The film degradation over time produced macro- and micro-plastics that were analysed. Both the pristine and the aged samples showed physical and chemical alterations since the beginning of the field test. Material surface loss and starch depletion were observed, especially for the aged samples. After burial, the relative content of aromatic moieties in the film increased, and microplastics were released in the soil. The latter were extracted and investigated in terms of composition and amount released in soil. This research, based on real field conditions, addresses the emerging issue of the biodegradation of mulch films. The presented results aim at drawing attention to the need for experimental field tests to investigate the actual impacts that the use of biodegradable mulch films has on soil. This is ever more urgent and imperative to preserve the health of the soil and the whole agroecosystem.

PP02-008 | Optimizing autonomous robotic navigation through sampling map-driven path planning

Gavriela Asiminari[1,3], Vasileios Moysiadis[1,2], Theodoros Petropoulos[1], Konstantinos Tiggos[1], Dimitrios Kateris[1], Dionysis Bochtis[1]
[1]Institute for Bio-Economy and Agri-Technology (iBO), Centre for Research and Technology-Hellas (CERTH), 6th Km Charilaou-Thermi Rd., 57001, Thessaloniki, Greece, [2]Department of Computer Science and Telecommunications, University of Thessaly, 35131, Lamia, Greece, [3]Department of Supply Chain Management, International Hellenic University, 57001 , Thessaloniki, Greece

Soil properties are critical factors in crop management, exerting significant influence on plant growth, yield, and product quality. Achieving an accurate assessment of these properties requires thorough soil sampling across the field. However, due to the heterogeneity of the soil properties in the field, evenly distributing sampling locations may not be sufficient. In this study, a novel approach is proposed, to define sampling locations by partitioning the field into homogeneous management zones based on electrical conductivity (ECa) values. Subsequently, an equal number of sampling points were strategically distributed within each zone, forming the basis for creating a sampling map. Following the points of the map, an autonomous navigation path was generated to optimize the movement of the robotic platform for sample collection. This path was then uploaded to the robotic platform, equipped with a digital penetrometer for collecting data for soil compaction at the sampling points. The path was successfully executed on the robotic platform, and the actual movement was compared to the simulated one. The results showed a close alignment between simulated and executed paths, proving the efficiency of the methodology. Additionally, soil pH data were collected manually from sampling points by utilizing mobile technology. The collected data were integrated to create a fusion map, offering comprehension of soil variability and precision agriculture decision making. This research highlights the potential of autonomous robotic platforms equipped with sensor technology to optimize soil sampling procedure, enabling precise data collection essential for agricultural management properties.

Keywords: Farm technology, Lameness detection, Machine Learning, Inertial Measurement Unit

Funding: This research was carried out as part of the project «SIMS - Soil information management system» (Project code: KMP6-0190726) under the framework of the Action «Investment Plans of Innovation» of the Operational Program «Central Macedonia 2021-2027», that is co-funded by the European Regional Development Fund and Greece.

PP02-009 | Strategies to reduce mechanical harvesting costs in traditional olive orchards

Arlindo Almeida[1], Anabela A. Fernandes-Silva[2]
[1]Centro de Investigação de Montanha (CIMO), Instituto Politécnico de Bragança, Bragança, Portugal, [2]Centre for Research and Technology of Agro-Environment and Biological Sciences University of Trás-os-Montes e Alto Douro , Vila Real , Portugal

Olive harvesting mechanization is adopted in different types of olive orchards: traditional, intensive, in hedgerows.
In Mediterranean basin, traditional olive orchards have an important economic value. In this type of olive orchards planting densities are 100 to 240 trees per hectare, and over 30 years old.
In these olive orchards, the most used mechanical harvesting system is based on a trunk shaker to detach fruits, and an inverted umbrella to collect them.
With this harvesting system it is usual to collect 70% to 90% of the production.
The olives that remain in the tree is a problem. To solve it, farmers adopt manual harvesting as a complementary task.
This procedure increases the cost of harvesting with the addition of labour and reduces the mechanical harvesting system work rate (trees.hour-1).
It is important to understand if this complementary manual harvesting is advantageous or not.
In field tests carried out in the Northeast of Portugal on traditional olive orchards with 'Cobrançosa Transmontana' cultivar, two different procedures were compared: (I) mechanical harvest performance complemented by manual harvesting; (II) mechanical harvest performance without the addition of manual work.
In both procedures were evaluated: a) work rate (trees.hour-1); b) production harvested; b) associated costs; c) harvest efficiency considering it as the percentage of fruits collected in relation to total production.
To evaluate work rate system, a methodology based on measurement of each elementary operation time (in minutes) was adopted.
Costs was computed under international standards for agricultural machinery management.
Main results:
The harvest efficiency measured is higher than 85%.
Medium working rate using complementary manual harvesting - 24.1 trees.hour-1.
Without complementary manual harvesting - 49.5 trees.hour-1.
Medium cost of production harvested with complementary manual harvesting - 0.12 €.kg-1.
Without complementary manual harvesting it - €0.07.kg-1.
With complementary manual harvesting there was an average increase in production collected of 9.6%.
The labour medium cost to obtain this increase in harvest - €0.49.kg-1.
We can conclude that before taking the decision to adopt complementary manual harvesting, it is important to assess if this is necessary. It is important to evaluate harvesting efficiency expected.
With the values in field tests presented (harvest efficiency higher than 85%), they may have led to an increase in harvesting costs, without the respective return.
Complementary manual harvesting may be a solution, but an evaluation of other agronomic and mechanical solutions is recommended.

Keywords: olive orchard; mechanization; trunk shaker; costs; labour.

PP02-010 | PRAGMATIC - Innovative IT platform for yield and cost prediction of agricultural production

Tomasz Wojciechowski[1], Gniewko Niedbala[1], Krzysztof Bobran[2]
[1]Poznań Univeristy Of Life Science, Poznań, Poland, [2]Seth Software, Głogów Małopolski, Poland

The aim of the R&D was to develop a prototype of an innovative IT platform containing algorithms for predicting yields and production costs of agricultural commodities for three reference crops, i.e.: blueberries, apples and potatoes in the supply chain from the field to the production line. The system are using predictive models based on machine learning and artificial intelligence methods, using ground data and satellite imaging data. The system consist of the following modules:

- Knowledge Base (BW) module in the form of a data repository, synchronized on an ongoing basis with available datasets,

- Violation and Anomaly Detection (WNA) Module, which will allow detection of data records that do not match the analyzed datasets,

- Yield Prediction Module (PPL) which will allow prediction of yields for a selected crop type taking into account various factors (attributes),

- Cost Prediction Module (PPK) will serve users as an aid to production optimization and budget planning,

- Performance Visualization and Configuration Library (WWK). This library, have set of various components, used by analytical modules to visualize results and display them in the form of diagrams and charts with appropriate marking of prediction confidence levels (PPL and PPK modules) and signaling of possible problems when anomalies are detected in the data (WNA module).

The primary goal of the project were achieved by: 1) Acquisition of different types of data, i.e. agronomic, economic, meteorological, soil and phenological data, from various sources: e.g. satellite data, proximal data, private as well as public data, i.e. in open access; 2) development and implementation of hybrid predictive AI models based on the most accessible data to the end user, without and with the definition of varietal diversity within species; 3) development of tools to carry out the optimization and testing process with data fraud detection.

The main recipients of the project's results are medium and large farms, cultivating selected varieties of apple, potato or blueberry, which are looking for intelligent, precise, algorithm-based tools, allowing them to obtain yields adequate to market demand and carry out agrotechnical treatments in an environmentally, climate and people-friendly manner.

Key words: machine learning, yield prediction, cost prediction, sustainable farming, blueberry, potato, apple,

PP02-011 | Mapping the spatial variability of soil water fluxes through the integration of electromagnetic induction surveys and process-based modeling

Tiago Ramos[1], Ana Oliveira[1], Hanaa Darouich[1], Mohammad Farzamian[1]
[1]University Of Lisbon, Lisbon, Portugal

Knowledge of the soil water balance is fundamental for improving crop water use in agricultural fields. Estimates are normally for representative and homogeneous areas where the variability of soil properties is neglected. However, this variability significantly impacts soil water dynamics at the field scale. In this study, the MOHID-Land distributed process-based model was used to compute the spatially explicit soil water dynamics in a 22.6-ha almond field located in southern Portugal. An electromagnetic induction survey was first performed to obtain electromagnetic images of the real soil conductivity in depth, which were related to soil texture. Then, pedotransfer functions were used to convert soil texture into soil hydraulic data. MOHID-Land results included maps of the spatial distribution of soil water contents, actual crop transpiration, actual soil evaporation, percolation below the rootzone, and surface runoff. These allowed identifying preferential flow pathways as well as the main control factors influencing soil water dynamics at the field scale. Some development needs were identified, and overcoming them would enhance the significance of contributions such as this study to the field of precision agriculture.
This work was financed through national funds under the scope of project HYDROVAR (http://doi.org/10.54499/2022.03921.PTDC).

Keywords: Irrigation water management; Pedotransfer functions; Soil water balance; Soil variability; Three-dimensional modeling.

PP02-012 | Increasing microalgae biomass feedstock by valorising wine gaseous and liquid residues

Miguel Cachão[1], Ana Chambel[1]
[1]Avipe, Palmela, Portugal

Global warming due to greenhouse gases (GHG) has become a serious worldwide concern. The new EU Green Deal aims t0 achieve GHG emissions reduction by at least 55% by 2030 and a climate neutral EU economy by 2050. The deal strongly encourages GHG reducing measures at local, national and European levels. The REDWine project will demonstrate the technical, economic and environmental feasibility of reducing by, at least, 31% of the CO2 eq. emissions produced in the winery industry value chain by utilizing biogenic fermentation CO2 for microalgae biomass production.
REDWine concept will be realized through the establishment of an integrated Living Lab demonstrating the viability of the system at TRL 7. The Living Lab will be able to utilize 2 ton of fermentation off-gas/year (90% of total CO2 produced in the fermenter) and 80 m3 of liquid effluent (100% of the liquid effluent generated during fermenter washing) to produce 1 ton (dry weight) of Chlorella biomass/year. This biomass will be processed under a downstream extraction process to obtain added-value extracts and applied in food, cosmetic and agricultural end-products and to generate a new EcoWine. REDWine will focus on the recovery of off-gas from a 20.000L fermenter of red wine production existing in Adega Cooperativa de Palmela (ACP, located in Palmela, Portugal).
REDWine’s microalgae were tested in 2022 and 2023 with 4 purposes in vineyard: improve flowering stages, contribute to high temperature resistance, biofungicide against downy mildew and increasing in nitrogen content in ripening to help fermentation and improve aromatic compounds. It was also used in winemaking processes as a clarificant or anti-oxidant.
So far, results were interesting on wine making process but need more trials and results to assess vineyard activity.

PP02-013 | Implementation of the circular economy concept in greenhouse production systems: Microalgae and biofertiliser production using soilless crops' drainage nutrient solution

Nikolaos Katsoulas[1], Sofia Faliagka[1], Eleftheria Pechlivani[2]
[1]University of Thessaly, Volos, Greece, [2]Centre for Research and Technology Hellas,Information Technologies Institute, Thessaloniki, Greece

The challenges to feed the world in 2050 are becoming more and more apparent. This calls for producing more with fewer inputs (most of them under scarcity), higher resource efficiency, minimum or zero effect on the environment, and higher sustainability. Therefore, increasing the circularity of production systems is highly significant for their sustainability. Protected horticulture offers opportunities for maximum resource efficiency across various levels within and between farms and at the regional level), high-quality production and contributes significantly to the nutrition security as part of the world food production. In greenhouses, closed soilless cultivation systems give the opportunity to increase the water and nutrients use efficiency and reduce the environmental impact of the cultivation system by the reuse of the drained water and nutrients. However, due to low quality of the water used in the Mediterranean countries, a completely closed systems is not feasible. Partial discharge of the drainage nutrient solution when the levels of electrical conductivity (EC) or of the toxic ions in the system are reached, is still a necessity. Thus, in the frame of the circular economy concept, this work presents the utilisation of the drainage solution of soilless cultivation systems for microalgae and of biofertilisers production. The system includes a greenhouse equipped with a soilless cultivation system, a drainage solution collection tank, a closed bioreactor for microalgae production and a biocatalysis tank. The bioreactor tested in the frame of this work includes two closed tube loops of a capacity of 1000 L each where, after the initial inoculation, the microalgae is developed using as growth medium the drainage solution collected from the greenhouse crops. The bioreactor includes light and temperature control while pH still is manually regulated. As soon as the microalgae culture reaches a certain density level, 20% of the culture is harvested and the culture system is refiled by drainage nutrient solution. The microalgae produced is going through a biocatalysis process which leads to the production of a rich to aminoacids (and nitrogen) biofertiliser. The produced biofertiliser is then used for the fertilisation of the greenhouse crops. The complete production cycle along with the effects of the biofertiliser produced in crop growth and yield are presented and discussed in this manuscript. This work was carried out under the PestNu project that has received funding from the European Union's Horizon 2020 research and innovation programme under the Green Deal grant agreement No. 101037128 — PestNu.

PP02-014 | Tuber weight estimation using a neural network and ensemble Kalman filtering

Sjoerd Boersma[1], Bernardo Maestrini[1], Frits van Evert[1]
[1]Wageningen University, Wageningen, Netherlands

Farmers are interested in knowing how the potatoes on their field are developing. Even though nowadays more measurements can be taken from the field (like leaf area), there are still important quantities that cannot be measured. One of these is the tuber weight since the tuber is growing in the ground. Even though it cannot be measured, tuber weight can be estimated by a potato growth model. However, all models are an approximation of the reality and errors in the tuber weight's estimation are thus inevitable. In order to improve the model-based estimation of tuber weight, data assimilation can be applied. Here, in season measurements of the leaf area index and model estimations are combined (assimilated) to obtain a more accurate estimation of the tuber weight, while taking model and measurement uncertainty into account. This work demonstrates the application of a data assimilation method (Ensemble Kalman filtering) in order to obtain reliable tuber weight estimations. The Ensemble Kalman filter requires a relatively fast dynamical model, which is in this work a dynamical neural network (neural ODE) that is trained using data from a high fidelity potato growth model named TIPSTAR. The results show that it is possible to reliably estimate the tuber weight from the leaf area measurement by using an Ensemble Kalman filter. This estimation can consequently be used in a decision support algorithm.

Keyword: arable farming, Ensemble Kalman filtering, tuber estimation, neural ODE

PP02-015 | A neural network approach for real-time monitoring of Cannabis sativa L. Germination

José Antonio Brenes Carranza[1], Ana Codes Alcaraz[2], Carmen Rocamora Osorio[2], Francisco Javier Ferrandez Pastor[3]
[1]University of Costa Rica, CITIC-ECCI-PPCI, , Costa Rica, [2]CIAGRO, Miguel Hernández University, Orihuela, Spain, [3]UCIE Ars Innovatio, University of Alicante, Alicante, Spain

This study investigates the effectiveness of convolutional neural network (CNN) and CNN+LSTM hybrid models in detecting germination in seedbed images, focusing particularly on the challenges posed by overlapping seedlings. Utilizing a substantial dataset comprising over 80,000 meticulously labelled images of Cannabis sativa plants, our research aims to compare the performance of standalone CNN models with hybrid architectures. A noteworthy aspect of our experimental methodology is the deliberate omission of data augmentation techniques during dataset preparation. This decision enables us to evaluate the inherent quality and utility of our meticulously curated dataset without introducing artificial modifications. Furthermore, recognizing the significance of incorporating a temporal component in germination detection, we conduct a specific assessment of the hybrid model against the standalone CNN model. Through experimentation and analysis, we scrutinize the relative effectiveness of each model in accurately classifying germination status across varying degrees of seedling overlap. Preliminary results reflect a better performance of the hybrid model compared to the standalone CNN model. However, it is crucial to consider the computational resources, time, and effort required for training and testing the model. Thus, our study provides valuable insights into the intricate interplay among model architecture, dataset characteristics, and the complexity of the germination detection task. Moreover, this research contributes to the advancement of practical applications of deep learning methodologies in agricultural monitoring, emphasizing the necessity of tailored model designs to overcome the unique challenges encountered in greenhouse environments.
Keywords: CNN, LSTM, Computer vision, Germination, Cannabis sativa

PP02-016 | Hydraulic performance evaluation of low-cost gravity-fed drip irrigation systems under falling head conditions

Camille Martinez[1], Henry Mark Binahon[1], Jeffrey Gonzales[1], Arthur Fajardo[1], Victor Ella[1]
[1]University Of The Philippines Los Banos, Los Banos, Philippines

To ensure optimal water efficiency in drip irrigation, it is imperative to assess the hydraulic performance of the system. Hence, this study evaluated and compared the hydraulic performance of two locally available low-cost drip irrigation kits in the Philippines (denoted as Drip Kit A and Drip Kit B) under falling head conditions, simulating actual field conditions where the water level in the tank decreases during operation. Built upon the previous study of Martinez et al. (2022) that focused on the hydraulic performance of low-cost gravity-fed drip irrigations under constant head conditions, this study employed the same drip kit components but under falling head conditions of 4.3 m to 4.1 m, 4.1 m to 3.9 m, and 3.9 m to 3.7 m. Results revealed a decrease in emitter discharge rates as the operating head falls. For both drip kits, Christiansen's coefficient of uniformity (CU), emission uniformity (EU), and coefficient of variation (CV) varied from 91.89 to 96.02, 84.13 to 92.19, and 0.08 to 0.15, respectively. Also, Statistical analysis indicated that varying the operating heads did not significantly affect (α=5%) the CU, EU, and CV of both drip kits. Moreover, Drip Kit A (0.53 to 0.57 lph) demonstrated higher emitter discharges compared to Drip Kit B (0.52 to 0.54 lph), therefore, establishing Drip Kit A's superior performance. The CU and EU during the falling head test did not deviate far from the constant head test. In terms of design and operation, the factors to be considered in relation to emitter discharge are irrigation period, water supply, and wetting area.

PP02-017 | Site-specific application of solid organic fertilisers

Tomasz Wojciechowski[1], Mirosław Czechlowski[1]
[1]Poznań Univeristy Of Life Science, Poznań, Poland

Various fertilizer spreaders, including those for organic fertilizer, are known on the agricultural machinery market. Some of them are equipped with various types of sensors that, based on prior mapping of the field, allow the appropriate amount of fertilizer to be dispensed from a given place in the field, based on the predetermined vegetative demand of a given section of the field. Well-described systems for mapping a field based on vegetative indices allow the evaluation of the variability of a crop canopy within a field, if only in terms of its different nutrient requirements. This makes it possible to adjust the appropriate amount of fertilizers to particular parts of the field, and consequently achieve optimal vegetation.

In the agricultural machinery market, there are spreaders for both artificial and natural liquid organic fertilizers that dispense the right amount based on pre-existing maps. Artificial fertilizers, with fixed chemical compositions, do not require real-time verification during application. However, organic fertilizers exhibit composition variability. Liquid fertilizer application using slurry spreaders has solutions for evaluating the composition and adjusting dosages accordingly.

Precise application of solid organic fertilizers poses a challenge due to their variable and often unknown composition. Real-time monitoring during spreader operation becomes crucial. However, the accuracy of such measurements is compromised by the high compactness of manure in the spreader's loading box. This compactness creates gaps between manure "lumps," hindering measurements with optical probes that rely on direct contact with the material.

The study focuses on a device and method for the precise application of solid organic fertilizers in manure spreaders. A VIS-NIR contact probe is employed to measure manure quality, requiring dedicated calibration models developed through model tests and simulated operational conditions. While existing solutions use NIR spectroscopy for in-spreader assessment of macroelement abundance, the proposed method introduces an electrohydraulically controlled mechanism. This mechanism stops, compacts, and presses the manure sample against the spectrometer probe window, ensuring reproducible density for more accurate spectrometric measurements. The device evaluates macronutrient content in basic organic solid manures during manure spreader operation, expressed in kg/t or kg/m3. This innovation improves the precision and reliability of fertilizer application, contributing to sustainable and efficient agricultural practices.

keywords: variable rate application, solid manure, manure spreader, spectrometry,

PP02-018 | Greenhouses energy audits – procedures and results

Cathrine Baxevanou[1], Dimitris Feidaros[1], Chryssoula Papaioannou[1], Nikolaos Katsoulas[1]
[1]University of Thessaly, , Greece

Modern greenhouses are energy consumers in order to control appropriately the internal microclimate and to serve the requirements of the crop growth. For the design of energy-efficient greenhouses with the possibility of utilizing locally available renewable energy sources, it is necessary to know not only the total annual energy consumption but also additional data such as: a) The time distribution of energy consumption (daily and yearly variation), b) The type of consumed energy (thermal or electrical) and, c) its distribution among the various production and environment control procedures. This information will allow the choice of adequate energy type, energy sources and equipment characteristics that would ensure reduced energy consumption and reduced environmental footprint.

For the collection of the above information a procedure of energy audit is required. In the present text a procedure for the first steps of operational rating review is presented and applied to various greenhouses in Greece. In this procedure various parameters affecting the energy consumption are accounted like: a) the local external climatic conditions, b) the cultivation characteristics, c) the greenhouse construction, d) the greenhouse operation strategy, e) the installed equipment for production and environmental control.

The energy audits results are presented in terms of (i) energy distribution pies by energy type and procedure, (ii) SANKEY diagrams, (iii) greenhouse gases emissions and (iii) energy indices per greenhouses area and per production unit. To date, in the existing relevant bibliography it is customary to calculate the energy consumption in greenhouses by reduction to the area unit of the greenhouse. This is something that leads to a wide dispersion of prices even for greenhouses located in the same climatic conditions and with the same cultivation. The reason for this dispersion is that greenhouses with different degrees of mechanization are considered, with the result that low-tech greenhouses appear better than high-tech greenhouses in terms of energy consumption. This clearly leads to a distorted picture because it ignores the greater productivity of high-tech greenhouses. For this reason, in this work both energy indicators are calculated, energy consumption reduced to the area of the greenhouse so that it is possible to compare with the literature and energy consumption reduced to the annual production of the greenhouse. The energy audit results allow the identification of the most energy consuming procedure and can guide the greenhouse manager to decision about operational strategy, used type of energy, equipment characteristics and local energy sources exploitation.

PP02-019 | Comparing the impact of different work phases on operator and driver exposure to whole-body vibration during olive harvesting activities

Gianluca Coltrinari[1], Danilo Monarca[1], Massimo Cecchini[1]
[1]University Of Tuscia, Viterbo, Italy

During olive harvesting activities, special machines are used that expose drivers to Whole-Body Vibration (WBV). This issue is significant because machines drivers are subjected to mechanical stresses that can lead to serious health problems. Italian legislative decree 81/2008 requires that the assessment of the risk of exposure to WBV is based on the evaluation of daily exposure A(8), expressed as equivalent continuous acceleration over a one-hour period. The vibratory stress is caused by the tractor engine and the movements of the mechanical arm installed at the rear for olive harvesting. The objective of this work is to compare the influence of different work phases on the operator's and driver's exposure to WBV during olive harvesting activities. An experimental campaign was conducted in a farm in central Italy under the same boundary conditions. Whole-body vibration (WBV) measurements, according to ISO 2631, were performed on two different vehicles during the olive harvest: a New Holland TD5105 tractor and a New Holland TN55D. During the experimental campaign, signals from front and rear and vertical accelerations were acquired at the driver's seat using a tri-axial accelerometer in both vehicles. To characterize the actual exposure of the workers, field measurements were conducted under real working conditions for the drivers of both machines (tractor and olive harvester). The data obtained show that the highest WBV values were recorded with the olive harvester in an upright position for both tractors; the mechanical movement of the arm influences the accelerations because it generates high stresses at maximum extension compared to the source signal produced by the tractor engine. Furthermore, the data were compared to highlight the differences between the operator of the mechanical arm and the tractor driver. The same computing process was applied to compare the values obtained in the measurement campaign with those established by Italian legislative decree 81/2008.

PP02-020 | D4AgEcol platform: A web platform to promote the use of digital tools and technologies in agroecology

Evangelos Anastasiou[1], Panagiotis Stamatelopoulos[1], Pothitos Kotsiomitis[1], Spyros Fountas[1], Friederike Schwierz[2], Andreas Meyer-Aurich[2]
[1]Agricultural University Of Athens, Athens, Greece, [2]Leibniz Institute for Agricultural Engineering and Bioeconomy , Potsdam, Germany

Agroecology is an important approach to address modern challenges in agriculture, such as climate change, soil degradation, and food insecurity. Agroecology is defined by the Food and Agriculture Organization of the United Nations (FAO) as an approach that "applies ecological concepts and principles to manage interactions between plants, animals, humans and the environment for food security and nutrition". Digitalisation can support agroecology by enabling farmers to work more precisely, efficiently, and sustainably. Digital technologies can help farmers to collect and analyze data on soil health, weather patterns, and crop yields, which can inform decision-making and improve resource management. However, it is important to align digitalisation with agroecological principles to ensure that it supports a transformation agenda towards sustainable and equitable food systems. D4AgEcol, a Horizon Europe funded research project, will provide knowledge for the transition to agroecological farming by identifying appropriate digital tools and technologies. D4AgEcol has developed a web platform in which agricultural stakeholders can access and learn about digital tools and technologies relevant to the aim of agroecology. There are three main categories from which users can derive information related to the use of digital tools and technologies in the context of agroecology. These are research articles, research projects and commercial products. In these categories, the users of the D4AgEcol platform can find useful information on the farming systems that can be used, the technologies that they use, and the social, economic and environmental impacts they have on the various farming sectors. Currently, more than 500 records belonging to the aforementioned categories can be found on the platform which were identified through extensive search and screening in relevant online databases as well as on commercial websites. The D4AgEcol platform will contribute to the farming sector by enhancing the knowledge of farmers and other stakeholders on the ways that digital tools and technologies can be utilized in the context of agroecology to promote increased agricultural productivity, improved resource efficiency, increased environmental protection, and mitigation of climate change impacts. Ultimately, the D4AgEcol platform will contribute to the adoption of more resilient and sustainable agricultural practices by farmers and other agricultural stakeholders.

Keywords: agroecology, digitalisation, web platform, D4AgEcol, Horizon Europe project

PP02-021 | Environmental analysis of greenhouse powered by photovoltaics: An LCA case study

Maria Ravani[1], Georgios Liantas[1], Georgios Ntinas[1]
[1]ELLINIKOS GEORGIKOS ORGANISMOS - DIMITRA, THESSALONIKI, Greece

The cultivation of agricultural products in greenhouses offers multiple benefits, under the prism of reduced resource availability and increased demand for food, through year-round production under controlled conditions to maximize yield, with the capability of utilizing renewable energy sources. However, it is also important to consider the sustainability of greenhouse facilities, as they may contribute to the release of high amounts of greenhouse gas emissions. In the present study, the Life Cycle Assessment (LCA) method was used to evaluate the environmental impact of the construction materials of a greenhouse structure powered by photovoltaic (PV) panels. For the calculation of environmental indicators, such as Carbon Footprint and Abiotic Depletion, which are affected by the infrastructure of the greenhouse unit under study, raw data were collected, and conversion factors were extracted from the Ecoinvent v.3 database. Environmental assessment was carried out in SimaPro v.9.4.0.2 software with the implementation of the CML-IA baseline EU25 method for 11 impact categories. The analysis showcased that the greatest effect on most environmental indicators was observed for glass (22.6-82.0%) used as a covering material and steel (8.9-59.5%) used as a support material for the greenhouse frame. Photovoltaic batteries had the greatest effect (38.7%) on the Abiotic Depletion impact category. Indicatively, the value of the Carbon Footprint was calculated at 78.6 kg CO_2-eq per square meter, with the floor cement accounting for 23.3 kg of the total value, steel for 24.7 kg, and glass for 26.9 kg CO_2-eq per square meter respectively. The above results constitute an important first step in the evaluation of the sustainability degree of the materials used for the PV-greenhouse system under consideration. The findings of the present study, in combination with future investigations of alternative construction plans may lead to the selection of the most sustainable greenhouse construction solution, depending on the requirements of each crop.
Keywords: Life Cycle Assessment, Carbon Footprint, greenhouse structure, photovoltaics, Renewable Energy Sources

PP02-022 | A circular production system combining crop, fish, and insects: Effects on lettuce yield and physiology

Michalis Chatzinikolaou[5]
[1]Mourantian Anastasia, Volos, Greece, [2]Katsoulas Nikolaos, Volos, Greece, [3]Athanasiou Christos, Volos, Greece, [4]Karapanagiotidis Ioannis, Volos, Greece, [5]Levizou Efi, Volos, Greece
A circular production system combining crop, fish, and insects: effects on lettuce yield and physiology
Chatzinikolaou Michalis1, Mourantian Anastasia1, Katsoulas Nikolaos1, Athanasiou Christos1, Karapanagiotidis Ioannis2 and Levizou Efi1
1Department of Agriculture Crop Production and Rural Environment, University of Thessaly, N. Ionia Magnisias, Greece
2Department of Ichthyology and Aquatic Environment, University of Thessaly, N. Ionia Magnisias, Greece

Meeting the food needs of a growing world population through the sustainable intensification of agriculture is a challenging, yet urgent, goal. One promising approach is to incorporate circular economy principles into production systems. This involves reducing resource usage by recycling and reusing by-products that would otherwise be discarded. Aquaponics, which combines hydroponic crop cultivation with fish farming, is an example of such a system. The nutrients derived by fish metabolism are diluted in the water which irrigates the crop, succeeding its nutrition without chemical inputs. In this work we present a more sophisticated circular system that upgrades the aquaponics by introducing the Black soldier fly insect (Hermetia illucens L.) rearing that closes the nutrition cycle; the larvae of the fly are incorporated into fish feed as insect meal, while they are fed on residues of lettuce. In the present experiment lettuce was co-cultivated with red tilapia (Oreochromis spp.) for 45 days, under three treatments: coupled aquaponics, decoupled aquaponics, and hydroponics, the latter used as control. During the lettuce cultivation period, regular measurements of growth and functional characteristics were carried out. Emphasis was given on parameters related to the state and efficiency of the photosynthetic apparatus, like those derived by the in vivo chlorophyll a fluorescence, gas exchange and total chlorophyll content. The analysis of the results is ongoing. Conclusions are expected to be drawn about the effectiveness of each cultivation system, their limitations, and the applicability of the circular production system to lettuce production.

Keywords: circular economy, aquaponics, hydroponics, greenhouse, plant phsyiology

The project is funded by the Green Fund, under the Programme "Natural Environment & Innovative Actions 2022" / P.A. 3 "RESEARCH AND APPLICATION”

PP02-023 | Monitoring environmental contaminants concentrations emitted from broilers in Greece: A real-time study

Alkmini Gavriil[1], Dimitris Giannopoulos[1], Vasileios Anestis[1], Thomas Bartzanas[1]
[1]Agricultural University Of Athens, Laboratory of Farm Structures, Department of Natural Resources Management & Agricultural Engineering, Athens, Greece

Introduction: The impact of livestock in the emission of environmental (aerial) contaminants is increasingly gaining scientific attention, especially the last decades where intensive livestock is more prevalent.

Purpose: This study aimed to monitor in real-time the environmental and climate conditions of a large-scale poultry facility and to identify potential correlations among the recorded variables.

Methods: Two different sensor systems, uradmonitorA3 and Cynomys, were placed inhouse a large-scale (~ 17.000 broilers), closed-type, forced-ventilated poultry house in Greece. Sensor installation was performed at a representative spot of the facility, approximately 30 – 40 cm above the ground. Monitoring was performed during the broilers' growing period, from March to May 2022 (54 days). Monitored parameters included air temperature and humidity, carbon dioxide (CO_2), volatile organic compounds (VOCs), particulate matter of 1.0, 2.5 and 10 µm (PM1.0, PM2.5, PM10), noise levels, ammonia and luminosity. The measurements were recorded every 5 (CO_2, VOCs, PM1.0, PM2.5, PM10, noise levels) or 15 minutes (ammonia, luminosity), based on the technical characteristics of each sensor. Air temperature and humidity were recorded in both sensor systems. Data were remotely collected from the cloud platforms and were used to calculate the daily mean values of each variable. The correlation between the variables was determined using the Pearson linear correlation coefficient.

Results: A gradual increase ($P < 0.05$) in the ammonia daily mean concentration levels from 0.1 up to ~ 3.0 – 3.5 ppm was observed during the first 30 – 31 days of growth. This increase was followed by an approximately 2 units reduction ($P < 0.0.5$) until the end of growth period. The final ammonia concentrations were between 1.2 – 1.5 ppm. On the contrary, the daily VOCs and CO_2 concentrations fluctuated during the first 30 -31 days of growth, followed by a gradual increase ($P < 0.05$) and decrease ($P < 0.05$), respectively, to their final levels. Pearson statistical analysis showed a strong positive correlation between CO_2 and temperature, whereas VOCs levels had a strong negative correlation with both temperature and CO_2. Particulate matters (PM1.0, PM2.5, PM10) were strongly correlated to each other.

Conclusions: During intensive livestock farming, air quality is changing as a result of animal – related emitted compounds. Given the multiple adverse effects of these aerial contaminants both on animal health and the environment, monitoring their concentration levels is essential for establishing farm-specific control and mitigation practices.

Key words: environmental contaminants, sensors, real – time monitoring

PP02-024 | Assessing the growth and physiological attributes of strawberry plants under greenhouse integrated semi-transparent photovoltaics

Angeliki Kavga[1], Theodoros Petrakis[1], Paraskevi Ioannou[2], Foteini Kitsiou[3], George Grammatikopoulos[3], Nikos Karamanos[2,4]
[1]Department of Agriculture, University of Patras, 26504 Patras, Greece, [2]Biochemistry, Biochemical Analysis & Matrix Pathobiology Research Group, Laboratory of Biochemistry,Department of Chemistry, University of Patras, 26504 Patras, Greece, [3]Laboratory of Plant Physiology, Department of Biology, University of Patras, 26504 Patras, Greece, [4]Foundation for Research and Technology-Hellas (FORTH) / Institute of Chemical Engineering Sciences (ICE-HT), Patras, Greece

Due to the simultaneous production of electricity and food from the same piece of land, integrating semi-transparent photovoltaic modules into greenhouse roofs might be a great practice, assisting in lessening existing land competition and increasing agricultural yield. Shading is a practice used in greenhouses to maintain the microclimate. In countries with particularly high temperatures, especially in summer, shading by reducing the incoming solar radiation can be a tool to maintain the desired temperature. However, because of the significance of light, the constant shade formed by a PV module integrated into the greenhouse might interfere with growth and other biological processes. In this study, the shadowed area was determined using an algorithm developed according to the greenhouse and the PV array, allowing the investigation of the effect of the shade on a strawberry crop (Fragaria ananassa) cultivated within it. The study focused not only on the growth, which is directly affected by solar radiation but also on the quality of the fruits due to the existence of secondary metabolites, such as phenolics and flavonoids. The study was based on the comparison of plants and fruits between two different planting lines inside the greenhouse, which received different light intensities, due to the spatial and temporal difference in the shading caused by the photovoltaics. More specifically, in approximately six months (from planting to the last harvest), the percentage change in shading between lines (shaded and non-shaded plants) reached ~199%. The growth parameters measured were the total number of leaves in each row, the flowers, the ripe fruits, and their weight respectively, with measurements taken every 15 days. The results indicated a minimal percentage (~1%) variation between rows for leaves, whereas the corresponding change for the flowers was slightly higher (~6.5%). Furthermore, the change in the number of ripe fruits (~10%) was lower than the change in the equivalent weight (~34%), suggesting that the fruits grew larger in less shaded conditions. Finally, concerning the antioxidant capacity, the results showed that the shade boosted both the overall phenolic content and the free radical scavenging activity of the harvested fruits. Although semi-transparent photovoltaics do not increase fruit yield, they do contribute to greater fruit quality and have the potential to integrate sustainable agriculture with renewable energy systems. Combining greenhouses with photovoltaics provides a dual solution: environmentally friendly energy generation and improved greenhouse crop quality, addressing food security and climate change issues for a more sustainable future.

PP02-025 | Crops under cover - hydroponics. A new challenge in distance education from the Hellenic Open University and the Agricultural University of Athens

Petros Kokkinos[1], Georgia Ntatsi[2], Angeliki Paraskevopoulou[2], Evangelini Kitta[3], Nikolaos Katsoulas[3], Epameinondas Paplomatas[2], Dimitrios Savvas[2], Ioannis Kalavrouziotis[1]
[1]Hellenic Open University, Patras, Greece, [2]Agricultural University of Athens, School of Plant Sciences, Department of Crop Science , Athens, Greece, [3]University of Thessaly, Department of Agriculture Crop Production and Rural Environment, Volos, Greece

Cultivations under cover, such as in greenhouses, screenhouses and low tunnels, serve as powerful tools in mitigating risks related to water depletion, soil degradation, and climate change. However, in order the development of protected horticulture to be both feasible and economically sustainable, new agricultural management practices must be applied. This can be achieved through the use of techniques and technologies such as hydroponics, aiming to improve the yield and product quality, reduce energy usage and agrochemical inputs and better manage water and natural resources.
In response to the above challenges, the Hellenic Open University and the Agricultural University of Athens have co-designed and implementing, since March 2021, an innovative distance learning Inter-Institutional Master's Program entitled "Cultivations under Cover - Hydroponics" (CUC). CUC aims to address the existing gap in the integrated training of scientists in the areas of construction, greenhouse equipment, hydroponics, organic farming of protected cultivation, abiotic stress physiology, water and nutrition management and environmental and crop protection. This program has been designed for scientists and post-graduates of Environmental, Agricultural, Polytechnic and Natural Sciences. Participants, through their master's thesis, will acquire horizontal knowledge of the "Cultivations under Cover" ecosystem, coupled with specialized vertical knowledge for in-depth understanding of different cultivation management practices that enhance product quality and yield. The Inter-Institutional Master's Program CUC, is of particular importance in today's national and global context of increased population, expensive energy, climate change and increased need for food autonomy, along with the demand for high-quality distance education, thereby broadening the carrier perspectives of its graduates.

PP02-026 | AgRobPlanner: An open-source library for field operation using multi-agent cooperative robots

Yde Jansen[1], Eldert van Henten[1], Jan Benders[2], Congcong Sun[4]
[1]Wageningen University & Research, Wageningen, Netherlands, [2]HAN University of Applied Sciences, Arnhem, Netherlands

Handling heavy machinery used in open-field agriculture requires skilled laborers, of whom there is a shortage [1]. Additionally, the use of combined heavy machinery can cause irreversible soil compaction damage on the farm. An approach to reduce workload and skill requirements, increase operational efficiency, and reduce soil compaction is having multiple smaller autonomous machinery work field operations cooperatively[3].

During open-field harvesting operations, the harvester is followed by a chaser bin that stores the harvest. Once full, the chaser must be replaced, which interrupts harvesting. Chaser Replacement Decisions, when to request new chasers, where and how to execute switchovers, are important for minimizing harvester downtime. These can be planned and optimized using, for example, Reinforcement Learning (RL) and Model Predictive Control. These require software that simulates the harvesting procedure to compute or learn optimal decisions, which are not available yet.

Therefore, we propose AgRobPlanner, an open source Python library that provides a usable, discrete-event simulation based interface for such algorithms.
It can function as a benchmark for algorithm training and performance comparisons, and as an easy-to-use tool to help farmers plan their field operations.

The library is designed modularly and is easily customized and extended. It facilitates a wide variety of user-definable field layout options (field shape, headland distance, etc.) and properties (crop type and distribution, soil type, etc.), and vehicle settings (e.g., number of harvesters and chasers, vehicle weight and load capacity).
The library consists of two core modules:
– FieldEnv: Gymnasium environment that simulates the execution of the entire harvesting procedure.
– ActionPlanner: Computes Chaser Replacement Decisions and sends these to FieldEnv.

The FieldEnv module contains several submodules:
– FarmFieldBuilder: Generates the farm field and headland from a user-provided KML file containing the farmland outline.
– HarvesterRoutePlanner: Plans the row sequences the harvesters will execute.
– TaskManager: Contains the currently active tasks (e.g., switching, harvesting, returning to depot) and their assigned vehicles. It also processes completed and new tasks requests. Low-level vehicle control is handled autonomously within tasks via behaviour trees.

FieldEnv is the access point for optimization algorithms (e.g. when training RL agents). It takes and processes action requests from customisable decisionmaking algorithms that implement the ActionPlanner interface, and returns a state observation and reward at every simulation step. A Graphical User Interface allows farmers easy access; they can set the desired configurations, farm and planner, and evaluate a visualization of the harvesting procedure in a bird's-eye view.

PP02-027 | Modelling nitrogen transport at the regional scale with MOHID-land. A preliminary evaluation

Ana Oliveira[1], Débora Pereira[1], Ramiro Neves[1], Tiago B. Ramos[1]
[1]MARETEC, Instituto Superior Técnico, ULisboa, Lisbon, Portugal

Agricultural diffuse pollution is directly associated with the excessive use of fertilizers and pesticides in agriculture, which are then transported by rainwater or irrigation to the nearest aquifers or watercourses. This form of pollution can result in adverse effects such as toxic algal blooms, degradation of water quality and loss of biodiversity. Furthermore, contamination of water resources can compromise food safety, as contaminated water can affect the quality of the food grown. Therefore, the adoption of sustainable agricultural practices, the efficient management of irrigation and fertilization and the awareness of farmers are fundamental to minimizing agricultural diffuse pollution and promoting more sustainable and ecologically balanced agriculture.
Nonetheless, farmers typically manage irrigation and crop fertilization at the plot scale, considering the timeframe of the crop season. They adopt strategies aligned with their own ideas, hoping to maximize their incomes. Awareness of the resulting environmental effects is not always easy, as these effects often occur further downstream. This creates a gap between causes and consequences, posing challenges for environmental agencies responsible for managing and safeguarding water resources.
While the link between field and watershed scales is clear, the need to address them using the same tools typically only becomes evident when water pollution becomes an issue during periods of scarcity. Detailed information from field plots is scarce, making it difficult to establish a direct link between water quality and specific agricultural practices. This difficulty is reinforced by the timescale of transport of a pollutant from agricultural fields to water reservoirs, where problems are usually first observed. This limitation only further highlights the need for an integrative modelling approach, capable of considering the different spatial and temporal scales that occur at a regional scale.
In this work, different nitrogen fertilization scenarios were simulated with the distributed model MOHID-Land, implemented at a regional scale, over three hydrological years. The case study was the Roxo irrigation perimeter in southern Portugal. For each scenario, the fate of nitrogen fertilizer (crop, soil, leaching) in the form of nitrate was evaluated and different strategies were studied to reduce the resulting diffuse pollution.
Although the results are still preliminary, they show the potential of the MOHID-Land model in simulating the effects of agricultural practices on the quality of water resources at the scale studied.
This work was financed through national funds under the scope of project HYDROVAR (http://doi.org/10.54499/2022.03921.PTDC).

PP02-028 | Route-planning system for unmanned ground vehicle in vineyard field

Vasileios Moysiadis[1,2], Gavriela Asiminari[1,3], Dimitrios Katikaridis[1,2], Ioannis Menexes[1], Dimitrios Kateris[1], Athanasios Balafoutis[1], Dionysis Bochtis[1]
[1]Institute for Bio-Economy and Agri-Technology (iBO), Centre of Research and Technology-Hellas (CERTH),6th Km Charilaou-Thermi Rd., 57001, Thessaloniki, Greece, [2]Department of Informatics and Telecommunications, University of Thessaly, 35131, Lamia, Greece, [3]Department of Supply Chain Management, International Hellenic University, 57001, Thessaloniki, Greece

In recent years, unmanned ground vehicles have been increasingly used in different indoor and outdoor agricultural environments. These vehicles play an important role in many agricultural applications, as they reduce human labor and enhance the safety of the execution of the respective work. The need to develop autonomous navigation systems to support unmanned vehicles in different field situations is imperative since these vehicles can now perform various automated agricultural tasks such as planting, spraying, fertilizing, harvesting, thinning, weeding and inspection. In recent years, advanced technology has led to the development of more intelligent and customizable navigation systems. These systems should possess sufficient intelligence to behave rationally over a long period of time while performing specific tasks in the field.
This study presents a navigation system designed for unmanned ground vehicles operating in vineyard fields, facilitating bidirectional communication between a farm management information system (FMIS) and the unmanned vehicles, within the broader context of smart farming implementation. The developed system integrates advanced route-planning algorithms within an FMIS, a comprehensive algorithmic package compatible with agricultural vehicles using the Robot Operating System (ROS), and a communicational and computational unit (CCU) linking the FMIS algorithms, the corresponding user interface, and the vehicles. The system's effectiveness was demonstrated through the deployment of two robotic vehicles (Thorvald, Saga Robotics and Husky, Clearpath Robotics) in executing route tasks in a vineyard field. Case studies revealed field traversal efficiency higher than 80%. Moreover, the implementation of the system's optimal route-planning functionality led to an improvement of up to 9.5% in field efficiency.

Keywords: unmanned ground vehicle; vineyard; agri-robots; operations planning; farm management information system.

Funding: This research was carried out as part of the project «ΑΓΡΟΣΥΣ - Development of an autonomous collaborative robotic system of precision viticulture incorporating electrically powered terrestrial and airborne unmanned vehicles and small-scale solar charging stations» (Project code: ΤΑΕΔΚ-06184) under the framework of the Action «Research-Create-Innovate», Greece 2.0 National Recovery and Resilience Plan that is co-funded by the European Union and ESPA 2021-2027.

PP02-029 | Hyperspectral imaging based on AI algorithms for early detection of plant fungal diseases

Panagiotis Christakakis[1], Nikolaos Giakoumoglou[1], Christos Klaridopoulos[2], Eleni Kalogeropoulou[3], Dimitrios Tzovaras[1], Eleftheria Maria Pechlivani[1]
[1]Information Technologies Institute, Centre for Research and Technology Hellas, 57001 Thessaloniki, Greece, [2]iKnowHow S.A., 15451 Athens, Greece, [3]Benaki Phytopathological Institute, 14561 Athens, Greece

In agriculture, timely intervention of crop pathogens is crucial, as fungal pathogens worldwide cause significant crop losses worth $100-$200 billion annually. To mitigate such substantial economic losses, the use of Artificial Intelligence (AI) is vital for helping in the early detection process. To date, the detection of a potential infection is done visually and then by specialized laboratory analyses, which are time-consuming processes. Therefore, early detection of economically important plant diseases is considered important not only for the rapid application of disease control strategies but also to minimize impacts on crop production and the environment. To that end, this study aims for the early detection of grey mould caused by Botrytis cinerea on cucumber plants, showcasing that the innovative integration of Deep Learning (DL) techniques and multispectral imaging can establish a new standard for early disease detection. By artificially inoculating cucumber leaves with B. cinerea and employing multispectral imaging in the initial days post-inoculation, a dataset was created for diverse DL models. Both classification and object detection techniques were utilized to evaluate the models, demonstrating remarkable accuracy. Regarding the first technique, the best-performing model achieved 0.93 accuracy and 0.89 F1-score, while the second reached a commendable 0.88 mAP50 (mean Average Precision), giving encouraging and valuable information about which wavelengths are more informative. Further developing the above effort, research on early detection of B. cinerea was conducted, but this time on the more challenging DL task of semantic segmentation. A comprehensive dataset featuring healthy and infected plants subjected to two different inoculation methods was created in order to produce DL models that segmented specific regions of cucumber leaves. The dataset contained photographs of the cucumber plants captured with a multispectral camera during the experiment, focusing on the early days, to test whether it is possible to detect early symptoms that are invisible to the naked eye. The resulting model exhibited impressive accuracy of 0.90 and Dice Coefficient of 0.65, while it showed a highly promising ability to detect early symptoms from the second to the sixth day, where the first obvious symptoms started to become visible, providing a crucial window for timely intervention. In conclusion, the above implementations showcase AI's transformative potential for early pathogen detection in agriculture, while the ability to apply these models to a fully autonomously navigated agro-robot and to mobile apps can enhance real-time monitoring, paving the way for efficient and timely proactive disease management strategies.

Keywords:artificial-intelligence;deep-learning;hyperspectral-imaging;early-detection;smart-agriculture

PP02-030 | FPGA design to facilitate vast connection of heterogeneous IoT devices in agrifood applications

Charalampos Patsianotakis, Apostolos Xenakis, Georgios Stamoulis
[1]Department of Electrical and Computer Engineering, University of Thessaly, Volos, Greece,
[2]Department of Digital Systems, University of Thessaly, Larissa, Greece

Over the past decade, the Internet of Things (IoT) has emerged as a pivotal technology in AgriFood applications, with its significance expected to amplify in the forthcoming years. Consisting of ground sensors, weather stations, actuators, and other devices, this comprehensive solution enables farmers to effectively manage their operations through personal computers (PCs) or mobile phones. While these IoT devices are instrumental in maintaining optimal crop, conditions amidst the challenges posed by climate change, it is imperative to keep their prices low to mitigate potential impacts on the prices of food ingredients in consumer markets.
The conventional approach of developing distinct board designs for each device, not only elongates development timelines and escalates costs but also heightens the probability of encountering diverse bugs and complexity in troubleshooting. Broadly, the elements of these devices can be categorized into two segments: components common to all system devices and those unique to specific device applications. For example, the Main Processor with its associated memory and Radio-Frequency components are ubiquitous across all devices, whereas a valve device may necessitate a relay, and a moisture sensor typically integrates temperature and relative humidity sensors. The former category is instantiated on a general board known as the Main-Board, which undergoes large-scale production and encapsulates a significant portion of device complexity, while the latter is accommodated on Peripheral-Boards.
The challenge arises with the integration of new peripheral elements, necessitating updates to the Main Board's interface. This requirement may stem from IoT system expansion, stock shortages, and various other factors. However, updating the Main-Board entails a proliferation of production codes, accompanied by the aforementioned drawbacks. Therefore, there arises a need for a simplified and uniform interface. This can be achieved by shifting the translation logic to the peripheral board, thereby enabling communication between the peripheral board and the Main-Board through the simple interface. The instantiation of a Field Programmable Gate Array (FPGA) fulfils this purpose, through its digital hardware implementation.
This solution aims at consolidating the production parts diversity within AgroFood Internet of Things (IoT) applications, thereby streamlining manufacturing processes and enhancing logistics personnel productivity. The proposed approach revolves around the instantiation of a communication protocol translator between the Integrated Circuits (ICs) of Peripheral-Boards and the Main-Board, effectively simplifying the interface across all productions.

Keywords:
FPGA, AgriFood Electronics, IoT, Production, Precision Agriculture

PP02-031 | The Environmental Policy Integrated Climate (EPIC) model: Historical development, applications and contributions to other models, and future directions

Philip Gassman[1], Jaehak Jeong[1], Luca Doro[1], Jimmy Williams[1], Xiuying Wang[1], James Kiniry[1]
[1]Center For Agricultural And Rural Development, Iowa State University, Ames, United States of America

The development of the field-scale Environmental Policy Integrated Climate (EPIC) model (https://epicapex.tamu.edu/about/epic/) was initiated in 1981 to support assessments of soil erosion impacts on soil productivity for soil, climate and cropping conditions representative of a broad spectrum of U.S. agricultural production regions. The first major application of EPIC was an analysis of soil water erosion impacts for 135 U.S. land resource regions, performed in support of the 1985 Resources Conservation Act (RCA) assessment, which reflected the original name of the model (Erosion Productivity Impact Calculator). The model has continuously evolved since then and has been applied to a wide range of field, regional, and national studies in the U.S. and other countries. The range of EPIC applications has also significantly expanded over that time, including analyses of (1) surface runoff and leaching estimates of nitrogen and phosphorus losses from fertilizer and manure applications, (2) leaching and runoff from simulated pesticide applications, (3) soil losses from wind-driven erosion, (4) climate change impacts on crop yield and soil erosion, (5) simulation of crop yields for row crops and horticultural crops, and (6) carbon sequestration assessments. The EPIC acronym now stands for Environmental Policy Impact Integrated Climate to reflect the greater diversity of problems to which the model is currently applied.

The historical development of the EPIC model over multiple decades will be presented including major algorithm revisions required for more accurate simulations of soil carbon cycling and other processes. The developmental phase will further incorporate how EPIC served as the foundational model for the Agricultural Policy/Environmental eXtender (APEX) model (https://blackland.tamu.edu/models/apex/) and has contributed key components to several other models such as the core crop growth submodel in the Soil and Water Assessment Tool (SWAT) ecohydrological model (https://swat.tamu.edu/). Overviews of different types of model applications and summaries of EPIC modeling results across multiple studies (e.g., comparisons of simulated versus measured crop yields) and scales will be presented next. The final portion of the presentation will focus on future directions for the model.

PP02-032 | Optimization of mechanical and operating parameters for improving chisel plow performance in heavy clay soils

Abdul Salam J. Almoosawi[1], Majid H. Alheidary[1], Murtadha A. Alfaris[1]
[1]University of Basrah, College of Agriculture, Department of Agricultural Machines & Equipment, Basrah/ Basrah/ Basrah, Iraq

A chisel plow is considered an effective implement in different agricultural soils, especially in heavy soils requiring improvement of their physical properties. The effectiveness of this plow may differ depending on various parameters as soil type, tillage depth, operating work conditions, power required, and chisel tines shape. So, the main goal of this study is to ameliorate the performance of chisel plow in heavy soils using different mechanical and operating parameters. Three main factors were studied four sweep chisel shapes (pointed-15cm, pointed-20cm, severed-15cm, and served-20 cm), three tillage depths (15, 20, and 35cm), and two tillage speeds (1.87, and 2.74km.hr-1). A complete randomized block design in split-split plot was used to analyze data. The findings illustrated that the chisel pointed shape-20 cm using a tillage depth of 15 cm and the tillage speed of 2.74 kmh-1 significantly influenced compared to the other chisel shapes in recording the lowest draft force of 10.46 kN.cm-2 and the lowest slippage percentage of 11.8%, and the lowest fuel consumption rate (19.14 lha-1). Although the severed chisel with a width of 20 cm was superior in increasing the percentage of pulverized soil and reducing the percentage of resistance to the soil penetration (1.08 kPa), it recorded the highest percentage of slippage, 52%. The interaction between the forward speed (2.74 km.h-1) and the chisel-pointed shape at 20 cm width recorded the highest value in the efficiency of energy (38.35 Mj.m-3) using the tillage depth 15cm. it is recommended by using a chisel-pointed shape, a maximum tillage speed, and the lowest depth as result to ameliorate the performance of the chisel plow under heavy soil conditions.

PP02-033 | Assessing the liquid-phase from hydrothermal liquefaction (HTL) of distilled biomass of Lavandula X Intermedia for novel herbicide development

Gonzalo Ortiz de Elguea-Culebras[1], Jaime Carrasco[1], Tamara Ferrando-Beneyto[1], Enrique Melero-Bravo[1], Antti Haapala[2,3], Aitor Barberlo-López[2]
[1]Regional Institute Of Agri-food And Forestry Research And Development Of Castilla-la Mancha, Tomelloso (ciudad Real), Spain, [2]Department of Chemistry - University of Eastern Finland, Joensuu , Finland, [3]FSCN Research Centre- Mid Sweden University, Sundsvall, Sweden

Hydrothermal liquefaction (HTL) has emerged as a prominent technique for the decomposition of biomass using reactors under standardized conditions, with temperatures ranging between 250°C and 450°C and pressures exceeding 100 bar. This process generates a wide range of chemical fractions, including a solid hydrochar phase and valuable liquid-phase constituents, with promising applications in agricultural phytosanitary bio-based products.
Lavandin (Lavandula x intermedia) is one of the most cultivated aromatic species, particularly in the Provence region of France, and has subsequently spread to many other southern Mediterranean countries. Since essential oil yield in lavandin is rarely higher than 2-3%, the remaining residual biomass can account for more than 98% of the raw vegetal material. Numerous studies propose valorizing the solid residue to extract non-volatile metabolites such as triterpenes or phenols, renowned for their biological capacities (antifungals, antioxidants, etc.). However, as these techniques aim to improve the profitability of aromatic crops, a lignocellulosic fraction still remains after these extractive processes, suggesting the need for further exploration focused on achieving comprehensive biomass utilization and zero-waste generation.
Alternatively, we propose the use of HTL to process the biomass distilled from this plant with the aim of full valorization of the organic matter. Briefly, the HTL process applied was as follows: 20 % of dry distilled biomass of L. x intermedia was mixed with 80 % water and introduced into the HTL reactor. Ten bars of nitrogen were incorporated to the atmosphere of the HTL reactor and the temperature was raised to 300 °C and maintained for 90 minutes while continuously stirring. As a result of the HTL process, two fractions were obtained: (1) a solid phase in the form of hydrochar (promising as an agronomic soil improver), and (2) a rich aqueous phase advancing usefulness for biological characterization. In this sense, the aqueous fraction was tested on phytotoxic model seeds of Lactuca sativa and Lolium perenne. Tests were conducted with 40 seeds per concentration, with germination monitored for up to 7 days (L. sativa) or 10 days (L. perenne). After this period, the length of roots (L. sativa) or roots/leaves (L. perenne) of 25 random seeds was measured. Promising results showed full inhibition effects at concentrations higher than 5-10% (v/v). This may lead to the development of novel plant-based herbicides of residual origin, as well as contributing to the achievement of the principles of the circular bioeconomy outlined in the UN's 2030 Agenda.

PP02-034 | Development of a low-cost RGB camera system for soybean crop monitoring

Jordi Llop[1], Albert Aguasca[1], Antoni Broquetas[1], Aitor Meraver[1], Ramón Salcedo[1], Francisco García-Ruiz[1], Emilio Gil[1]
[1]Universitat Politècnica de Catalunya, Castelldefels, Spain

In the face of climate change and the growing need for food, modern farming is changing in big ways. Technology and the digital transition appear as a fundamental solution to improve the efficiency of companies in the agrifood sector and respond to the current problems. One aspect in which technology can improve the work of farmers is in crop monitoring, since it is a valuable tool to optimize agricultural production, study the evolution of the crop, identify problematic areas within the field, etc. This project aims to improve the acquisition and analysis of data on vegetative parameters of a crop using a low-cost RGB camera (camera acquisition cost was 35€) and image processing software with which valuable vegetation indexes of interest could be extracted. A low-cost RGB camera LILYGO TTGO T-Camera ESP32 WROVER (Lylygo, Guangdong, China), mounted on a dedicated 2 m high frame was used to monitor a soybean crop (Glycine maz (L.) Merril) seeded on April 2023. This camera was operated and images were acquired by mobile App. Image analysis was carried out using ImageJ free software obtaining Excess Green Index (ExGI) and the ground canopy cover (GCC). ExGI and GCC were compared with main crop parameters obtained by destructive methodologies (plant biomass, plant water content and leaf area index) and manual non-destructive methodologies (phenological stage and height of plant). The ExGI showed a strong correlation with the water content of plants and with plant biomass (R2 =0.9) indicating this technic as a prominent tool to reduce efforts on field for crop monitoring. In addition, ground canopy coverage expressed as a ratio of the ground and ground covered by leaves, was related with leaf area index (R2 = 0.84) with maximum values of LAI of 0.84. The low-cost RGB camera arises as a fast and cheap solution for intense crop monitoring both for research purpose and for farmer. Data obtained is correlated with main indicators of health of the crop (water content, biomass and leaf area index) that are used for crop management inputs such us crop protection, fertilization and irrigation needs.

Key words: Low-cost image, ExGI, Soybean, digitalization, crop monitoring

PP02-035 | Historical spatiotemporal drought assessment in semi-arid regions of Greece

Stavros Sakellariou[1], Marios Spiliotopoulos[2], Nicolaos Alpanakis[3], Georgios Tziatzios[2], Ioannis Faraslis[1], Pantelis Sidiropoulos[3], Vangelis Brisimis[2], George Karoutsos[4], Nicolas R. Dalezios[2], Nicholas Dercas[5]
[1]Department of Environmental Sciences, University of Thessaly, 41500 Larisa, Greece, Larissa, Greece, [2]Aristotle University of Thesssaloniki, Thessaloniki, Greece, [3]School of Rural and Surveying Engineering, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece, Thessaloniki, Greece, [4]General Aviation Applications “3D” S.A., 2 Skiathou Str., 54646 Thessaloniki, Greece, Thessaloniki, Greece, [5]Department of Natural Resources Management and Agricultural Engineering, Agricultural University of Athens, 11855 Athens, Greece, Athens, Greece

This paper addresses the pressing issue of drought, a significant environmental threat to crop viability and productivity. It focuses on utilizing the Standardized Precipitation Index (SPI) to analyze and categorize drought events. The SPI compares precipitation during a specific period to its long-term average, offering a widely used metric for assessing drought severity. The study aims to perform a comprehensive spatiotemporal analysis of drought, estimate severity using SPI, pinpoint dry and wet periods, classify drought levels, determine the degree of drought or wetness across various timescales, and compute and categorize SPI12 values for each month spanning from 1982 to 2020. The study area consists of the semi-arid regions of Greece, namely, the hydrological district areas of Thessaly, Eastern Central Greece and Eastern Peloponnese. The innovation of this paper is the spatiotemporal drought analysis through the use of CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) instead of conventional meteorological data, avoiding the use of a prevailed sparse weather stations network, and the difficulties arising from that. The research outcomes indicated that all the regions experienced the most extreme drought in the hydrological year of 1989 yielding differentiated SPI12 values. Specifically: i) the SPI12 for the Region of Thessaly yielded to -2.27; ii) the SPI12 for the Region of Eastern Central Greece amounted to -2.35; ii) the SPI12 for the Region of Eastern Peloponnese yielded to -2.22. Beyond the annual statistical assessment of drought, the spatial variability has been mapped for each study region to spatially discriminate the variation of drought levels/categories. In these circumstances, delineating the spatial and seasonal variations across the research area enables the implementation of more precise strategies rather than broad, uniform policies.

Keywords: drought; SPI; CHIRPS; semi-arid regions; Greece;

PP02-036 | Using an electronic atmometer to estimate reference evapotranspiration in a semi-arid region

Georgios Nikolaou[1], Damianos Neocleous[2], Efstathios Evangelides, Evangelini Kitta[1]
[1]Department Of Agriculture Crop Production And Rural Environment, School Of Agricultural Sciences, University Of Thessaly, Volos, Greece, [2]Department of Natural Resources and Environment, Agricultural Research Institute, Ministry of Agriculture. , Nicosia, Cyprus

The objective of this study was to evaluate an electronic recording atmometer (ETgage Model E; equipped with a canvas #54 cover) to estimate reference evapotranspiration (ETr), against the Penman-Monteith evapotranspiration (FAO-56 Method). The result indicates a high correlation coefficient (r2=0.89) between daily ETr estimated by the atmometer and ETr estimated with the Penman-Monteith Equation. Thus, this study suggest that atmometers can be used within the field of interest to estimate daily reference evapotranspiration at a lower cost than electronic weather stations once they are locally adapted.

PP02-037 | Artificial intelligence algorithms revolutionizing insect monitoring and detection challenges

Panagiotis Christakakis[1], Dimitrios Kapetas[1], Sofia Faliagka[2], Nikolaos Katsoulas[2], Dimitrios Tzovaras[1], Eleftheria Maria Pechlivani[1]
[1]Information Technologies Institute, Centre for Research and Technology Hellas, 57001 Thessaloniki, Greece, [2]Department of Agriculture Crop Production and Rural Environment, University of Thessaly, 38446 Volos, Greece

Tiny insect attacks on farmers crops are a particularly challenging task that can be addressed using Artificial Intelligence (AI). Early detection and prediction of insect population growth in major Mediterranean and European crops holds promise for enhancing farming practices and bolstering yield in both open fields and greenhouse cultivations. Olive trees, vulnerable to the olive fruit fly (Bactrocera oleae), and vegetables like tomatoes and cucumbers, constantly attacked by pests like Tuta absoluta, aphids, and whiteflies, underscore the significance of AI in agricultural applications. In this study, our approach is to provide efficient Deep Learning (DL) models for crop monitoring and early detection of these aforementioned insects and their symptoms on plants, aligning with the principles of agricultural sustainability and reduced reliance on chemical pesticides as outlined in Green Deal 2030. This study utilizes available RGB images from libraries captured in real-life settings in combination with synthetic datasets and datasets created with insect traps. In particular, four implementations were developed. a) For detecting infestations of Tuta absoluta, a notorious tomato insect that spread rapidly across the Mediterranean, DL was combined with ensemble techniques. This process merged outputs from multiple models, enhancing detection metrics by 20% and elevating the mAP50 (mean Average Precision) from 0.58 to 0.70. b) To overcome the lack of data concerning very small insects measuring between 1 and 4 mm, adhesive traps were employed to capture images of prevalent insects in vegetable crops, including whiteflies and black aphids. The DL models tackled this challenge, reaching a 0.75 mAP50 for the detection of these miniscule insects. c) To tackle the data scarcity concerning whiteflies, a synthetic dataset was generated for their detection. This effort yielded a new dataset, pushing the trained DL model to a commendable 0.66 mAP50, coupled with a high accuracy of 0.76. d) For the detection of Bactrocera oleae, a threat to olive cultivation and oil production standards, a DL technique aiming to create lightweight models was used, reaching a remarkable 0.81 mAP50 for detecting the olive fruit fly, enabling real-time detection in the field. These high-performing results apply to a range of digital tools, including mobile apps and robotic systems like autonomous argo-robots and AI-based traps. They enable real-time monitoring, insect population growth prediction, and integration with Decision Support Systems (DSS). This aids professionals and promotes citizen science, providing essential data for informed decision-making in crop protection while also enabling timely intervention.

Keywords:artificial-intelligence;smart-agriculture;deep-learning;insect-detection;smart-farming

PP02-038 | Estimation of cotton actual evapotranspiration in Thessaly Greece using ESA's sentinel imagery and WRF model

Marios Spiliotopoulos[2], Georgios Sakellariou[1], Nicolaos Alpanakis[3], Ioannis Faraslis[2], Stavros Sakellariou[2], Pantelis Sidiropoulos[3], Vangelis Brisimis[1], George Karoutsos[4], Nicolas R. Dalezios[1], Nicholas Dercas[5]
[1]Department of Civil Engineering, University of Thessaly, VOLOS, Greece, [2]Department of Environmental Sciences, Larissa, Greece, Larissa, Greece, [3]School of Rural and Surveying Engineering, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece, Thessaloniki, Greece, [4]General Aviation Applications "3D" S.A., 2 Skiathou Str., 54646 Thessaloniki, Greece, Athens, Greece, [5]Department of Natural Resources Management and Agricultural Engineering, Agricultural University of Athens, 11855 Athens, Greece, Athens, Greece

Abstract: This study deals with the estimation of actual evapotranspiration (ETa) above selected cotton fields located in the semi-arid region of Thessaly, Greece, for the growing season of 2022. Sen-ET SNAP graphical user interface developed by the European Space Agency is used to esti-mate ETa, with the use of Sentinel 2 and Sentinel 3 satellite data, as well as meteorological data from the Weather Research and Forecast (WRF) model. The main innovation of the study is the use of WRF model instead of the initially proposed ERA-5 for the retrieval of the related mete-orological data. Another innovation is the computation of the adjustment factor, which leads to realistic values for daily ETa. There is potential significance for improving the monitoring and management of irrigation water needs in semi-arid regions like Thessaly, Greece. The results are very promising; however, this study still needs validation through in-situ experiments.
Keywords: Actual evapotranspiration; ESA; SNAP; WRF; Sentinel; cotton; Thessaly; Greece

PP02-039 | Strategic path planning for unmanned aerial vehicles in overhead agrivoltaic system management

Sergio Vélez[1], Gonzalo Mier[2], João Valente[3], Mar Ariza-Sentís[4], Tamara Bretzel[1], Matthew F. Berwind[1], Max Trommsdorff[1]
[1]Group Agrivoltaics, Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany, [2]Laboratory of Geo-Information Science and Remote Sensing, Wageningen University & Research , Wageningen, Netherlands, [3]Centre for Automation and Robotics (CAR), Spanish National Research Council (CSIC), Madrid, Spain, [4]Information Technology Group, Wageningen University & Research, Wageningen, Netherlands

This research focuses on the application of drones, or Unmanned Aerial Vehicles (UAVs) in agrivoltaic systems. UAVs face significant navigation challenges due to the complex environment and the intricate layout of these installations. However, by employing state-of-the-art path planning algorithms and the Structure from Motion (SfM) technique, it is possible to gather information from the landscape and consider the biophysical environment. These models help in creating accurate Digital Elevation Models (DEMs) and precise 3D models that inform drone navigation, ensuring comprehensive coverage of the agrivoltaic system. Then, a feedback loop that integrates the RRT* path planning algorithm with visual data from the drone's sensors is implemented. This approach enhances the information gathered beneath solar panels and ensures avoidance of collisions with unstructured environmental obstacles, like tree branches, enabling the creation of an efficient drone flight path. This method could significantly improve the monitoring capabilities within agrivoltaic systems, ultimately enhancing the Land Equivalent Ratio (LER), highlighting the potential for tailored remote sensing solutions that consider the variety of crops, system layouts, and monitoring objectives. This research suggests several potential advancements in remote sensing for agrivoltaics, pointing to the development of more sophisticated algorithms for drone navigation that can consider information such as shadows cast by solar panels and other obstructions. Future research might explore the integration of artificial intelligence and machine learning to automate the analysis of data, as well as, combining data from unmanned ground vehicles (UGVs) with UAV observations to provide comprehensive insights for better crop management and energy efficiency.

Keywords:
Drone Navigation; Route Planning Algorithms; Structure from Motion SfM; Precision Agriculture; Crop Monitoring

PP02-040 | Automatic feed pushing in dairy barns: Considerations on TMR leftovers particle size

Andrea Lazzari[2], Simone Giovinazzo[1], Massimo Brambilla[1], Francesco Maria Tangorra[3], Aldo Calcante[4], Carlo Bisaglia[1]
[1]Crea - Research Centre for Engineering and Agro-Food Processing. Via Milano, 43, 24047, Treviglio (BG), Italy, [2]CREA - Research Centre Animal Production and Aquaculture, Via Antonio Lombardo, 11, 26900, Lodi (LO), Italy, [3]Department of Veterinary Medicine and Animal Sciences, Università Degli Studi di Milano, Via Dell'Università, 6, 26900, Lodi (LO), Italy, [4]Department of Agricultural and Environmental Sciences-Production Territory Agroenergy, Università Degli Studi di Milano, Via Celoria 2, 20133, Milan, Italy

For years, dairy cows have commonly been fed a total mixed ration (TMR), consisting of a blend of forage, cereals, by-products, concentrated supplements, vitamins, and mineral salts, all combined into a single feed. This complete diet is tailored to each farm's specific needs.
Providing a quality ration is crucial for the production cycle, but optimizing feed bunk management is equally important to maximize TMR's nutritional benefits. Consistent feeding times, high-quality components, and frequent replenishment of the TMR near the feeding bunk ensure cows have a regular, high-quality diet 24 hours a day, every day of the week.
The study introduces a monitoring of the TMR leftovers of four dairy farms and one fattening bull farm in Northern Italy. In such farms, TMR processing took place thanks to automatic feeding systems (AFS) and mixing wagons, while the leftover feed pushing took place manually (twice a day) and automatically (rotary drum feed pusher and AFS).
TMR leftover samples, collected just before the administering of fresh feed, underwent particle size analysis using a Penn State Particle Separator with screens of 19, 8, and 1.18 mm and a bottom pan. Data processing has pointed out that leftover particle size composition varies depending on feed-pushing techniques. The pushing-up action of the AFS results in a leftover particle size similar to the operator-based one and contains a high percentage of particles higher than 8 mm. On the other hand, pushing back the feed with a drum feed pusher results in leftover particle size with a high percentage of long fibres in the 19 mm and 8 mm screens, which results from the animal sorting activity against longer particles.
These results indicate that the way feed is pushed back to the feeding trough affects the innate feed-sorting behaviour of the animals, interacting with the other factors resulting from the housing characteristics.

PP02-041 | Development of a method for the real-time assessment of the risk from severe-hot microclimate in agricultural and forestry environments

Massimo Cecchini[1], Alfredo Mancini[1], Filippo Cossio[1], Carlo Macor[1]
[1]University Of Tuscia, Viterbo, Italy

Agricultural workers, operating both in open fields and in greenhouses, are exposed to several risks, including exposure to severe hot microclimates. The study, carried out in an open field and in a greenhouse in central Italy, allowed the detection of the main microclimatic parameters to be used for risk assessment according to the technical standard UNI EN ISO 7933 (Predict Heat Strain model). The aim of this work was to identify, by implementing the P.H.S. model, any achievement of the critical threshold of rectal temperature (Tre) and the total water loss (Swmax), which, if exceeded, would compromise the worker's safety. This study is the basis for the development of a tool to provide, in real time and with the use of modern technologies (e.g. smartphone or smartwatch), a warning signal to the worker before he or she reaches the critical threshold of heat exposure and is subject to immediate safety risks.

PP02-042 | Manure collecting robots: Investigations on cleaning quality and practical experiences on cattle farms

Sabine Schrade[1], Lea Pitzen[1], Frigga Dohme-Meier[2], Michael Zaehner[1]
[1]Agroscope, Ruminant Nutrition and Emissions, Ettenhausen, Switzerland, [2]Agroscope, Ruminant Nutrition and Emissions, Posieux, Switzerland

Manure collecting robots are being installed more frequently for solid floors in loose housings for cattle, both in new buildings and in conversions. Depending on the manufacturer, these robots collect feces, urine, straw and feed residues from floors using a vacuum, a rotating lifting system or an auger rotor and transport the mixture to a discharge point. Since no systematic studies of this relatively new technology are known, we wanted to gather experiences of farm managers regarding functionality, management, limits of use, animal welfare, etc. In addition, residual soiling mass should be quantified as an indication of cleaning quality.

A survey including a structured interview and a housing inspection was carried out on 31 commercial cattle farms in Switzerland and southern Germany. Of the farms, 23 had a Lely robot while four each a DeLaval and JOZ robot, whereby the latter are technically identical. Quantification of residual soiling mass was conducted on 6 farms with a Lely robot and 6 with a DeLaval robot. Immediately after manure removal, a defined area was sealed with a waterproof frame. The remaining soiling inside the frame was diluted with water and collected with a vacuum cleaner and weighed.

Farm managers most frequently cited function (18), dealer or brand loyalty (13), flexible routes including cleaning of cross aisles and outdoor exercise areas (8) as reasons for their purchase decision. Increased manure removal frequency compared to stationary scrapers was also mentioned (14). However, this is limited due to the long charging times of the robot. Challenges in terms of functionality were identified as bedding and feed residues (17) and weather conditions (5). Other challenges mentioned were structural conditions, capacity, animal welfare and health, and safety issues. Farm managers reported calves being pushed by the robot (16), other injuries/loss of calves (3), tail injuries (13), injuries to animals trapped in the feeding barrier (5) and injuries to a person (1). Potential hazards were identified as management errors (e.g. forgetting to unlock the feeding barrier), dead ends, poorly secured discharge points and the absence of a contact breaker on one type of robot.

The average residual soiling mass per m2 was 460 g for Lely robots and 730 g for DeLaval robots (all farms) respectively 560 g (DeLaval with rubber mats). There were large differences between farms, but no significant differences between the two manure collecting robots (only farms with rubber mats).

manure collecting robot, cleaning quality

PP02-043 | Hybrid robotic UAV-vehicle using multi sensors and deep learning cooperation for proactive prognosis and treatment of plant diseases

Apostolos Xenakis[1], Konstantinos Kalovrektis[1], Georgios Spiliopoulos[1]
[1]University Of Thessaly, Volos, Greece

The significance of primary production lies in its role as the foundation for the entire food system. Efficient and sustainable primary production practices are crucial for ensuring a stable and secure food supply, supporting rural economies, and promoting overall food security. Advances in technology, research, and sustainable farming practices continue to play a vital role in optimizing primary production, addressing global challenges like population growth and climate change. Precision agriculture closely relates to utilizing technologies such as GPS, sensors, drones, and data analytics, which allows farmers to make informed decisions about resource allocation, irrigation, fertilization, pest control, and other critical aspects of primary production. This targeted and data-driven approach not only improves the overall productivity and quality of crops and livestock but also contributes to sustainable and environmentally conscious farming practices. In particular, precision agriculture involves the use of advanced technologies and data analytics to optimize various aspects of farming, including crop cultivation and livestock management. The primary goal of precision agriculture is to enhance efficiency, reduce waste, and maximize yields in the production of crops and livestock.

In this work, we propose a hybrid robotic multisensory UAV system, which uses deep learning algorithms, to early detect plant diseases and dynamically help the farmer to adjust the spray. If not treated in time, plant diseases in combination with pests, threaten to destroy the entire crop. The speed with which a disease spreads is great and the time to identify the cause and the correct diagnosis is short. In particular, the system consists of a drone and a robotic vehicle. The drone's camera takes plant photos, decides if, and classifies them to the following categories: healthy, bacteria, virus, late blight, and fungous infected leaves. The robot vehicle is equipped with robotic direct injection system, for the cases of infected leaves. In particular, the sensory data acquisition system of the robot vehicle include a PAR sensor, which measures photosynthetic light levels (400 to 700 nm), a temperature and humidity sensor (DHT22/ AM2302) and an Arduino UNO platform with WiFi module. According to our testbed scenario, the robot vehicle transports the data acquisition system and takes in real time PAR, temperature and humidity data, according to a grid mapping of the field. These data correlates with the position of the plants, which have a high infection probability and the drone adjust the spraying rate accordingly

PP02-044 | A machine learning approach for lameness identification in cattle using IMU sensors

Konstantinos Dolaptsis[1], Georgios Tziotzios[1], Antonios Morellos[1], Dimitrios Katikaridis[1], Panagiotis Papazisis[1], Dimitrios Kateris[1], Dionysis Bochtis[1]
[1]Institute for Bio-Economy and Agri-Technology (iBO), Centre for Research and Technology-Hellas (CERTH), 6th Km Charilaou-Thermi Rd., 57001, Thessaloniki, Greece

Lameness is a significant concern in the farming industry, as it affects both the welfare and productivity of farm animals. Current methods for lameness detection rely on visual inspection by trained individuals which can be subjective and inconsistent. To address this issue, this study aims to develop an objective methodology for lameness detection by utilizing data collected from sensors attached to cattle limbs. Inertial Measurement Units (IMU), with a sampling rate of 1125Hz, were affixed to all four legs of cattle from multiple farms in Northern Greece. The animals were then left walking freely, simulating their normal behaviour. The sensors collected raw signals from the animals' movement, which were subjected to pre-processing techniques to replace possible missing values. The collected datasets were used to derive time- and frequency-domain features, that describe the movement characteristics of the animals, using a sliding window of 2s with 50% overlap for each feature value. Two features from the gyroscope and two features from the accelerometer were decided to be the most informative according to the ReliefF feature selection algorithms that were employed for the feature selection for accurately distinguishing between differences in the dataset. The selected features were used to train a KNN classification model to distinguish between 3 classes based on lameness severity – healthy, lame and with early signs of disease. The preliminary results showcase a classification accuracy of 92% for each model in lameness identification. The findings of this study underline the possibility of the correct identification of animals exhibiting early sign of the disease may be utilized as a warning system for the farmer to take appropriate action to combat the lameness symptoms before the severity of the disease causes loss of production due to animal stress. This study advocates for further refinement of IMU units, modified for use in farming, and the employment of a machine learning methodology for analysing their signal as a novel, objective, decision-making approach to replace the visual identification of lameness by humans as the go-to standard in farming operations.

Keywords: Farm technology, Lameness detection, Machine Learning, Inertial Measurement Unit

Funding: This research was funded by the Action «Rural Development Programme of Greece 2014–2020» under the call Measure 16 , Sub-Measure 16.1–16.2 that is co-funded by the European Regional Development Fund and Region of Eastern Macedonia and Thrace, «COWLAM—Lameness identification system at milk- producing cow units in the Region of Eastern Macedonia and Thrace» (M16ΣΥΝ2-00031).

PP02-045 | Concurrent geospatial data for supervising invasive species in small and dispersed areas

Fernando Rojano[1], Alba Closa-Tarres
[1]West Virginia State University, Institute, United States of America

Geospatial data from multiple disciplines are strategic for determining small and dispersed areas of interest (AOI) that aim to determine habitat suitability of a vegetation type over a large-scale aerial images. Various disciplines contribute with geospatial data such as weather, soil and geomorphology. However, multiple geospatial datasets increase computational time. Here we propose a preprocessing stage using a limited set of geospatial data serving to define the AOI. To develop this approach, we selected the kudzu plant (Pueraria montana), an invasive species in many regions of the globe, with the attribute of being commonly found in small and dispersed areas. This type of vegetation is commonly found in land that underwent human modification such as abandoned fields, roadsides and those areas with conditions to retain soil moisture. Geospatial datasets from the USGS were used containing habitat suitability and locations where the kudzu plant was found. To confirm locations along roadsides, we used a set of google street view images from a virtual field campaign. The habitat suitability was associated with global human modification (GHM) and the topographic wetness index (TWI) as key proxies to outline the AOI where this invasive species can be potentially propagated, reducing the area to investigate. In this way, geospatial information aided to assess field conditions minimizing field trips to keep track of this invasive species as well as computational time during analysis.

PP02-046 | Effects of assistance of high-frequency dielectric heating on vacuum freeze drying characteristics of all biomass wet-extruded plate

Hana Tsuneoka[1], Ken-ichiro Suehara[1], Hiroshi Nonaka[1], Atsushi Hashimoto[1]
[1]Mie University, Tsu, Japan

As an alternative material for plastic products, all biomass materials are attracting attentions. However, deformation and shrinkage during drying after forming are the serious problem during the production process, and a drying method with less deformation in a short time is desirable. This study then focused on a vacuum freeze drying method assisted with high-frequency dielectric heating for shortening the drying time with less deformation.
The wet extruded cylindrical plates made of wood powders (?47 mm x D4.3 mm) were used as the drying samples. Drying experiments were performed in a lab-scale vacuum chamber (Espec Co., Ltd., Osaka, Japan) equipped with the high-frequency dielectric heating system. Six samples were put on the Teflon® plate kept in a freezer set at 253 K overnight. The samples and the plate were then placed on the lower electrode. To avoid the heat transfer from the lower electrode to the sample, a Teflon® O-ring was put on the lower electrode. After the pressure in the chamber was reduced to 100 Pa, high-frequency waves of the power of 0 to 25 W were irradiated. During drying, the sample temperature and the pressure in the chamber were continuously monitored, and the moisture content of the sample after drying was obtained.
By combining high-frequency heating with vacuum freeze drying, the drying rate was accelerated especially in the latter half of the drying process, and the rise in the sample temperature was only a few degrees. The effect of high-frequency heating on the acceleration of drying was more remarkable with higher irradiation power, and it was possible to shorten the drying time by several tens of percent. Additionally, near-infrared spectroscopic imaging, visible imaging and material strength measurements were performed to evaluate the chemical, morphological and mechanical characteristics of the sample after drying. As a result, no significant difference was observed except for the absorption band of water at 1940 nm. For the samples dried under the irradiation at 25 W, significant shrinkage and deformation were observed, and the material strength was weaker than those dried under other conditions. These results suggest that the high-frequency dielectric irradiation at 20W was the optimal for the combined drying method. Consequently, by combining high-frequency dielectric heating with vacuum freeze drying of all biomass wet-extruded material made of wood powder, the drying time could be shortened while maintaining chemical quality and preventing large deformation of the sample after drying.

PP02-047 | Detection of bacterial pathogen residues in milk samples from mastitis-infected cattle using a sers-based biosensor

Divagar Muthukumar[1], Giorgi Shtenberg[1]
[1]ARO- Volcani Institute, Rishon Lezion, Israel

The dairy sector is frequently affected by contagious and environmental factors that spread between animals by numerous means and induce the inflammatory disease of bovine mastitis (BM). Herein, silver decorated porous silicon (Ag-pSi) SERS platform was designed for rapid and reliable Escherichia coli (predominant BM pathogen) detection in various milk origins. The inherent surface void and pore morphology were physically optimized to augment the SERS effect using 4-aminothiphenol (4ATP) while achieving an enhancement factor >4.6×107. An indirect immunoassay evaluated the residual unreacted antibodies using an optimized 4ATP/Ag-pSi SERS platform modified with secondary antibodies. Under optimized conditions, the porous substrate offered high sensitivity toward target bacteria detection of 3 CFU mL-1 and linear response of log1 - log5 CFU mL-1. Moreover, the selectivity and specificity of the designed sensing platform were cross-validated against other interfering bacteria without compromising its performance efficiencies. Finally, the applicability of the developed system for real-life conditions was elucidated in different milk samples (bovine, goat, sheep) with recovery values of 78-115% compared to the conventional culture technique. Considering the complex media analysis, the miniaturized SERS platform is highly reliable, rapid and accurate that could be applicable for routine on-site analysis of various emerging pathogens relevant to BM management.

Keywords: Escherichia coli; milk; pathogens detection; porous silicon; SERS

PP02-048 | The agro future climate stress project: Crop and livestock stress under climate change scenarios

Dimitris Papanastasiou[1], Dimitris Melas[2], Anastasia Poupkou[3], Stavros Keppas[2], Dimitris Voloudakis[3], Ioannis Faraslis[1], Ageliki Elvanidi[4], Athanasios Gelasakis[5], Persefoni Maletsika[4], John Kapsomenakis[3], Konstantinos Douvis[3], Ioannis Stergiou[2], Athena Progiou[3], Nikolaos Katsoulas[4]
[1]University of Thessaly, Department of Environmental Sciences, Larissa, Greece, [2]Aristotle University of Thessaloniki, School of Physics, Thessaloniki, Greece, [3]Academy of Athens, Research Centre for Atmospheric Physics and Climatology, Athens, Greece, [4]University of Thessaly, Department of Agriculture Crop Production and Rural Environment, Volos, Greece, [5]Agricultural University of Athens, Department of Animal Science, Athens, Greece

The AGRO FUTURE CLIMATE STRESS supports the principles of "One Health Initiative": It follows a collaborative, multi-sectoral and trans-disciplinary approach, aiming to achieve health outcomes, recognizing the interconnections between climate and the health of animals and plants. Specifically, it quantitatively and qualitatively studies the impact of climate change on primary production in Greece, through the assessment of the impact of future climate conditions on crops and livestock health in terms of different types of stress, with the ultimate goal of supporting food sufficiency and safety. The Weather Research and Forecasting (WRF) model will be used as a high-resolution regional climate model in order to simulate future climate conditions for the whole country and will be applied for two emission scenarios, namely the RCP4.5 (intermediate) and the RCP8.5 (worst-case). Climate projections will be exploited to assess changes in water stress of popular crops (wheat and olive) and thermal stress of popular farmed animals (cattle and sheep) in the future and then to map the country thus highlighting favourable and unfavourable areas and proposing relevant adaptation measures. The evolution of the cultivation / breeding of these plants / animals is crucial for food sufficiency and security, while significantly affecting sectors of the agricultural economy, as well as the agricultural income. The research activities are organized in three work packages (WRF application, indices calculation, mapping and adaptation measures), supported by a management work package and supporting a dissemination and communication work package. The project's results will be published in scientific journals, presented in conferences, captured on GIS maps, and used to produce guides for crop and livestock farmers recommending good practices for dealing with worsening of crop and livestock stress. The project has a strong interdisciplinary and collaborative nature and involves researchers with experience in the topics it deals with (application of climate models and evaluation of their results, monitoring and evaluation of crop and livestock stress, GIS applications, investigation and proposal of climate change adaptation measures).

Keywords: Climate change, climate projections, crops, animals, GIS maps, Greece

Acknowledgement: This project is carried out within the framework of the National Recovery and Resilience Plan Greece 2.0, funded by the European Union – NextGenerationEU (Implementation body: HFRI).

PP02-049 | Sustainable management of olive oil production surpluses: The INOVCIRCOLIVE project

Vasco Fitas Cruz[1], Fatima Baptista[1], José Carlos Rico[2], Diogo Rezende Coelho[2]
[1]MED – Mediterranean Institute for Agriculture, Environment and Development & CHANGE – Global Change and Sustainability Institute, Departamento de Engenharia Rural, Escola de Ciências e Tecnologia, Universidade de Évora, Pólo da Mitra, Ap. 94, 7006-554 Évora, , Portugal, [2]MED – Mediterranean Institute for Agriculture, Environment and Development & CHANGE – Global Change and Sustainability Institute, Institute for Advanced Studies and Research, Universidade de Évora, Pólo da Mitra, Ap. 94, 7006-554 Évora, , Portugal

Estimates indicate that for the 2023/2024 campaign, olive oil production in Portugal will range between 150 to 160 thousand tons. As the production and business volume in the olive oil sector continue to rise, sustainability concerns arise regarding this activity. During the olive oil extraction process, significant amounts of waste and by-products are generated, which are now referred to in circular economy terms as "surpluses." The most concerning surplus is the wet olive pomace. This surplus is four times more abundant than the olive oil, making it the most prevalent among all by-products generated by olive mills. Typically, wet pomace is processed in drying units with limited capacity to cope with the continuous increase in olive production. However, these surpluses can add ecological value by contributing to a nearly zero-waste circular economy, providing significant environmental benefits that enhance the olive oil sector. Given this situation, the INOVCIRCOLIVE Project was created to address the challenge of giving a new life to olive oil production surpluses, guided by the principle of the circular economy. The project aims to promote innovative solutions for the integrated valorization of olive oil production surpluses (olive pomace, olive tree pruning residues and leaves, wastewater, and olive pits) and other leftovers from the agri-food chain. One of the strategies adopted in the INOVCIRCOLIVE Project is the valorization of olive oil production surpluses through the composting process. An experimental protocol has been developed and implemented by the partners for the construction of compost piles, primarily utilizing olive oil production surpluses as raw materials. It is expected that the results obtained will help reduce pressure on natural resources caused by extractive activities and contribute to new methods of treatment and/or valorization of surpluses. This will enable the promotion of a circular bioeconomy for the olive sector, introducing new business models and opening promising perspectives for the implementation of industrial symbiosis practices.
Keywords: olive sector; sustainability; Circular Economy; composting; wet olive pomace.

PP02-050 | A holistic data insight into pig husbandry: Practical perspectives on smart livestock farming

Hannah Graef[1], Barbara Sturm[2], Jonas Payerl[1], Boris Kulig[1], Jan Adolph[1], Abozar Nasirahmadi[3], Oliver Hensel[1]
[1]University Of Kassel, Section Agricultural and Biosystems Engineering, Witzenhausen, Germany,
[2]Leibniz Institute for Agricultural Engineering and Bioeconomy e.V. (ATB), Potsdam, Germany,
[3]Swedish University of Agricultural Sciences, Department of Energy and Technology, Uppsala, Sweden

At present, the pork industry is facing considerable economic and social challenges. Smart Livestock Farming using sensors (optical and non-optical), emerges as a vital support in this context, leveraging the potential to improve various aspects of pig husbandry. However, addressing the complexity of real-life scenarios requires shifting from focusing solely on specific areas within pig husbandry to a more holistic approach considering individual animal-based measures. Thus, it is essential to investigate interrelationships of relevant pig husbandry parameters in real-world context such as practical farms. This study focuses on identifying relationships of relevant process parameters for process optimization while considering the complexity of practical pig husbandry based on the information of individual pigs.
A study in Thuringia, Germany, examined a pig value chain by individually monitoring five consecutive pig batches from birth to slaughter using RFID transponders in 2022-2024. The pigs, a crossbreed of Topigs Norsvin TN 70 (Large White X Landrace) and Pietrain (Tempo), were housed together in the same farrowing compartment, and reared in similar barn compartments, and were fattened in identical three compartments across the five batches. The collected data included genetic origin, litter details, health and performance parameters, slaughter information, and barn climate conditions (temperature, ammonia, carbon dioxide, air velocity, and relative humidity). Analyzing the acquired data for correlations, multicollinearity and patterns preceded the development of Random Forest models.
The different analysis methods not only showed already known relationships and patterns such as piglets with more initial birth weight showing greater daily weight gains. They also offered a holistic view into deviations from expected results due to for example changes in practical management. Our findings show that a holistic approach to understanding relationships is useful to analyze the complex pig production. Therefore, future Smart Livestock Farming solutions should consider a broader variety of relevant parameters (data analytics perspective) and include animal-based measurements to enhance the product feedback.

PP02-051 | Rapid prediction of ammonia, nitrite and nitrate concentrations in water of Recirculating Aquaculture Systems (RAS) using portable near-infrared spectroscopy combined with PCA-neural network-based model

Eleonora Buoio[1], Annamaria Costa[1], Gian Luca Chiarello[2], Alessia Di Giancamillo[3], Daniela Bertotto[4], Giuseppe Radaelli[4], Nadia Cherif[5], Tarek Temraz[6], Francesco Tangorra[1]
[1]Department of Veterinary Medicine and Animal Sciences, Università Degli Studi Di Milano , Lodi, Italy, [2]Department of Chemistry, Università degli Studi di Milano, Milan, Italy, [3]Department of Biomedical Sciences for Health, Università degli Studi di Milano, Milan, Italy, [4]Department of Comparative Biomedicine and Food Science, Università degli Studi di Padova, Padua, Italy, [5]Aquaculture Laboratory, National Institute of Sea Sciences and Technologies, Salamboo, Tunisia, [6]Department of Marine Sciences, Faculty of Science, Suez Canal University, Ismailia, Egypt

Recirculating aquaculture systems (RAS) are land-based, closed-loop systems that reuse water by passing it through a filtration system, reducing the amount of fresh, clean water used and the space required for fish farming. They are therefore sustainable systems that provide a controlled and biologically safe environment in which to grow fish. The success of a fish farm is significantly depending on whether the fish can live in an environment with optimal water quality. A key process in RAS for purifying water is nitrification, a process in which bacteria convert ammonia excreted by fish into nitrite and then nitrate. Ammonia and nitrite are extremely toxic for fish, so they need to be prompt detected and monitored.
The aim of the study was to assess the ammonia, nitrite and nitrate concentration in water of RAS using an ultra-compact Near Infrared (NIR) spectrometer. In the context of the Fish-PhotoCAT Project, 32 samples of water were collected from six experimental RAS in which adult rainbow trout were reared at a density of 15 kg/m3 for 30 days. NIR calibrations were developed by means of principal component analysis (PCA)-neural network obtaining models with a fairly good coefficient of determination (R2C = 0.83 and R2CV = 0.85 for NH3-N, R2C = 0.79 and R2CV = 0.80 for NO2-N, R2C = 0.89 and R2CV = 0.88 for NO3-N) and a reasonable prediction error (RMSECV = 0.05, 0.12 and 12.33 for NH3-N, NO2-N and NO3-N respectively). Based on these results, the portable spectrometer would be useful for providing a fast screening of NH3-N, NO2-N and NO3-N in water samples at farm level, enabling proper management of recirculating aquaculture systems and rapid turnaround in plants advisory systems.

Keywords: water samples, proximal sensing, optical sensors, fish farming management

PP02-052 | Evaluation of plant-response irrigation model in greenhouses

Angeliki Elvanidi[1], Yannis Naonoulis[1], Nikolaos Katsoulas[1]
[1]Uth, Volos, Ελλάδα

Determining the timing and quantity of irrigation in hydroponic is crucial for effective greenhouse management. Traditionally, for automated irrigation management in greenhouses, most farmers have used a timer to regularly drive irrigation or measure the substrate water content and air humidity neglecting to consider the plant physiological state. The development of Decision support systems (DSSs) that combine environmental and crop data can assist growers in making more precise and consistent decisions in irrigation management. In the current research, a model that evaluates stomata conductance (gws) and photosynthesis rate (Ps) as the plant-response key in the decision making process was developed. The innovation of the current model lies in the integration of Ps values estimated by means of remote sensing using a photochemical reflectance index (PRI). Logistic regression was employed using independent variables like temperature (Tair), vapor pressure deficit (VPD), and leaf-air temperature difference, to predict gsw status. Next, the correlation between gsw and Ps was initially established to fit a logarithmic curve. The mean response of Ps at maximum gsw was considered as Psmax. Control standards of 90%, 80%, and 70% of Psmax were maintained as control standard. Then the regression model was utilized to inversely predict gsw values corresponding to these percentages of Psmax, resulting in the determination of different gsw cutoff points. When gsw status was "low," the system activated the environmental control component to assess if VPD and photosynthetic photon flux density (PPFD) were within the normal range. If not, the system provided recommendations for environmental control. Conversely, when both parameters were normal, the system determined irrigation was needed, estimating the amount using the evapotranspiration model. Statistical performance of the model was evaluated. The results indicate that the system achieved a significantly small error.

PP02-053 | Study of the individual information collection system for weaner pigs

Yi-Chich Chiu[1]
[1]National Ilan University, Yilan County, Taiwan

The objective of this research is to develop an individual information collection system for weaner pigs, and integrate the Internet of Things technology for system construction. The weight change of weaner pigs during growth has a certain relationship with health. Therefore, it is very important to accurately measure the weight of pigs. However, it is difficult to measure the weight of weaner pigs by hand, which is easy to cause the pigs to be scared and urgent. Weaners are pigs that are between weaning and 56 days of age and weigh 6–20 kg. The system can give different feeds according to weight changes and nutritional needs during the growth of weaner pigs. Through the system, you can monitor the daily weight changes of each pig, track the growth status of individual pigs and mark them. When the abnormality is detected during the feeding process, it can be immediately improved to prevent more property loss and achieve maximum economic benefits. The system was divided into control unit, import and export unit, weighing unit and feeding unit. The system control was through the programming logical controller (PLC), including import and export gates, weight measurement and feed supply control. Use RFID to detect the number of each pig, and record the weight change, feed intake, etc., calculate the feed conversion rate and evaluate the growth rate of pigs by cloud system. In this study, the dynamic weighing test was carried out through three standard weights of 45, 50 and 55 kg. The optimal sampling time was 0.1 second, and the weighing system error rate was 1.2%. The test results showed that the individual information collection system of the weaner pigs was stability. Through the establishment of the individual information collection system for pigs, it can be reduced the burden on the on-site breeding staff, and obtained the pig weight growth curve instantly. Individual observations can be made during the breeding period, and pigs with poor growth status can be found early, in addition to improve pig breeding quality.

PP02-054 | Harvesting date influence on multi-trunk traditional olive productivity in next years

Francisco J. Soto-Torres[1], Gregorio L. Blanco-Roldán[1], Sergio Peña-Valero[2], Francisco J. Castillo-ruiz[1]
[1]University Of Córdoba, Córdoba, Spain, [2]Trituradoras Serrat. Construcciones Mecánicas Alcay S. L., Castejón del Puente, Huesca, Spain

Olive (Olea europaea L.) was mainly distributed within the Mediterranean basin, being Spain the main producer with 2.77 million hectares. Modern olive orchards require high technology control systems to optimize agronomical behavior, and mechanized processes to keep costs under control. Harvesting requires the highest amount of labor hours for both, machines and workforce, thus, optimize harvesting date and resources required was highly important in areas in which olive supposes a monoculture. The aim of this research was to determine if harvesting date influence next year production of fruit or olive oil. For this purpose, production data of several orchards from two different farmers located in Jaén Province, southeastern Spain, were gathered. All data was obtained from multi-trunk traditional olive orchards, which have the highest requirements in terms of labor and machine work to be harvested. Harvesting date was considered as the date in which fruit was delivered to the olive mill. Dates were transformed into day of the year (DOY) and modified DOY which zero value was considered as 1st November. Harvesting dates for fruit harvested from the soil were not considered because it did not affect next year production. Fruit, oil and oil yield were analyzed to determine if olive productivity was affected by previous harvesting dates. Optimal harvesting data will help to plan labor and machine resources to maximize obtained olive oil in terms of quantity and quality. Harvesting date influence on olive oil quality was already demonstrated, but the present research provided new evidence to encourage farmers from some areas of southern Spain to came early harvesting.

PP02-055 | Upgrade of a Vicon RS-EDW spreader to variable rate application: Development of a microcontroller for communication between systems

João Serrano[1], Alexandre Amaral[1], Shakib Shahidian[1], Carlos Escribano[2], Francisco Moral[3], José Marques da Silva[1]
[1]MED- University of Évora, Évora, Portugal, [2]AMS Ibérica, Madrid, Spain, [3]University of Extremadura, Badajoz, Spain

Over the last two decades, a considerable amount of equipment has been acquired (spreaders, seeders, sprayers, among others) to respond to the challenges of Precision Agriculture (PA) concept. Most of this equipment has been purchased at high costs. However, many of them, despite still being functional and equipped with sensors, actuators, and electronic processing units, capable of adjusting to variations in speed, have become obsolete in terms of communication, incompatible with new monitoring and control systems based on “Isobus” protocol. This work aims to present a solution for updating the control system (“Ferticontrol”) of a “Vicon RS-EDW” spreader with variable rate application (VRA), making it compatible with the “InCommand” system from “Ag Leader”. The solution includes low-cost “Arduino” and “Raspberry Pi” microcontrollers and open-source software. The development shows that it is possible to implement a solution that is accessible to farmers in general. It also provides a niche business opportunity for young researchers to set up small technology-based enterprises associated with universities and research centers. These partnerships guarantee permanent innovation and represent a decisive step towards modern, technological, competitive, and sustainable agriculture.
Keywords: technological update, compatibility, microcontroller, VRT, precision agriculture.

AgEng 2024

1-4 July 2024
Athens-Greece

PROFESSIONAL CONGRESS ORGANIZER
convin
www.convin.gr

MEMBER OF
IAPCO ACCREDITED
ICCA Member

YOUR FLEXSTABILITY PARTNER!!