FARM MACHINERY AND PROCESSES MANAGEMENT IN SUSTAINABLE AGRICULTURE

XIII International Scientific Symposium

University of Bari Aldo Moro

Book of Abstracts

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Farm Machinery and Process Management in Sustainable Agricultura (FMPMSA)

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Topic 01

Management of field and livestock production machinery

Theoretical investigation of the parameters of the side-cutting knives of a vibratory digging working body for carrot root crops

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Abstract. This paper presents an analytical study and substantiation of the parameters of the oscillatory process performed by the side-cutting knives of a vibratory digging working body intended for digging carrot root crops. The aim of the study was to determine the influence of the design-kinematic and dynamic parameters of the knife on the soil resistance force and to obtain response-surface regression models suitable for engineering calculations. On the basis of an equivalent scheme of knife-soil interaction, a differential equation of motion was formulated, and analytical expressions were obtained for the absolute velocity of the knife and the instantaneous soil resistance force. For steady-state conditions, the extreme values of the resistance force were determined, and a computational experiment was carried out over the factor ranges H = 100…450 N, m = 1.5…5.5 kg, ω = 20…70 s–1. Two response surfaces of the minimum steady-state soil resistance force were constructed: as functions of H and ω at a constant knife mass, and as functions of m and ω at a constant amplitude of the excitation force. It was established that increasing H reduces the minimum resistance force, whereas increasing m and ω within the adopted conditions weakens the effect of dynamic unloading and increases Fop.min. The obtained quadratic regression equations with coefficients of determination R2 = 0.999 and 0.994 can be used for preliminary optimization of the parameters of the side-cutting knives.

Keywords: carrot; vibratory digging working body; side-cutting knife; soil resistance force; response surface; mathematical model; regression equation.

Experimental studies of a combined pneumatic device for dosing and spot application of mineral fertilizers with an assessment of agro-robot productivity

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Abstract. This paper presents experimental studies of a combined pneumatic device for discrete dosing and targeted spot application of granular mineral fertilizers, intended for integration into a robotic precision-agriculture system, together with a calculated assessment of agro-robot productivity. The aim of the work is to link an experimentally verified mathematical model of fertilizer-portion motion in the application tube with an agro-robot productivity model as a function of air pressure, internal tube diameter, valve-opening duration, metering-unit output, fertilizer dose, travel speed and inter-plant distance. Bench-test data obtained for tube diameters of 10–20 mm and air pressures of 400–900 kPa were used to parameterize the pneumatic part; on this basis, a response surface of the outlet velocity of the portion, calculated productivity maps and a nomogram for selecting the allowable travel speed were developed. It is shown that the most stable operating mode for the investigated design corresponds to a pressure of 800–900 kPa and a tube diameter of 16–20 mm, while the main productivity-limiting factors during operation in plantations are the dose-formation time of the metering unit and synchronization of the device cycle with the agro-robot motion. The proposed model makes it possible to estimate the number of treated plants, the fertilizer mass application rate and the shift output, and to select pneumatic-device parameters for timely fertilizer application to the root zone during continuous agro-robot motion.

Keywords: precision agriculture; agro-robot; combined pneumatic device; mineral fertilizers; discrete dosing; application tube; air pressure; valve-opening time; productivity; nomogram; experimental validation.

Analytical study of the interaction between the working bodies of a feeler-rotary cleaner and sugar beet root crowns during removal of top residues

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Abstract. The task of sugar beet harvesting is to maximize the extraction of sugar-bearing mass per unit area while maintaining acceptable levels of losses, root damage and physical impurities. One of the technologically critical operations is cleaning the root crowns from top residues after the main cutting operation. This paper substantiates the design of a feeler-rotary cleaner with directed action of the cleaning elements, which ensures that the force is applied predominantly tangentially to the root crown. A mathematical model of the force interaction between the cleaning element, the feeler and the root crown was developed; the normal reaction in the feeler-root contact was adopted as the main criterion of functional suitability. The model was used for a numerical analysis of the influence of the machine forward speed, rotor angular speed and height of the root crown above the soil surface. It is shown that the rational interval of the normal reaction is 70–100 N: lower values reduce the probability of complete separation of top residues, whereas higher values increase the risk of damaging or dislodging the root from the soil. For a protrusion height of 60 mm and a forward speed of 2 $m \cdot s^{-1}$, the most stable operating mode is ensured at a rotor angular speed of 100–105 s^{-1}.

Keywords: sugar beet; top residues; root crown; feeler-rotary cleaner; cleaning element; normal reaction; mathematical model; forward speed; angular speed.

Determination of the Mean Spread Angle of Mineral Fertilizers Using a Centrifugal Disc Spreader

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Abstract. This publication presents the results of research on the effect of various design parameters of a centrifugal fertilizer disc spreader on the mean spread angle of mineral fertilizer distribution. Three fertilizers differing in physical properties and commonly used in agriculture were used in the study: ammonium sulfate, calcium ammonium nitrate and urea. The selected design parameters that significantly affect spreading quality were: disc rotational speed, vane angle setting on the disc and the fertilizer feeding point onto the disc. The lowest value of the mean spread angle of fertilizer distribution was recorded for calcium ammonium nitrate in the 600-A-L0 configuration and was equal to 69.23°. The highest value was obtained for ammonium sulfate, equal to 141.10°, in the 600-B-L3 configuration.
The influence of the type of fertilizer used for spreading on this process was also examined. To achieve the intended objective, a four-factor experimental model based on complete randomization was adopted. Analysis of variance for the fixed model of the average fertilizer spreading angle showed that three independent variables — fertilizer feeding point onto the disc, vane setting, and fertilizer type — explain 96.12% of the variance of the dependent variable. The vane settings on the disc alone explains as much as 31.78% of the total variability of the mean angle of mineral fertilizer distribution.

Keywords: mineral fertilizers; centrifugal disc spreader; mean spread angle; total static distribution pattern.

Technological possibilities for dog feed production

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Abstract. Introduction - Pet food production is a significant area of the food industry, with a growing demand for innovative technologies and products with diverse physicochemical properties. In response to these needs, an analysis of techniques used in commercial dog food production and implementation studies for a newly developed semi-moist product were conducted.
Research objective: The aim of the research was to determine the influence of the shape of semi-moist dog treats on their mechanical properties and to simultaneously develop and evaluate the production technology of a new type of food, along with the selection of appropriate equipment for the technological line.
Methods - As part of the work, a production line concept was developed, including the preparation of filling and dough, from which snacks of various geometries were formed.
Results - Analysis of selected texture parameters of samples formed as "molded cookies" and "sandwiches" revealed that the product's shape significantly determined its mechanical properties. These results highlight the importance of geometry as a technological factor influencing the structure and deformability of semi-moist dog treats. These conclusions can provide a basis for further optimization of production processes and the design of new food forms with controlled mechanical properties, crucial for both animal safety and the product's sensory acceptability.

Keywords: pet food, production, innovation, techniques.

Stress Relaxation of Potatoes under Quasi-static Loading Conditions

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Abstract. The stress relaxation tests of 'Vinieta' potatoes at different velocities under quasi-static loading conditions were carried out. The Maxwell model with constant elements was used to describe the experimental courses. The influence of the deformation velocity on the Maxwell model parameters as well as peak and minimum force response was studied. There was found the increase of the peak force response with the increasing deformation velocity which shows the viscoelastic nature of potato tissue. The force response at the end of the test describing the material condition after deformation decreased with the increasing deformation velocity. The relaxation times decreased with the increase of the deformation velocity.

Keywords: potato, Maxwell model, stress relaxation, viscoelasticity.

Topic 02

Management of biomass and agroenergy production

Paddle Tester For Determining The Suitability Of Loose Biomass For Storage

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Abstract. This paper presents a vane tester designed to assess the suitability of bulk biomass for storage, developed as part of the PBSIII project funded by the National Centre for Research and Development (NCBiR). The measurement station was designed and built by a consortium involving the Institute of Agrophysics of the Polish Academy of Sciences in Lublin and industrial partners to meet the needs of technologists and designers of biomass storage, transport, and processing installations. The project resulted in two measurement stations, a test methodology, and a catalog of bulk biomass properties, aimed at companies involved in biomass processing and combustion, as well as at research institutions and laboratories. The developed solution enables comprehensive characterization of the mechanical and physical properties of bulk materials. The laboratory vane tester, used at the Laboratory of Mechanics of Bulk Materials, IA PAN, represents an innovative combination of the classic vane tester concept with a modern load-applying system and an integrated measurement system. It enables the determination of key parameters such as shear strength, bulk density, and biomass moisture. Measurements are taken in a cylindrical chamber equipped with vanes placed on its inner walls. After pouring the material and pneumatically consolidating it, the sample is sheared by rotating the shaft with the vanes. The torque at the moment of material structure destruction is recorded using a torque sensor. The sample is loaded using a rubber bellows interacting with the chamber cover. Material density is determined based on mass and volume measurements. Mass is determined using force sensors, while volume is calculated based on the bed height. Material moisture is monitored using sensors placed in the chamber walls. All data is recorded by a data acquisition system and presented in real time. The obtained material parameters provide important information about the behavior of the biomass during storage and transport, including the loads occurring during tank emptying and the operation of transport equipment. The tester, along with the developed measurement methodology, has been patented. A simplified industrial version was also developed based on the laboratory stand, enabling quick (in minutes) determination of biomass properties and assessment of its compliance with industrial installation requirements. The device is characterized by simple operation, and the software guides the operator through the entire measurement process. The proposed solution is particularly useful in combined heat and power plants and power plants, enabling the verification of biomass quality before acceptance and the elimination of materials with undesirable properties. Technical documentation allows for the device to be implemented in industrial practice under license, as well as for its use in research activities.

Keywords: bulk density, biomass moisture, combined heat and power plants.

Effect Of Growth Conditions On Biomass Production And Metabolite Composition In Single-Celled Algae

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Abstract. Single-celled algae are a promising source of biomass for energy applications, including the production of biofuels. Their rapid growth and ability to synthesize valuable metabolites make them an important area of research, aimed at optimizing growth conditions and increasing biomass yields.
This study investigated the response of single-celled algae to different growth conditions, including stress conditions, in terms of growth parameters and cellular metabolite synthesis. The specific growth rate was determined spectrophotometrically by measuring the optical density of the samples. Biomass productivity and yield were determined using the gravimetric method. Lipids were extracted using a modified Bligh and Dyer method. Fatty acid methyl ester content was determined using gas chromatography–mass spectrometry.
The results showed that the applied conditions influenced the specific growth rate, biomass accumulation, and lipid content. Analysis of the fatty acid profile revealed that the dominant fatty acids were saturated and monounsaturated species, primarily palmitic, palmitoleic, and oleic acids. There was also an increase in the proportion of monounsaturated fatty acids. These findings suggest that altering growth conditions can significantly impact the biochemical composition of algal biomass, which is important for its potential applications, including biofuel production.
This research was funded by National Science Centre, Poland, OPUS 26, Grant number: 2023/51/B/NZ9/02479.

Keywords: microalgal biomass, metabolite composition, fatty acid profile and biofuel potential.

Effects of an AGRI-PV system with bifacial modules on microclimate, crop and electricity yield in an organic crop rotation in Eastern Austria

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Abstract. The dual-purpose utilization of arable land for crop production and electricity generation in AGRI-PV is a system for increasing the fixation of solar radiation. In the research AGRI-PV plants of the Wien Energy GmbH in the city of Vienna the effect of the vertically installed PV-panels on microclimate and crop yield as well as the electricity yield was investigated in the long-run (2022-2025). Due to vertical PV-modules (north-south direction), the shadow effect on microclimate and crop yield was detected. The highest yield was in the middle part of the crop strip. The photosynthetic energy yield in the crop accounts for lower than 10% of the total energy yield (above-ground biomass and electricity). In the conventional AGRI-PV-plant without crop production and with inclined PV-modules, the electricity yield was 4.5 higher than the electricity yield in the AGRI-PV with bifacial modules and crop production. The utilization of solar radiation in the dual purpose AGRI-PV plant was 2.4% (electricity and crop biomass) and 10.1% (only electricity for the conventional AGRI-PV-plant without crop production and with inclined PV-modules).

Keywords: Agri-photovoltaic, bifacial PV modules, microclimate, solar radiation, crop yield, electricity yield, Pannonian conditions.

Evaluation of the Feasibility of Utilizing Orchard Production Waste Biomass for the Manufacture of Commercial-Quality Fuel Pellets

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Abstract. Orchard pruning residues, typically regarded as problematic due to their tendency to spread fungal diseases, represent a promising but underexploited feedstock which energy potential has not been sufficiently assessed. The objective of this study was to evaluate the feasibility of using pruning residues from blackcurrant, raspberry, and chokeberry plantations as a raw material for producing fuel pellets that meet normative quality requirements. Pruning residues characterized by elevated nitrogen levels (0.503%–1.363%) were collected from commercial plantations. To improve the fuel quality parameters, the residues were blended with industrial hardwood sawdust containing 0.165% nitrogen. Mixtures were prepared with sawdust proportions ranging from 70% to 90% by weight. The resulting mixtures were evaluated for key physicochemical properties relevant to compliance with pellet quality standards. The results confirm that orchard pruning residues can be effectively integrated into the renewable energy biomass supply chain.

Keywords: Biomass. wood pellets. waste orchard biomass. quality of solid biofuels.

Topic 03

Reduction of costs, energy and machinery input

Outsourcing of technological processes as one of the methods of reducing production costs in agriculture

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Abstract. Modern agriculture demands mechanized technology as a result of not only the development of new techniques, biological advances, or precision farming conditions. The other motives are related to increasing environmental constraints, including those related to climate change. Scheduling work is challenging due to factors such as droughts and rainfall, which provoke shortening of the time windows to perform technological task. In that context, continuous monitoring and precise weather forecasting are essential. That imposes the use of numerous modern, yet expensive, machines and equipment. For family farms, with relatively small areas, the resulting income, limits their investment opportunities. That directly apply to family farms predominate in European agriculture; with an average area of 17.4 hectares (2020). Farmers normally cannot afford to purchase modern, efficient machinery. Therefore, it is necessary to successfully obtain other avenues to gain access to modern machinery and technologies; the avenues should project beyond conventional ownership. The rapid development of autonomous vehicles and robots enables increased efficiency and reduces production costs. However, the cost of purchasing such solutions is a serious obstacle to the most of family farms.
Farmers, however, do not need to own their own machinery, as long as they have access to modern technologies. This is possible through resource outsourcing, using machinery services, renting machinery, sharing machinery, organizing machinery rings, neighborly collaboration, and other forms of cooperation, such as crop sharing.
Farmer collaboration is one of the ways of outsourcing and it can work as a critical mechanism to improve economic indicators, such as lower production costs, for example. At the same time, it improves the social conditions of farmers and their families by reducing the workload and time for further training, for instance.
The paper discusses the most important factors affecting the development of outsourcing and related trends of change.

Keywords: technology, operation costs, profitability of mechanization, management of farm machinery, outsourcing.

Berry fruits as valuable additives in directly expanded gluten-free snacks processed via extrusion-cooking

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Abstract. This paper presents the results of tests on selected physical properties of directly expanded gluten-free snacks enhanced nutritionally with the addition of dried berries into a basic recipe. Corn-based crisps were produced using a single screw extruder at variable screw speeds. Black and red currants, blueberries, chokeberries and gooseberries in amount of 5 to 20% were the separately incorporated berry fruits. The addition of fruit reduced the radial expansion ratio and increased the bulk density of the obtained snacks. Adding fruit in amounts up to 10% into the basic recipe, however, resulted in snacks with a satisfactory expansion. The introduction of berries resulted in a significant, visible change in the color of the supplemented snacks compared to plain corn crisps. Moreover, increasing the amount of berry fruits darkened the color of the tested gluten-free snacks. The darkest color was found in crisps with blueberries or chokeberries recipe inclusion, while the lightest color was seen in snacks with the incorporation of gooseberries. The snacks produced from recipes incorporating berries were characterized by lower cutting forces compared to that of plain corn crisps. Here, increasing the amount of the additives resulted in a decrease of the cutting force of snacks due to their less compact structure, especially at 15 and 20% of berry powder supplementation.

Keywords: Extrusion-cooking; Gluten-free snacks; Berry fruits; Expansion index; Bulk density; Cutting force; Color change.

Topic 04

Plant protection, soil management and agrochemicals application

A biomimetic artificial foam simulates Philaenus spittle in laboratory tests

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Abstract. Juveniles of Aphrophoridae vectors of *Xylella fastidiosa* Wells et al 1987 live embedded in spittle-like, foamy masses, which play a key role in insects' survival during their short post-embryonic development. Several control actions can affect spittle before the insect reaches adulthood, leading to the death of juveniles. Spittle stays in nature for a short interval, so we developed a biomimetic artificial foam simulacrum to experiment with year-round disruption of the foam. We intentionally mixed inverted sugar with a biodegradable soap formulation containing C12-14 alcohols (ethoxylated and sulfated), sodium salts, anionic surfactants, 5-chloro-2-methyl-4-isothiazolin-3-one, 2-methyl-4-isothiazolin-3-one, citral, and limonene across various formulations. We bubbled them through various nozzles until we achieved a replica of the size, density, and lifespan of natural bubbles. The simulacrum formula now exceeds the natural spittle life interval, as well as the limits in spittle abundance. We propose this laboratory-made biomimetic artificial foam model for testing in spittle leaching experiments. Having foam "on demand" enables evaluation of available control means and subsequent control actions.

Keywords: Hemiptera, xylem sap feeder; modelling; non-natural foam; IPM; Integrated transmission management; insect-borne Ectosymbiotic microorganisms, Ectosymbionts.

RiskPPP: A decision-making tool to prevent point source pollution by plant protection products

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Abstract. It is now widely recognised by the scientific community that the application of plant protection products (PPPs) for agricultural use exerts a pressure on several environmental compartments, including water resources. These pressures are categorized into two groups: diffuse and point source pollution. The former is caused by the repeated application of PPPs over a large area, while the latter occurs accidentally and/or over a very localised area. In this case, it is generally due to the product being applied to a particularly sensitive area, which can facilitate the transfer of the active substances of the product to watercourses or groundwater.
To prevent such contamination and protect sensitive populations, Belgian and Walloon regulations define risk-mitigation measures related to the characteristics of the plot (e.g. sensitivity to erosion, karstic formation) or its surroundings (e.g. proximity to a school, water catchment). The latter is materialized through buffer zones around these sensitive areas where the use of PPPs is prohibited under specific conditions. As some of these buffer zones can vary in size depending on the product, the equipment, the crop type and the spraying techniques, it is a major difficulty for farmers to identify which restrictions apply to each of their plots and therefore to comply with them. This challenge is further compounded by constantly changing legislation.
In partnership with the Public Water Management Company (SPGE) and the Public Service of Wallonia (SPW), the Walloon Agricultural Research Centre (CRA-W) has developed RiskPPP, a WebGIS platform to address this issue. By providing the above-mentioned parameters, farmers can identify the areas where they can or cannot apply their product. This output can then be downloaded to a tractor's console so that spraying stops automatically when the tractor leaves the authorised area. The web service is connected to DBPPP, a database that contains all legal information regarding the approved uses of PPPs and is updated according to the changing legislation. This database is accessible to all through both a graphic interface and an API.
The combination of these two platforms helps farmers access, understand, and comply with various legislations more easily through a single focal point, enables agricultural advisors to identify the most suitable products based on specific local restrictions, and allows policymakers to visualize the overall impact of policies in the field, thereby reducing the gap between farmers and policymakers.

Keywords: Pesticide regulation, Decision-support tool, Risk mitigation, WebGIS.

OADérive : A decision-support tool for selecting mitigation measures to reduce pesticide spray drift exposure of nearby residents

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Abstract. Exposure of populations living near agricultural areas to plant protection products (PPPs) is a growing public health concern, largely driven by spray drift during and after pesticide applications. Although many mitigation measures are well known and generally understood by farmers, their implementation remains constrained by the lack of integrated tools to support context-specific decision-making. In this context, we developed a comprehensive toolkit of drift mitigation measures, along with a decision-support tool (DST) named OADérive. The toolkit organizes measures acting at different stages of the drift process. It includes preventive approaches, such as reducing droplet size and drift potential, as well as exposure-reduction measures, including buffer zones and physical barriers. These measures are adapted to a range of cropping systems, including arable fields, orchards and vineyards. OADérive is a spatial, map-based tool that identifies agricultural parcels near residential areas and evaluates their relative risk of off-target exposure. Parcels are classified based on their proximity to dwellings, spraying techniques, and practices. A scoring system defines a target level of drift reduction and guides users in selecting appropriate measures. The tool will be tested in pilot areas across Wallonia to support users in implementing effective strategies to reduce pesticide drift and human exposure.

Keywords: Pesticide drift; Mitigation measures; Resident exposure; Decision-support tool; toolkit**.**

UAV-Based Spraying in Italy: A Technical Study and Regulatory Analysis of the Authorization Regime between Environmental Protections and Experimental Simplifications

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Abstract. Abstract. The use of Unmanned aerial vehicles (UAVs) for pesticide application is experiencing significant global growth thanks to its effectiveness in precision agriculture. However, several aspects, including operational, technical, and legislative are limiting its final diffusion. The framework governing the application of plant protection products by agricultural UAVs is particularly complex. It is "multi-level", involving both European Union and national law; "distributed", as it spans both aviation and plant-health regulation; and "non-autonomous", since it must be coordinated with domestic administrative law. This paper investigates the framework of UAV-based spraying applications in Italy and performs a regulatory analysis of the actual authorization regime between environmental protections and experimental simplifications.

Keywords: agricultural UAV, spraying UAV, UAV-based spraying, precision agriculture, regulatory analysis.

Digestate as a biofertilizer in crop production: effects on yield, soil properties and sustainable nutrient management - a review

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Abstract. This paper presents a comprehensive review of current research concerning the use of digestate as an organic fertilizer in crop production systems. Digestate, a by-product of anaerobic digestion in biogas plants, has gained increasing attention as a sustainable source of nutrients capable of improving soil fertility and plant productivity. The study synthesizes recent scientific findings related to digestate chemical composition, fertilization efficiency, and application techniques, with particular emphasis on their effects on plant growth, yield parameters, and soil physicochemical properties. Environmental aspects associated with digestate use are also discussed, including nutrient cycling, soil organic matter enrichment, and potential risks resulting from improper application practices. The reviewed literature indicates that digestate can serve as an effective alternative to mineral fertilizers when applied at appropriate rates and using suitable techniques. The conclusions highlight the agronomic potential of digestate fertilization and identify key research gaps as well as practical challenges requiring further investigation.

Keywords: digestate; organic fertilization; crop production; plant yield; soil properties; sustainable agriculture; digestate composition; fertilizer application techniques; nutrient cycling; biogas plants.

Weed management alternatives in chicory: assessment of localized herbicide applications, non-selective products with safety zones, and intra-row mechanical weeding

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Abstract. Root chicory (Cichorium intybus) requires effective weed management, while several post emergence herbicides historically used in this crop are being progressively withdrawn from the market, reducing the range of available chemical options. The aim of this study was to evaluate alternative weed control strategies and identify management programs compatible with these regulatory constraints. The experiment was conducted in 2025 on a 0.47 ha experimental field using a randomized design with four replicates. Seven modalities were compared: a broadcast chemical reference, four ultra-localized spraying strategies two using selective herbicides still authorized and two modalities applying non selective herbicides(with safety zone around the crop), and two intra row mechanical weeding systems.

Weed and crop dynamics were monitored using georeferenced drone imagery taken before and after treatments, complemented by a final manual count. This approach enabled the quantification of: (1) total weed numbers per plot; (2) number of weeds destroyed, based on spatial matching of individuals between consecutive flights; (3) newly emerged weeds; and (4) destroyed chicory plants. For the ultra-localized spraying modalities, additional indicators were calculated : correct detection rate (proportion of weeds sprayed), non-detection rate (weeds not sprayed), false positive rate (sprays occurring on soil or crop) and the percentage of chicory plants sprayed.

Initial infestation levels were similar across the chemical treatments, whereas the mechanical modalities showed higher weed densities due to the absence of pre emergence herbicides. During the season, all modalities exhibited marked reductions in weed numbers, with different temporal patterns depending on the treatment program. At the final assessment, the lowest weed densities were observed in the mechanical modalities and in one modality applying a non-selective herbicide with a safety zone. The ultra-localized spraying treatments with selective herbicides have showed a poorer control. No significant differences in crop selectivity were detected among the treatments.

Keywords: chicory (Cichorium intybus), weed management, localized herbicide application, mechanical intra-row weeding and spatial weed monitoring.

A review of the application of UAV-based Thermal Remote Sensing in precision agriculture

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Abstract. In an age where resources are limited and optimal management is crucial, precision agriculture aims to solve contemporary challenges. The use of increasingly advanced data collection and monitoring tools is therefore necessary. Unmanned aerial vehicles (UAVs) integrated with thermal technologies can play a central role in this regard, enabling detailed monitoring of the physiological state and stress levels of crops. This study analyses literature from the last five years to provide an overview of aerial thermography applications, including methods for processing and interpreting results. The results indicate that UAV-based thermography can detect intra-parcellar variations in plant surface temperature. This provides indirect information on water and health status and the efficiency of agronomic crop treatments. This contributes to more precise and sustainable management decisions. While the potential of this technology is clear, limitations and technical challenges remain, including the extraction of agronomic information, atmospheric attenuation and absorption, calibration, climatic conditions, different crop growth stages and the complex interaction between soil and plant. These factors have so far limited its use in the agricultural sector. However, technological advances in drones and the growing demand for precision in agricultural applications could foster the greater integration of thermal remote sensing into agricultural decision-making processes, opening new possibilities for more efficient and sustainable crop management.

Keywords: Remote sensing, Monitoring, Thermography, Drone, Water status.

Topic 05

Methodologies, procedures and measurements in sustainable agriculture

Consumer profiling and preferences for alternative protein products

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Abstract. The growing interest in alternative protein sources is due to the need to reduce the negative impact of food production on the environment and to the growing health awareness of consumers. Plant-based products are an important part of the transformation of food systems, but their acceptance depends on usability, sensory and functional preferences. The aim of the study was to analyze consumer preferences regarding storage and culinary methods of application of VegePro products (a group of innovative products covered by the project NUTRITECH1/003A/2022) and identification of consumer profiles. Methods: The survey was conducted using an online survey, made available on selected platforms and forums. After verifying the correctness of the completion, 91 questionnaires were qualified for analysis. Declarations regarding expectations towards product forms, ways of their use, packaging preferences and openness to innovation were analysed. Results: Based on the responses, three consumer profiles were distinguished: (1) eco-conscious vegans and vegetarians, (2) flexitarians open to innovation, and (3) traditional price-driven consumers. The majority of respondents declared openness to innovation (87.9%) and expected a wide range of product forms, including variants inspired by traditional meat products, cutlet forms, snack forms and ready meals. High importance was given to elements that support use, such as recipes (78.8%) and spice sets (71.2%). Respondents also showed interest in products inspired by world cuisines and collective packaging for gastronomy. Conclusions: The results indicate a high market potential of alternative protein products and growing consumer openness to their use. However, the acceptance of products depends on adapting their form, functionality and culinary support to the diverse needs of recipients. Products such as VegePro can support the transformation of food systems towards greater sustainability, provided that the offer is properly matched to consumer expectations.

Keywords: alternative protein sources; consumer preferences; consumer profiling; food innovations; sustainable food systems; eating behaviour.

Non-invasive evaluation of the effects of biostimulation of runner bean using a portable spectrometer in the aspect of sustainable crop management

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Abstract.
The aim of this study was to evaluate the feasibility of using a portable spectrometer to non-invasively monitor the effects of biostimulation of runner bean (*Phaseolus coccineus* L.) cultivar Eureka. Kelpak biostimulant (*Ecklonia maxima* extract) was used in the field experiment at three concentrations (0.6, 1.0, and 1.4%), and measurements were taken before and 10 days after application using a PolyPen RP410/UVIS spectrometer. NDVI, TCARI, NPQI, PRI, and NPCI indices were determined and related to yield parameters. Biostimulant resulted in an increase in NDVI, indicating increased biomass and photosynthetic activity, and a decrease in NPQI and NPCI, indicating reduced stress and chlorophyll degradation. The PRI index, reflecting improved photosynthetic efficiency, demonstrated the highest sensitivity. Application of the preparation increased pod number and seed yield. The results confirm the usefulness of portable spectrometry as a rapid tool for assessing biostimulant and its potential in precision agriculture.

Keywords: *Phaseolus coccineus* L.; Biostimulator; Kelpak; Yield; NDVI; TCARI; NPQI; PRI; NPCI.

Dynamic analysis of a road-transportable mobile power station

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Abstract. Objectives: The transition from fossil based energy systems to renewable solutions is essential for reducing environmental impact in modern agriculture. Autonomous agricultural robots operating in remote areas require reliable energy supply to ensure continuous field operation. A road transportable mobile renewable energy station has been developed to provide on site solar power generation, battery exchange capability, and integrated fertilizer storage for automated field operations. The station is constructed using a lightweight high strength aluminum alloy truss structure to minimize mass while maintaining structural integrity. However, its large dimensions, extensive solar panel surfaces, and the presence of a fertilizer bunker with variable filling level create complex dynamic behavior during road transport. Although the energy performance of the station has been evaluated, its transport dynamic response under realistic road excitation and aerodynamic loading has not been systematically investigated. Therefore, the objective of this study is to evaluate the dynamic behavior and transport stability of the mobile energy station under varying mass distribution and external disturbances, and to quantify their effect on structural response and load transfer during transport.
Methods: A multibody dynamic (MBD) model of the mobile energy station and its transport configuration was developed. The structure was represented as a rigid body system with equivalent mass and inertia properties derived from the aluminum support structure and mounted components. Stochastic road profiles were applied as vertical excitations, and aerodynamic effects were introduced as lateral wind loads. Simulations at representative highway speeds evaluated angular motion, accelerations, and reaction forces relative to static assumptions.
Results: Simulation results indicate that dynamic amplification may significantly increase transient load levels compared to static design assumptions. Mass distribution, bunker filling level, structural stiffness, and aerodynamic exposure critically influence yaw, roll, and pitch stability. The developed model provides a systematic approach for evaluating transport safety and optimizing the structural design of large-scale mobile energy systems.

Keywords: Energy production, multibody dynamics, mobile renewable power station, transport stability.

Image analysis to monitor weeding dynamics and improve the evaluation of mechanical weeding techniques

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Abstract. The use of herbicides has been called into question due to their impact on health and the environment, in particular, water resources. European legislation establishes a framework for the reduction of use of pesticides (Directive 2009/128/CE). Among alternatives to chemical weeding, a diverse range of mechanical solutions exists or is being developed. Some have already been used for many years in organic farming and are expected to evolve rapidly through the integration of new technologies. Weed detection trained by AI models or crop mapping plays an important role because they make it possible to actuate mechanical tools to destroy weeds located within the crop row. They are also used in ultra-spot spraying technologies or laser weeding. It is essential to evaluate these new implements and provide agricultural professionals with reference data relevant to their specific cropping conditions. Several specific characteristics of mechanical weed control require adaptations to the existing evaluation protocol. Mechanical weed control has a direct impact on weed destruction but has a shorter-lasting effect than herbicides, requiring more frequent passes and closer monitoring of weed populations. Because mechanical weed control disturbs the soil and alters weed emergence between interventions, assessing its effectiveness requires distinguishing newly emerged weeds from those previously present and either controlled or unaffected by the prior treatment. Furthermore, when weed control depends on detection models, the evaluation becomes more complex. The overall effectiveness is not only influenced by the weeding strategy itself but also by the quality of the model of weed/crop detection. A more comprehensive method to assess weed control is currently being developed and tested. It enables season-long monitoring of geolocated weed populations through the integration of GNSS-based data acquisition, drone imagery and spatial map processing. This article presents this method and illustrates its application using data from trials conducted as part of the Interreg AgRoboConnect project and the Chicory and Beet Dissemination Program which aims to evaluate innovative automated solutions to reduce the use of herbicides. The potential for improving the method lies in automating annotation processes to count both weeds and crops.

Keywords: Mechanical weeding, image analysis, weeding effectiveness, total weed destruction, assessment, weed dynamics.

Preliminary results of UAV-based thermography for assessing water stress conditions in an almond orchard

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Abstract. Thermal images provide essential information for the general comprehension of the physiological state of a crop. When acquired using unmanned aerial vehicles (UAVs), thermal images increase the amount of information that can be obtained performing manual measurements. This improves crop monitoring thanks to continuous and high-resolution spatial and temporal distribution of data, that allows to identify critical areas within a plot that can be difficult to be observed from ground measurements. In this study, UAV-based thermography has been proved extremely useful for assessing the water stress conditions in an almond orchard located in Apulia region, Southern Italy. The Mavic 3T DJI drone, equipped with an RGB and a thermal camera, was used to evaluate the influence of different water management strategies (control, moderate regulated deficit irrigation, severe regulated deficit irrigation) on canopy temperature and assess the effectiveness of using remote sensing approach. The data acquired by the UAV were compared with the ones acquired on the ground by the LI-COR LI-600 instrument, to validate the remote measurements taken. Eight different flights were performed in June, July, and August 2025 until harvest. The images were processed using the Pix4D software. Physiological variables showed consistent relationships with thermal parameters. The leaf temperature values obtained from the UAV are highly correlated with proximal measurements ($r = 0.89$), confirming the robustness of remote thermography. In contrast, the correlation between leaf-to-air temperature difference (ΔT) acquired by drone and ΔT measured proximally was low ($r = 0.18$), due to the difference of the two employed approaches and dependence to their characteristics, such as viewing angle, spatial resolution, and canopy depth. Remote leaf temperature showed moderate correlations with leaf Vapor Pressure Deficit ($r = 0.71$), highlighting good sensitivity to local microclimatic conditions. Overall, the results demonstrate that remote thermography based on UAV is an effective tool for thermal canopy monitoring.

Keywords: Canopy temperature, Vapor Pressure Deficit, Remote sensing, Regulated Deficit Irrigation.

Topic 06

Smart Farming and sustainability

Smart strategy for insect targeting: influence of nozzle location and pressure on droplet deposition and efficacy

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Abstract. Spray application as an effective method is necessary for controlling whitefly, a major insect in the greenhouses. This investigation evaluated the influences of spray nozzle location and pressure on spray characteristics, including droplet size, spray deposition, and amount of deposition, and their relation to whitefly control efficacy. Five spray nozzle locations toward the plant canopy were evaluated: vertical (V), lateral (L), from under canopy (U), dual spraying (V + L) (D), and combined spraying (D and U) (C), at two different operating pressures (2 and 5 bar). The outcomes showed that both spray nozzle locations and pressure significantly affected spray characteristics and whitefly mortality. The spraying in a vertical location to the plant canopy, particularly, resulted in low coverage and deposition on the bottom leaf layers and consequently an unsatisfactory result of whitefly control. Notably, the under-canopy spraying improved whitefly efficacy by improving spray deposition on the bottom layers of the leaf, whereas the dual spraying (D) further intensified plant canopy coverage and control efficacy. The elevation in whitefly mortality was also consistently established with the combined spraying (C), especially at 5 bar, due to ameliorated multi-direction with higher spray coverage and droplet deposition on the entire plant canopy. The finding also showed that increasing the operating pressure from 2 to 5 bar generally improved whitefly control; however, the optimal whitefly efficacy was essentially dependent on the suitable spray nozzle location. These results highlight the significance of strategies of operating pressure with suitable integrated multi-directional spray to ameliorate whitefly efficacy in the greenhouse conditions.

Keywords: Spray orientation; pressure; spray deposition; Whitefly; eggplant.

Experimental Validation of EKF-Based Lateral Position Estimation for GNSS-Free Inter-Row Navigation Using RTK Reference Measurements

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Abstract. Reliable estimation of vehicle position relative to crop rows is essential for autonomous navigation in agricultural environments where Global Navigation Satellite System (GNSS) measurements are unavailable or degraded. A previously developed GNSS-free navigation framework used Light Detection and Ranging (LiDAR) observations of vineyard posts to estimate rover position within vineyard inter-row corridors. In the present work, an Extended Kalman Filter (EKF)-based state estimation framework was introduced to combine LiDAR observations with vehicle motion information and improve lateral position estimation. This paper presents the first quantitative validation of the EKF-based lateral position estimation in the GNSS-free vineyard navigation framework. Experiments were carried out in a vineyard with absent canopy using an autonomous electric rover equipped with a LiDAR and a Real-Time Kinematic (RTK) receiver. EKF-estimated lateral distances were compared with RTK-derived reference measurements. The proposed framework achieved an average Root Mean Square Error (RMSE) of 0.021 m, a Mean Absolute Error (MAE) of 0.016 m, a bias of −0.001 m, and a maximum absolute error of 0.074 m. Compared with the direct LiDAR-derived geometric measurement, the EKF reduced estimation errors while maintaining centimetric level positioning accuracy. The results show that the EKF-based state estimation is effective for GNSS-free autonomous navigation in structured agricultural environments.

Keywords: EKF; GNSS-free navigation; LiDAR; RTK; Inter-row navigation; Agricultural robotics; Autonomous navigation.

A hybrid AI-FEM model for predicting flow instability of Dead Sea salt in vibrating conveyors

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Abstract. In this paper, we present a hybrid computational framework combining the Finite Element Method (FEM) with advanced machine learning (ML) algorithms for real-time prediction of hygroscopic salt flow instability. The novelty lies in using **Discrete Element Method (DEM)** simulations solely as a high-fidelity data generator, whose results train a Long Short-Term Memory (LSTM) neural network. This trained LSTM then acts as a constitutive material model within the FEM solver, replacing classical continuum models that fail to capture cohesive transitions. The model accounts for stress history, humidity changes (DRH at 33% for $MgCl_2$ phases), and the evolution of the salt-steel friction coefficient (μ_s in the range of 0.35–0.85). Validation was performed on a laboratory test bench equipped with a vibration tray capable of adjusting frequency (10–50 Hz) and amplitude (0.5–5.0 mm) under controlled climatic conditions (RH 30–70%). The results obtained indicate a 42% reduction in the frequency of flow interruptions and a 28% increase in transport speed compared to conventional control. The developed model enables adaptive tuning of the conveyor's operating parameters, which translates into an increase in packaging speed in packaging machines equipped with vibrating feeders by up to 35% while maintaining process stability.

Keywords: vibratory transport, hygroscopic salt, finite element method, machine learning, LSTM, DEM, instability prediction, packaging.

Calibration and testing of a handheld NIR spectrometer for soil moisture monitoring in tomato plants grown under different LED lighting conditions

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Abstract. Precision agriculture requires large amounts of quantitative soil data with high spatial and temporal resolution collected directly in the field to generate accurate soil property maps and define site-specific management zones. In the last decade, Near Infrared (NIR) reflectance spectroscopy has emerged as a promising method for quantitative soil analysis, offering several advantages compared to conventional analytical methods. However, until recently, NIR spectrometers were expensive and bulky, limiting their use to laboratory setting. Thanks to recent technological advances, accurate and low-cost portable NIR spectrometers are now available on the market. This study reports the calibration of the handheld NIR-S-R12 spectrometer (InnoSpectra Corporation, Hsinchu City, Taiwan) and its test on soil samples collected by tomato plants grown under three different LED lighting treatments. The aim of this study was to evaluate the linearity of the sensor and understand if the employed device can discriminate the influence of the different growing conditions on soil moisture. The calibration of the sensor was performed starting from a dried soil sample, by progressively adding 1 ml of water up to 10 ml. The spectra acquired from soil samples collected under the three different growing conditions were compared with the reference calibration curve, to estimate their moisture level. The results show that the handheld NIR spectrometer was able to successfully discriminate soil samples exposed to the three different LED treatment.

Keywords: handheld NIR spectrometer; NIR spectroscopy; soil moisture monitoring; LED lighting.

Investigating the potential of hyperspectral proximal sensing and multivariate analysis for assessing bean (Phaseolus vulgaris L.) response to water stress

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Abstract. This study evaluates a proximal hyperspectral sensor-based methodology for the non-destructive and early detection of common bean (*Phaseolus vulgaris* L.) water status, thereby potentially supporting irrigation management. The objectives are to assess bean crop response to water stress and explore the informative potential of hyperspectral data for water stress detection.
The field experiment was conducted in Valenzano (Southern Italy), where bean crop was grown under three irrigation treatments – full irrigation (FI), 50% deficit irrigation (DI) and rainfed (RF) – arranged in a completely randomized design with six replicates. Chlorophyll Content Index (CCI), Leaf Area Index (LAI), Aboveground Biomass (AGB) and Relative Water Content (RWC) were measured at 33, 54 and 63 days after sowing (DAS). A hand-held hyperspectral spectroradiometer (325–1075 nm) was used to acquire bean canopy spectral signatures and then selected structural, water band and chlorophyll and light use efficiency vegetation indices were computed. All the variables were analysed using one-way analysis of variance and correlation matrices. Moreover, Principal Component Analysis (PCA) was applied to hyperspectral data.
Bean proved to be a drought-sensitive species, with biometric and eco-physiological variables significantly affected by irrigation treatments from 33 DAS; these effects were reflected in yield losses at waxy and full maturity. Except for CIgreen, CIrededge, TCARI and MCARI, all VIs were significantly influenced by water stress at pods filling (54 DAS) and maturation (63 DAS) stages. The strongest correlations were observed between RVSI and EVI and both CCI (r=-0.74; r=0.73) and RWC (r=-0.75, r=0.76). The first two PCs explained 96.73% of the total variance, with the 640–690 nm wavelengths range exhibiting the strongest contribution to spectral variability and suggesting its high sensitivity for characterizing bean water status.

Keywords: irrigation; spectral signature, narrow-band vegetation indices.

The Izydor autonomous sprayer for row crop protection

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Abstract. Precision agriculture aims to reduce human labor demands, compensate for labor shortages, and improve the quality of agricultural products. In the Lublin region, the "Fruit 4.0" operational group secured funding to construct an autonomous self-propelled platform called Izydor, equipped with a vision module and a spraying module.

This paper presents the main design assumptions for an autonomous self-propelled platform with a built-in sprayer for row crops. The Izydor sprayer is an AGV (Automated Guided Vehicle) robot equipped with a line-following system, enabling navigation along a designated route. This route is pre-defined by the operator and can be encoded as lines on the surface or as virtual markers on a digital map. Using optical sensors, the robot continuously analyzes its position relative to the designated route and automatically corrects its trajectory, ensuring precise movement throughout the plantation. The robot was designed to support various agrotechnical tasks, such as monitoring crops, diagnosing plant health, and performing precise chemical spraying. As a result of its autonomous operation, the robot can perform selective spraying, applying plant protection products only in areas where pests or diseases have been detected.

The vehicle is characterized by a high degree of modularity, meaning that its individual components have been designed to function independently as separate products.

The aim of this study was to evaluate the use of the autonomous Izydor platform for spraying blackcurrant crops. Laboratory tests were conducted to determine the uniformity of liquid distribution delivered by the platform's spray module. The module consisted of a set of nozzles mounted on a spray frame operating adjacent to the airflow generated by the fan. The experiments were performed on a vertical grooved patternator table to assess the uniformity of liquid application by orchard sprayers. Next, the droplet size produced by the platform's spray systems was measured. Droplet size measurements were performed using a HELOS laser diffraction analyzer. The quality of spray deposition was assessed using water-sensitive paper.

Keywords: Autonomous sprayer; Automated guided vehicle; Precision agriculture; Row crops; Spraying; Droplet size; Spray uniformity.

Agricultural Quadruped Robots: A Brief Overview

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Abstract. Technological advancements play a crucial role in the rapid evolution of precision agriculture, improving productivity, sustainability, and efficiency. Among the most innovative technologies there are autonomous and remotely piloted robots, which can be applied in numerous agricultural applications. The most forefront type of robots which are starting to introduce in the agricultural sector are quadruped robots. They are emerging as a promising alternative, offering superior mobility and adaptability to harsh environments as agricultural scenarios. These agile and versatile machines equipped with several sensors can assist farmers in various farming tasks. This paper gives an overview of the use of quadruped robots in agricultural applications, highlighting the advantages and limitations of this technology, and providing some insights about future developments.

Keywords: agricultural quadruped robots, quadruped robots, legged robots, robotics, precision agriculture.

UAV- W@llHerbe: a Decision Support System for grassland management in Wallonia

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Abstract. In Wallonia (BE), grasslands cover 367 200 ha and represent the dominant land cover class (47% of Utilized Agricultural Area). The rising frequency and intensity of extreme weather events, including droughts and floods, are ex-pected to substantially alter grassland growth dynamics, thereby increasing un-certainty in livestock and forage management.

To address these challenges, the W@llHerbe decision-support tool provides a dynamic and interactive framework for pasture-based livestock management. The tool is designed to facilitate close collaboration between farmers and advisors, supporting the co-construction of adaptive management strategies tai-lored to local pedoclimatic and management conditions. W@llHerbe is based on a multi-source data integration approach that couples the ModVege grass growth model with spatially explicit information derived from satellite imagery from the European Copernicus programme (Sentinel-1 and Sentinel-2). This model–data fusion enables the generation of robust, field-scale, daily estimates of grass biomass availability. The calibration and validation of both the growth model and the remote sensing algo-rithms rely on a comprehensive set of input data, including meteorological variables (Agromet.be), soil physical properties, floristic composition of grasslands, management practices (grazing and cutting regimes), and in situ reference measurements. W@llHerbe is fully integrated into the WALLeSmart platform, providing seamless ac-cess to multiple agro-nomic and administrative databases, through farmer consent management. This integration enhances interoperability and significantly reduces the administra-tive and technical burden for farmers, thereby improving the operational ap-plicability of the tool.

Keywords: grassland monitoring, remote sensing, decision support tool, grass growth model.

The performance comparison of artificial intelligence algorithms with hyperspectral data to diagnosis of soybean infection intensity with charcoal rot disease

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Abstract. Artificial intelligence algorithms represent a promising approach for enhancing the efficiency of plant disease diagnosis. Accurate estimation of infection intensity is critical for informed decision-making regarding disease management strategies. In this study, we systematically evaluated the performance of several AI algorithms – including Artificial Neural Network (ANN), K-Nearest Neighbors (KNN), Logistic Regression (LR), Random Forest (RF), and Support Vector Machine (SVM) – for classifying soybean seedlings according to the duration of infection with charcoal rot disease. Hyperspectral reflectance data within the spectral range of 900–2350 nm served as input features for model development. The performance of each algorithm was assessed using key evaluation metrics, including precision, recall, F1-score, and overall accuracy. The findings indicate that ANN, LR, and SVM algorithms achieved the highest accuracies of 0.96, 0.98, and 0.98, respectively. In contrast, the RF and KNN algorithms exhibited comparatively lower accuracies of 0.64 and 0.56. These results underscore the potential of integrating hyperspectral data with suitably selected AI algorithms to effectively classify crops based on infection intensity, offering valuable insights for precision agriculture applications.

Keywords: Pesticide application, Machine learning algorithms, Hyperspectral spectroscopy, *Macrophomina phaseolina*, Pest detection.

UAV-Based Multispectral Monitoring for Crop Yield Estimation in Experimental Plots under Different Irrigation and Fertilization Treatments

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Abstract. Estimation of crop yield is a fundamental component of precision agriculture and sustainable farm management. This study presents an experimental approach for evaluating crop performance in a field trial subdivided into multiple plots characterized by different irrigation and fertilization treatments. Data acquisition was conducted using an unmanned aerial vehicle (UAV) equipped with a multispectral camera capable of capturing spectral bands suitable for the computation of vegetation indices. Multispectral imagery was collected and processed to generate vegetation indices used to obtain insight into crop development and spatial variability within the experimental area. The derived indices were analyzed in relation to the different agronomic treatments to investigate their effectiveness in predicting crop growth and potential yield differences among plots. The results point to the potential of UAV-based multispectral monitoring as a rapid and non-destructive tool for supporting agronomic decision-making, optimizing irrigation and fertilization strategies, and improving the accuracy of yield estimation in experimental and operational agricultural systems. The integration of remote sensing techniques with field experiments provides valuable insights into crop response to management practices and contributes to the development of data-driven precision agriculture approaches.

Keywords: Precision agriculture; UAV; Multispectral imaging; Vegetation indices; Crop yield estimation; Irrigation management; Fertilization management; Field experimentation; Machine Learning.

Design of a Robot for Gentle Fruit Picking

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Abstract. The increasing demand for automation in agriculture, driven by labor shortages and the need for higher efficiency and product quality, has motivated the development of robotic solutions for selective harvesting. This work presents the complete design of a mobile robotic system for tomato harvesting, focusing on the integration of commercially available, off-the-shelf components rather than highly customized hardware. The proposed system combines a mobile platform, the Clearpath Husky A200, with a collaborative manipulator, the Universal Robots UR10e. The robotic arm is equipped with an OnRobot soft gripper and an eye-in-hand Intel RealSense D405 RGB-D camera. For row navigation and mapping, the mobile manipulator is equipped with a Hokuyo UTM-30LX-EW and a Velodyne VLP-16 LiDAR. The main contribution of the software design lies in the fruit-picking process. Motion planning, arm control, and 3D reconstruction of the surroundings for collision avoidance are implemented within a ROS 2 framework. Tomatoes are detected using a Faster R-CNN deep learning model. Grasping is not performed solely by enclosing the tomato within the gripper's silicone cup. Instead, gravity is leveraged to guide the tomato into the soft gripper and ensure a secure grasp. Fruit detachment is achieved through a pulling motion, compensating for the absence of an integrated cutting tool. Proprioceptive feedback and force–torque sensing are exploited to assess grasp success and monitor detachment forces. The presented system demonstrates that reliable single-fruit harvesting can be achieved using standard robotic components, providing a practical and reproducible platform for future research on autonomous agricultural manipulation.

Keywords: Fruit picking robot, automatic harvesting.

Consumers' Perception of the Circular Economy – An Analysis of Survey Research Results

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Abstract. The article discusses consumers' perceptions of the circular economy based on a literature review and the results of a survey study. The theoretical part presents the concept of the circular economy, its main assumptions, and the role of consumers in implementing sustainable consumption patterns. The empirical part focuses on the analysis of survey results concerning the level of consumer awareness, attitudes, and behaviors related to circular economy practices. The findings indicate that although consumers increasingly recognize the importance of environmental protection and sustainable development, their knowledge and practical engagement in circular economy activities remain limited. The article highlights the need for further educational and promotional activities aimed at increasing public awareness and encouraging more sustainable consumer behavior.

Keywords: Gospodarka obiegu zamkniętego, circular economy, postrzeganie konsumentów, zachowania konsumenckie, świadomość ekologiczna, zrównoważona konsumpcja.

DSS (decision support systems) and On-line Pest Warning System as a support tool for integrated pest management

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Abstract. Guidelines for integrated pest management (IPM) along with forthcoming changes under the European Green Deal (EGD) require continuous support for agricultural practices in the field of monitoring, forecasting, and signaling (or/and forecasting) the occurrence of pests and diseases. The principles of IPM clearly emphasize the need for systematic field observations to identify current threats posed by diseases and pests. Systematic monitoring combined with the use of appropriate tools—such as simple sticky traps, yellow sticky boards, entomological nets — and their proper interpretation, constitute the basic elements of diagnostics. The next step involves the application of advisory systems within IPM. Decision support systems (DSS) consist of integrated datasets and guidelines (including, among others, climatic data, cultivar characteristics, and results of field observations) that ultimately aim to indicate to the farmer whether and when a chemical treatment should be applied.

This paper presents issues related to the usefulness of DSS in IPM and the possibilities for transferring scientific research findings directly into agricultural practice. The integration of DSS, pest monitoring, and signaling systems are essential elements in the decision-making process concerning the necessity of chemical control measures.

Keywords: Decision support systems; Online Pest Warning System; Integrated Control**.**

Topic 07

Labour organization and ergonomics

Increasing the resilience to cybersecurity threats of the University of Agriculture in Krakow through the implementation of the SOCCER project

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Abstract. The progressive digitization of higher education causes an increase in the exposure of universities to cybersecurity threats, including phishing, ransomware, identity theft, abuse of privileges and disruptions in the continuity of IT services. Universities are particularly vulnerable due to the open nature of the academic environment, the large number of users, the heterogeneous IT infrastructure and the need to protect scientific, administrative and personal data at the same time. To increase security, the University of Agriculture in Krakow, together with nine universities from five countries in the CEE region, is implementing the SOCCER project (Developing and Deploying SOC Capabilities for the Academic Sector – a Teamwork of Universities and RTOs in the CEE Region). The article presents actions taken at the University of Agriculture in Krakow to increase the university's cyber resilience.

Keywords: cybersecurity, SOC, e-learning, university security.

Impact of Industrial Automation and Data-Driven Management on Operational and Economic Efficiency in a Manufacturing Enterprise Supporting the Machinery Sector

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Abstract. Objectives: The aim of the study is to evaluate the impact of industrial automation and data-driven management on operational efficiency, process quality, and economic performance in a small or medium-sized manufacturing enterprise. The analysis focuses on areas that are relevant to the technical and organizational development of the machinery sector, including companies operating within supply chains linked to agriculture and sustainable production. Particular attention is given to the identification of process bottlenecks, the assessment of automation outcomes, and the economic justification of the investment.
Methods: The study was conducted as a case study of the Polish manufacturing company ZMG. The research framework combined an initial process-state assessment, multi-criteria decision analysis (MCDA) to select priority areas for automation, the Theory of Constraints (TOC) to identify and eliminate bottlenecks, and a performance-based evaluation using key indicators such as OEE and FPY. Two critical process areas were examined: welding and CNC machine tending. The analysis compared process parameters before and after the implementation of robotic workstations and a MES/SCADA system. The economic dimension of the investment was assessed using ROI and payback period indicators.
Results: The findings show a significant improvement in operational performance following the implementation of automation. The average welding cycle time was reduced from 80 to 45 minutes, representing a 44% decrease. OEE in CNC workstations increased from below 50% to over 85%, while the throughput of the welding cell rose from 5 to 11 units per shift. Process quality also improved substantially: FPY increased from approximately 95% to over 99.5%, and the lead time for the selected product was reduced by 51%. The economic analysis confirmed the viability of the investment, indicating an ROI of 13.45% and a payback period of 7.44 years. The results demonstrate that automation supported by real-time data analysis can be an effective tool for improving productivity, quality, and cost efficiency in enterprises developing a modern production base consistent with the principles of sustainable development.

Keywords: industrial automation, data-driven management, SME, operational efficiency, engineering economics.

Application of the 5S method to improve work ergonomics at an agricultural machinery repair workstation

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Abstract. The aim of the study was to analyze the possibility of applying the 5S method to improve work ergonomics at an agricultural machinery repair workstation. The study focused on identifying organizational and ergonomic deficiencies affecting work efficiency. The research was conducted at a workstation responsible for the maintenance of drivetrain components of agricultural tractors, including gearbox and differential mechanisms. The methodology included direct observation, analysis of task execution time, and the use of a structured checklist based on 5S principles and ergonomic criteria. The analysis focused on workplace organization, tool accessibility, and the occurrence of unnecessary movements during task execution. Particular attention was paid to the share of auxiliary activities in the total working time. The results revealed several deficiencies in workplace organization, particularly in tool arrangement, excess elements at the workstation, and the occurrence of auxiliary activities such as searching for tools. The analysis showed that a significant part of the working time was consumed by non-productive activities, including unnecessary movements and tool searching. Based on the identified problems, improvement actions consistent with 5S principles were proposed, including tool organization, elimination of unnecessary items, and standardization of workplace layout. The proposed solutions may contribute to improved ergonomics, reduced unnecessary movements, and increased efficiency of repair processes, as well as better organization of the working environment.

Keywords: 5S Method, Work Ergonomics, Workplace Organization, Agricultural Machinery, Machinery Repair.

Topic 10

Sustainable agriculture in the European Union and other countries

Safe2ReUse: A decision-making tool and solution-oriented tool to assess risk from wastewater reuse

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Abstract. Freshwater scarcity is a major challenge across the world but also across European countries and is expected to worsen due to climate change and human activities. Hydric stress poses health problems but also has an important impact on the economy whatever the sector of activity. In response, the EU adopted the Regulation 2020/741 on minimum requirements for the reuse of treated urban wastewater for agricultural irrigation, aquifer recharge but also urban activities. This regulation mandates a risk analysis strategy and the adoption of a consistent risk management. This risk-based approach facilitates the "fit-for-purpose" principle (water quality adapted to final use), the definition of "best practices" and feedback, as well as the active involvement of water managers in implementing water reuse projects. In this context, Wallonia (southern region of Belgium) is implementing strategies to preserve resources, with one of the strategic priorities being the use of alternative water resources. Amongst them, measure 31 (Circular Wallonia strategy) has been introduced to promote wastewater reuse. The decision-support tool developed in this project, Safe2ReUse, facilitates compliance with EU regulations and expands their scope by incorporating additional parameters and applications. Safe2ReUse has been developed to analyse the risks associated with multiple water reuse practices, and to propose measure to mitigate the potential risks for exposed compartments. Available as an online platform, Safe2ReUse enables users, prescribers and project developers to exchange project-related information and assist each stakeholder within the procedure of permits. The risk assessment methodology is based on a semi-quantitative approach combining the probability of an event occurring with its potential impact on human health (workers, by-stander and consumers) and the environment (surface water, groundwater and soil/plants) in relation to the use (urban, agricultural and industrial) and the quality of treated wastewater. Moreover, a total of 90 risky parameters have been implemented, covering several families of pollutants, including microbiological agents, nutrients, heavy metals, pharmaceutical compounds and pesticides. After introduction of both the environmental context of the claimed practices and the quality of the water intended to reuse, the model calculates the risk level and classifies it as negligible, weak, moderate or unacceptable. Safe2ReUse provides a risk level for each relevant parameter and compartment. If the risk is moderate or unacceptable, mitigation measures, such as use of personal protective equipment or additional treatment at wastewater treatment plant are proposed and the risk reassessed.

Keywords: Wastewater reuse, Decision-Support Tool, Risk management/assessment.

Regulatory framework for Exogenous Organic Matter (EOM) recycling: Alignment with soil contaminant threshold values

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Abstract. Exogenous organic matters (EOMs) refer to processed organic materials derived from various sources that can be used in agriculture. While the application of EOM improves soil fertility and supports circular economy objectives, it may also introduce contaminants with the potential to accumulate in soils. To promote organic waste recycling while controlling soil contamination risks, the Fertilising Products Regulation (EU) 2019/1009 was adopted, establishing threshold values for trace metals in fertilisers and including organic products that, once CE-certified, are no longer classified as waste. In Wallonia (Belgium), a scientific study was commissioned to revise decision-making guidelines for EOM application on soils, regardless of their legal status, ensuring consistency with soil contaminant threshold values defined in the Walloon Soil Decree. The proposed methodology derives acceptable contaminant flow rates from soil threshold values, defined as a permissible increase equivalent to 20% of the soil threshold over a 100-year period under a net accumulation assumption. Based on this framework, three EOM quality classes were defined using maximum application rates of 2, 4 and 6 $t_{DM} \cdot ha^{-1} \cdot yr^{-1}$ to ensure compliance with soil protection objectives. Contaminant limit values for EOMs were compared with those set in Regulation (EU) 2019/1009 to assess practical applicability. While suitable for most trace metals, the approach is limited for copper and zinc due to the net accumulation assumption and their role as essential micronutrients. This limitation could be addressed by integrating contaminant-specific fate processes such as crop uptake. The framework is transferable to any region or country with defined soil contaminant thresholds and can support regulatory assessments using local EOM composition data.

Keywords: Organic fertilisation; trace metals; soil contamination; digestate; compost; sewage sludge; soil quality thresholds; EU Fertilising Products Regulation 2019/1009.

Epoxidized Oils as Bio-Based Functional Materials for Agricultural Technologies

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Abstract. The increasing demand for sustainable agricultural technologies has intensified the search for environmentally friendly materials that can reduce the dependence on petroleum-based products used in farm machinery and related processes. Epoxidized oils, derived primarily from renewable vegetable oil resources, represent a promising class of bio-based functional materials due to their favorable physicochemical properties, biodegradability, and low environmental impact.

This paper presents a literature-based analysis of epoxidized oils with a focus on their functional potential for applications in agricultural technologies. Key properties relevant to agricultural machinery operation, including lubricity, oxidative stability, compatibility with metallic and polymeric components, and resistance to mechanical and thermal loads, are discussed based on current scientific reports. Particular attention is given to the role of epoxidized oils as base fluids or additives in lubricants, hydraulic fluids, and protective formulations used in agricultural machinery operating under variable and demanding field conditions.

In addition, environmental and sustainability aspects of epoxidized oils are analyzed, highlighting their contribution to reducing greenhouse gas emissions, improving biodegradability, and supporting circular economy strategies in agriculture. The paper also identifies current limitations and technical challenges related to the large-scale implementation of epoxidized oils in agricultural technologies, such as cost, long-term stability, and standardization requirements.

The presented analysis indicates that epoxidized oils have significant potential as functional bio-based materials for sustainable agricultural technologies. Finally, directions for future research and practical implementation are outlined, emphasizing the need for application-oriented testing in real operating conditions of agricultural machinery.

Keywords: epoxidized oils; bio-based materials, renewable resources, biodegradable lubricants.

The role of agricultural biogas plants in sustainable farm management and circular bioeconomy – a Review

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Abstract. Agricultural biogas plants are increasingly considered an important component of sustainable farm management and circular bioeconomy. Their significance results from the possibility of converting manure, slurry, crop residues and agro-food by-products into biogas, biomethane and digestate through anaerobic digestion. This review discusses the multifunctional role of agricultural biogas plants in farm-level resource management, with particular attention to biomass valorization, renewable energy generation, nutrient recycling, digestate use, greenhouse gas mitigation and rural economic diversification. The paper is based on recent scientific literature and institutional reports published mainly in 2021–2026. The analysis indicates that biogas plants may support the transition from linear waste management towards closed-loop agricultural systems, in which organic residues are transformed into energy carriers and fertilising products. At the same time, their environmental and economic performance depends on substrate selection, process stability, digestate quality, methane emission control and integration with local farming conditions. In light of the reviewed literature, agricultural biogas plants should be regarded not only as energy facilities, but also as agro-energy systems capable of linking farm production, nutrient management and circular use of biological resources. Their future role will depend on the ability to combine technological efficiency with agronomic usefulness, environmental safety and economic viability.

Keywords: Agricultural biogas plants; Anaerobic digestion; Sustainable farm management; Circular bioeconomy; Digestate; Biomethane; Nutrient recycling; Renewable energy; Manure management.

Selection of biogas technologies for available agricultural substrates: technological challenges and process optimization

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Abstract. Agricultural substrates such as slurry, manure, crop residues, and energy crops differ significantly in dry matter content, biodegradability, organic loading potential, and nutrient composition, which directly affects process stability and methane yield. Consequently, the selection of biogas production technology should be based on substrate characteristics rather than on standardised plant configurations.

This study discusses key technological challenges related to substrate-driven process design in agricultural biogas plants. Particular attention is paid to rheological behaviour, mass transfer limitations, sedimentation phenomena, and the formation of surface layers, which influence mixing efficiency and heat distribution within the digester. From a chemical perspective, variations in carbon-to-nitrogen ratio, volatile fatty acid accumulation, and ammonia concentration are identified as critical factors affecting microbial activity and process kinetics. Physical aspects, including substrate particle size, viscosity, and density, are also considered in relation to mechanical handling and energy demand.

The paper outlines criteria for technology selection, including digester type, feeding systems, pre-treatment methods, and mixing strategies, with reference to substrate variability and operational constraints. Emphasis is placed on process optimisation through the alignment of technological solutions with substrate properties, aiming to enhance biogas yield while maintaining stable operating conditions. The findings highlight the need for flexible and substrate-oriented technological approaches in agricultural biogas production to ensure efficient, reliable, and sustainable process performance.

Keywords: agricultural biogas production; substrate availability; technology selection; process optimisation; anaerobic digestion.

Flight dynamics of economically important aphid species collected using a Johnson's suction trap in Poznań (Wielkopolska Voivodeship, Poland) in 2024–2025.

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Abstract. Aphids are among the most economically important pests of cultivated plants, causing significant yield losses both directly through feeding and indirectly as vectors of viral diseases, with indirect damage often being more severe. Their high adaptive capacity, resulting from their small body size and rapid generation turnover, enables dynamic population growth and effective colonization of host plants. Due to their recurring impact on crops, long-term monitoring of aphid migration dynamics is essential for tracking changes in species composition. This study analyzed the species composition, migration timing, and population dynamics of economically important aphid species in the Wielkopolska region in 2024–2025. Monitoring was conducted using a Johnson's suction trap installed at the Institute of Plant Protection – National Research Institute in Poznań (IPP – NRI). The trap operated from early May to the end of October in 2024 and from early April to the end of October in 2025, with daily sampling at a fixed time. Aphids were separated from samples, identified to species level, counted, and preserved in 70% propanol. The analysis covered ten economically important species. The highest abundance was recorded in 2025, with 13,539 individuals. In both years, *Rhopalosiphum padi* and *Anoecia corni* were the dominant species, while the earliest migration in 2025 was recorded for *Aphis fabae*.

Keywords: aphids, flight dynamics, monitoring, Johnson's suction trap.

Precise variable application of solid organic fertilizers

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Abstract. In the agricultural machinery market, a variety of fertilizer spreaders is available, including those designed for organic fertilizers. Some of these spreaders come equipped with diverse sensors that, based on prior field mapping, enable the precise application of the right amount of fertilizer from specific locations within the field. This aplication is tailored to meet the predetermined vegetative requirements of particular field sections. Systems for generating field maps based on vegetative indices have been well-documented, facilitating the evaluation of variability in plant canopy within the field, especially concerning its nutritional needs. This, in turn, allows for the accurate application of the appropriate fertilizer quantities to distinct field sections, ultimately resulting in optimal vegetative growth. Within the agricultural machinery market, there are spreaders available for both liquid synthetic and organic fertilizers. These spreaders, guided by pre-prepared application maps, administer the correct amount of synthetic or natural fertilizer. Given that synthetic fertilizers have a fixed chemical composition or a known macroelement content, there's no need for additional real-time composition verification during machine operation. In contrast, organic fertilizers exhibit composition variability. For liquid manure application using manure spreaders, solutions exist for assessing the manure's composition and adjusting the dosage accordingly. However, the precise application of solid organic fertilizers presents challenges. Due to the variable and not always known composition of solid organic fertilizers, real-time monitoring is necessary while the spreader is in operation. These fertilizers are known for their low measurement accuracy. One significant issue affecting measurement precision in this manner is the density of the manure entering the spreader's loading box. As a result, significant void spaces exist between the "chunks" of fertilizer, making it difficult to periodically take measurements using optical probes that require direct contact with the analyzed material. Consequently, this research project focused on developing a device and method for accurately applying solid organic fertilizers in manure spreaders. The quality of the manure is assessed using a contact probe based on VIS-NIR technology. For this purpose, specialized calibration models were created under simulated operational conditions. An important part of this system is an electro-hydraulically controlled mechanism, the purpose of which is to compact and retain a several-centimetre-thick ‘wall’ layer of fertilizer and press it against the measuring windows of the spectrometer probes for the duration of the measurement. This enables the acquisition of standardised absorbance spectra recorded for fertiliser without interrupting the operation of the floor conveyor on the manure spreader. Tests of the prototype measuring system in conditions similar to the actual operating conditions of the manure spreader indicate the validity of using a mechanism to retain and compact organic fertiliser samples. Its use reduces prediction error (SEP and RMSE) by 25 to nearly 75% for models used to estimate the content of NKP macroelements, expressed in kilograms per metric ton or kilograms per cubic meter for basic solid organic fertilisers.

Keywords: variable rate application, solid manure, manure spreader, spectrometry.

An Integrated Experimental Framework for Agrivoltaic Systems in Mediterranean Sustainable Agriculture

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Abstract. Agrivoltaic systems are being explored as land-sharing infrastructures in which food production, renewable electricity, and ecological functions must be designed together rather than optimized separately. This paper defines the methodological basis of a planned experimental program at a 200 kW agrivoltaic plant in Valenzano, Bari, Southern Italy. The protocol has been developed for Mediterranean conditions, where summer radiation, heat stress, water availability, and the continuity of farm operations are critical design variables. Two single-axis tracking configurations, 1P and 2P, will be assessed against full sun control plots. The study is organized into four coordinated work packages covering agronomic response, machinery and process management, photovoltaic performance, and biodiversity monitoring. Crop trials will involve fruit trees, berries, vegetables, cereals, and legumes; machinery trials will examine tractor and implement operability, UAV-supported monitoring, and robotic platforms; energy analysis, microclimatic measurements, simulation benchmarks, and soiling tests; and biodiversity assessment will combine digital ecological mapping with field sensors. No experimental findings are reported at this stage. The contribution of the paper is a reproducible research design for assessing agrivoltaic systems as integrated agro-energy and agro-ecological infrastructures.

Keywords: Agrivoltaics; Sustainable agriculture; Farm machinery; Process management; Photovoltaic performance; Biodiversity; Mediterranean climate.

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