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Book of Abstracts of the European Conference on Agricultural Engineering AgEng2018

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Preface

This book of abstracts results from the AgEng2018 Agricultural Engineering Conference under auspices of the European Society of Agricultural Engineers, in Wageningen, the Netherlands, from 8-12 July 2018. This book contains all accepted abstracts and they were the base for the oral presentations and posters presented at the conference. We like to thank all participants, sponsors and the scientific committee of the conference for their indispensable contribution to this event. A special word of thanks goes to the municipality of Wageningen for organising a welcome reception as host city, and the many students and colleagues of chair groups and research institutes of Wageningen University & Research that helped in so many ways to make the conference a success.

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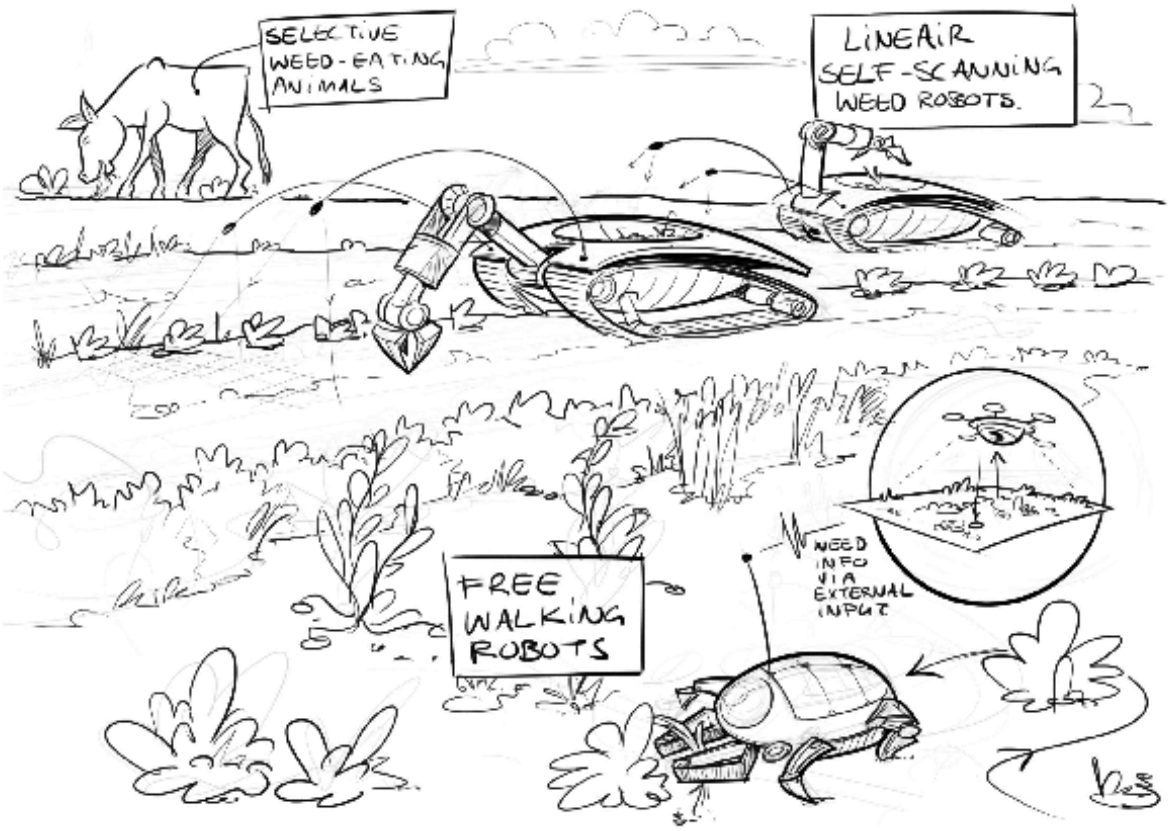
SELECTIVE WEED-EATING ANIMALS
LINEAR SELF-SCANNING WEED ROBOTS.
FREE WALKING ROBOTS
NEED INFO VIA EXTERNAL INPUT

Topic 1: Design Methods for Integrated and Sustainable Farming Systems (FS)

Theoretical concepts and methodological approaches to design novel concepts of farming systems (crops and greenhouses, animals, insects, algae, seaweed etc. and combinations thereof) that improve the performance on multiple aspects of sustainability. Examples are conservation agriculture, integrated pest management, tests and integrated assessment of concepts of farming systems, supply chain and market aspects.

New Farming Systems and Concepts

Towards further refinement of Integrated Pest Management (IPM) strategies: integration of landscape of fear (LOF)

Inge Milou Krijger[1,4], Steven Belmain[2], Grant Singleton[3], Peter Groot Koerkamp[4], Bastiaan Meerburg[5,1]

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Current pest management methods are often reactive and have serious disadvantages such as emerging genetic resistance and might lead to poisoning of non-target species. In the 1970s Integrated Pest Management (IPM) was developed as a result of the book Silent Spring by Rachel Carson, that criticised the reliance on poisons and the associated risks. One of the key aspects of IPM is the refined knowledge of ecology and behaviour of pest species. A tool which could further support the knowledge on the spatiotemporal behaviour of pest animals, is the landscape of fear (LOF). LOF reflects levels of anxiety a prey species perceives at diverse sites within its territory and characterizes the areal variation in scavenging cost as result of predation risk. In practice, LOF envisages habitat use as a result of perceived fear, which enables to predict where traps or bait are most expected to come across and used by pest animals. We focused particularly on the opportunities for better rodent control strategies: if pest controllers focus on those areas where rodents perceive the smallest amount of predation risk, rodent management could become more effective. However, the same mechanism could also be used in the future for other pest species.

Predictive Systems Model Simulating The Development Of Beehives And Honeybee Population (Apis Mellifera) In Professional Apicultures

Jochen Georg Wiecha, Sascha Wörz, Heinz Bernhardt

Technical University of Munich, Germany

Worldwide, beekeepers are fighting against the parasitism through Varroa mites infesting their colonies and start mite reproduction in sealed brood combs. In order to ensure pollination maintaining healthy honeybee colonies is crucial. Long-term predictions for rearing development of a single honeybee colony can be simulated by several software-based models with the purpose to investigate the effects of pesticides on the bee colony or the general biological development of honeybees in their beehive and the surrounding environmental.

Previous published models do not consider the beekeeping practice sufficiently. Ethological factors on beekeeping measures are neglected. Unfortunately, an interaction between the animals and the beekeeper cannot be studied. However, robbery of nectar among bee colonies and reinvasion of the Varroa mites must be attributed to disturbed predator-prey interaction and require the urgent intervention of the beekeeper. These models also do not consider that epigenetic switches adapt to the environmental conditions of honeybees. After swarming, several honeybee glands can develop again. All this is still missing in current prediction models.

In this work a new model for population development of honeybee colonies is presented. While using published probabilities from scholarly literature, the model covers beekeeping measures and involves for the first time the effects “robbery”, “invasion of the Varroa mites”, “age of queens” and “effects of professional breeding”. The apicultural system is fully determined and is the fundamental for the calculations in annual frequency.

With the proposed model beekeepers are able to plan their decisions with regard to a long-term apiculture system and to observe the effects of intensified breeding or beekeeping measures on the honeybee colony. Thus, the introduced model can also be used for decision-making in beekeeping.

A Methodological Framework To Incorporate Animal Capacities In A Structured Design Approach

Ellen Van Weeghel[1,2], Bram Bos[2], Peter Groot Koerkamp[1,2]

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Recent design projects applying Reflexive Interactive Design (RIO) - an interactive and structured design approach to contribute to system innovation –, have shown that the needs of animals can be successfully taken into account within an engineering design approach. Until now, these RIO-projects aimed at fulfilment of animal needs with the animal as a stakeholder, but only occasionally considered the animal as a contributor.

The designed environment of animals can motivate them to engage in activities that are meaningful for the animal itself and at the same time let the animal contribute to system goals, functions and sustainability aspects. Engineering design based on control over nature will not satisfy, as increased levels of control over animals will easily get in conflict with their needs. We elaborated an alternative that thinks in terms of ‘providing the possibilities’ to let animals take care of themselves, and –by doing this- contribute to system goals at the same time.

We present the groundwork, and an example for pigs, of a systematic design approach that provides a methodological framework to incorporate animal capacities in design: the Brief of Capacities (BoC). The BoC is a design tool that provides an overview of animal capacities of a specific animal species, ordered into categories and provides the additional information necessary to

understand and deploy these capacities in design. The BoC enables engineers to enlarge the (technical) solution space and to consider the biological domain in a structured manner as well as it is a tool to trigger the mind.

The results show that an overview of capacities can represent the biological system in an engineering context and make biological information accessible to designers. However, successful application of the approach and the technical BoC depends on an attitude shift towards 'providing agency' instead of 'taking care of' or 'controlling' animals.

Industrialization and Agricultural Mechanization in Africa

Lawrence Gumbe

Technical University of Kenya, Kenya

This paper reviews and recommends on the way forward on the policies on industrialization and agricultural mechanisation in Africa. The mutual reinforcing relationship between industry and agriculture can be harnessed so that the simultaneous development of both sectors can form the foundation for industrialization in Africa.

The mechanisation of agriculture requires the application of biochemical and mechanical inputs from industry. These inputs include water pumps, tractors, harvestors, crop driers, silos, computers, fertilizer, herbicides and pesticides. The output from agriculture can also be used in industry including: Cotton lint for production of clothes; cotton seeds for production of cooking oil; maize seed for production of flour, cooking oil and starch; sorghum for production of beer; meat products for production of sausage; milk for production of cheese and butter; and many other products in industry.

It is important that a carefully thought out policy framework be instituted so that the mutually reinforcing relationship between agriculture and industry is harnessed so as to simultaneously develop both sectors and the African economy in general.

Assessment of the Vegetation Parameters of Almond and Vine Plants for Designing a Compact Tractor

Pietro Catania, Antonio Comparetti, Pierluigi Febo, Giuseppe Morello, Santo Orlando, Mariangela Vallone

University of Palermo, Italy

The first step of this study was a survey on the use of safety equipment of tractors, aimed at identifying their critical issues causing accidents to the drivers of machines during field operations. The results show that tractor overturning is the main factor of the accidents and often death of the driver. Overturning is caused by several factors and the seriousness of its consequences is often due to the lack or non-use of Rolling Over Protective Structure (ROPS) or Falling Object Protective Structures (FOPS), together with safety belts. A protective structure, together with a regularly fastened safety belt, holds and protects the driver from the risk of crushing in case of overturning.

Fruit tree and vine farms are the most exposed ones to the above risk. In fact, compact tractors equipped with a roll-bar having two pillars, that can be lowered for facilitating the passage of the machine under the tree foliage, are generally used in the above farms. Unfortunately, after being lowered, the roll-bar is not often positioned again normally to the field plane and, therefore, its purpose of protecting the driver is nullified.

The aim of this research is to assess the vegetation parameters of almond and vine plants, aimed at designing a compact tractor suitable for these orchards. The research is part of the Italian project TRACLAS, involving the Universities of Palermo, Milan, Bari, "Tuscia" of Viterbo and Agricultural Research and Economics - Research Unit for Agricultural Engineering (CREA-ING) of Treviglio (Bergamo). Based on the results of the surveys carried out in a sample of almond and vine farms, it was possible to define the vegetation parameters that will allow to design a very low and narrow tractor equipped with a fixed ROPS and suitable for these orchards.

New Farming Concepts in Arable Farming

Sustainable Sensor-based Tillage

Ole Green[1,2], Frederik Foldager[1,3], Alevtina Evgrafova[1], Kirkegaard-Nielsen Søren[1,2], Dalgaard Tommy[1], Munkholm Lars Juhl[1]

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Sustainable intensification provides an attractive solution to the global challenges of the increasing world population and demand for food. The primary goal of sustainable intensification is a resource efficient agricultural sector combined with reduced environmental impact. Intensification of agricultural production (fertilizers, pesticides and heavy machinery) may increase soil degradation and thereby gradually decreasing the area suitable for agricultural production.

The implementation of sustainable intensification in practice farming may be obtained by applying an automation approach where sensors and control systems are utilized for adjusting site-specific tillage intensity, in order to minimize the risk of soil erosion (by tillage, water and wind) and compaction.

The concept of site-specific tillage utilizes the ideas known for many years in precision farming. Now, site-specific tillage intensity control is enabled by on-board sensors, as well as information gained before tillage, e.g. utilizing traffic registration from an auto-steering system for optimized primary tillage intensity for ploughing.

The work presented demonstrates how the research and development of modern farming equipment within soil tillage operations can be achieved with benefits in terms of yield and profit as well as reducing the environmental impact. New farming systems and practices developed specifically for tackling sustainability problems, including soil degradation, are not only theoretical and political goals but are getting operational and profitable for farmers and the society.

Smaragd – development of an innovative farming system in the Netherlands

Jan Kamp, Herman Schoorlemmer

Wageningen University & Research, The Netherlands

SMARAGD's ambition is to design a new agricultural concept for the cultivation of highly-validating arable and outdoor vegetable crops in which heavy large-scale mechanization is replaced by light, autonomous, innovative technologies. The increasing scale

of Dutch arable farming goes hand in hand with a high intensity of land use. The bigger and heavier mechanization is having strong negative side effects: about 50% of Dutch soils is suffering from declining soil quality and biodiversity, soil compaction and reduced yields. The growing interest in mixed cropping systems helps to stimulate partners in the project to work together.

Technological developments offer opportunities for developing high tech and small-scale solutions that save the soil and labor inputs. These solutions will include the use of autonomous (small-scale and light vehicles combined with sensing techniques in a controlled traffic farming system (CTF).

This research project consists of a modeling phase, to optimize the dimensions of the CTF system (bed with and length), based on technological options and economic preconditions. For the optimization of weed control vision technology combined with deep learning technology helps the farmer to recognize weed type and intensity and will be translated into a real time or task map based type of weed control. A special focal point of the project is the modeling of harvest – field transport. In the project we are developing a low tech (based on current technology) and a high tech option that minimizes the soil pressure. To be able to plow in a CTF system without mixed soil from the driving lanes in to the seedbed, a special eco plow is under construction that solves these problems.

In the presentation, the state-of-the-art of the project and its technological solutions will be discussed, as well as the future challenges we face.

Explaining the Reflexive Interactive Design (RIO) Method using Intercropping as an Example

Marjolein Derks[1], Peter Groot Koerkamp[1], Bram Bos[2]

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The aim of this work is to present a novel method of system innovations design, using intercropping as an example. With growing world populations, we need to find new ways to produce food in a sustainable way. This asks for system innovations: changes in the structure of the system as we know it. Currently, breakthroughs are often prohibited by conflicting interests: economics versus animal welfare, intensification versus biodiversity, etc. However, the nature of these conflicts may be caused by the way the system is historically shaped, and they can possibly be overcome by allowing another view on the system.

RIO is a method that aims to redesign systems, based on key functions in the system. It combines knowledge from system analysis, structured design, stakeholder management and transition management, and uses interactive and collaborative learning to (re)design novel food production systems, starting from a heterogeneous set of values and goals. It consists of three modules: 1) thinking, where the values and goals for the system are set together with the relevant stakeholders; 2) designing, where the key functions that the system should perform are analyzed and used to construct a new design that meets the goals from step one; and 3) acting, where the new design is anchored in a practical setting, together with the stakeholders involved.

RIO has previously been applied to livestock systems, and has led to novel designs like Windstreek (broiler production) and Roundel (poultry production). However, it can also be applied to arable farming systems. Intercropping, where several crops are mixed to increase biodiversity and improve soil quality (without the use of artificial fertilizers), will be used here as an example to show that RIO can really lead to novel systems that can readily be implemented in current food production systems.

Challenges for Future Livestock Systems

A Model to Assess Environmental Efficiency of Pig Production Systems

Luis Lassaletta[1,2], Fernando Estellés[3], Arthur Beusen[2], Lex Bowman[2], Salvador Calvet[3], Hans van Grinsven[2], Jonathan Doelman[2], Elke Stehfest[2], Aimable Uwizeye[4], Henk Westhoeck[2]

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In this work we developed a model to assess the environmental efficiency of pig production systems. Based on pork demand, production performance and dietary composition, the model predicts the global feed and land demand, nitrogen excretion and nitrogen use efficiency (NUE) for pig production systems. We considered 26 regions around the world (based on IMAGE global modelling framework). For each region, productive characteristics and dietary compositions were defined from 1970 to 2050 under different scenarios. Scenarios were built following the storylines of the Shared Socio-economic Pathways. Our model outcomes suggest that pig production systems will play a significant role in the global agro-food system in 2050 including protein supply, land demand and N fertilization. The sustainability of future pig production systems will strongly depend on the livestock production performances and feed rations. The model suggests that limits for system efficiency will be reached in some regions. The replacement of part of the soybeans by swill and industrial by-products in the feed ration of pigs is a promising solution to increase NUE as well as to reduce the land demand associated with pork production.

Monitoring Framework for the Assessment of the Integral Sustainability of Livestock Production

Abraham Bos[1], Daniel Puente Rodríguez[1], Peter Groot Koerkamp[1,2]

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Agricultural engineering has an important role in making food production more sustainable. Increasingly, this means improving on a range of diverse parameters, ranging from ghg-emissions, land use, to animal welfare and public health, while mitigating or overcoming trade-offs. Quantification of the current and expected performance on these diverse parameters is critical. Yet, an overarching framework is lacking as well as shared criteria for what could be seen as 'sustainable' levels.

In 2013 a governance network of stakeholders in and around the Dutch livestock sector (the 'UDV') formulated and endorsed 15 ambitions for integrally sustainable animal production, making the UN SDG's concrete for the Dutch context. We used these 15 ambitions as a starting point to develop a monitoring framework, that can be used to assess different livestock production systems on their performance on these ambitions. After identifying a small set of representative indicators per ambition, we defined a scale per indicator based on the desired performance as expressed in the qualitative ambition, and a minimum based on either

a theoretical or an historical worst case. Indicators were normalized and averaged per ambition. This setup not only enables a relative assessment across different production systems, but also enables to see the gap between desired state and current state.

The framework will be presented, as well as its application on the largest animal production sectors in the Netherlands, and on a few chain initiatives oriented at more sustainable production. The framework and results enable the debate on the inherent normative choices and different stakes regarding sustainability, the identification of trade-offs and relations between sustainability-parameters as well as future challenges.

Interactive System Analysis Of Livestock Production In The Galápagos Islands: Co-designing Through Knowledge-Practice Interfaces

Daniel Puente Rodríguez[1], **Bram Bos**[1], **Peter Groot Koerkamp**[1,2]

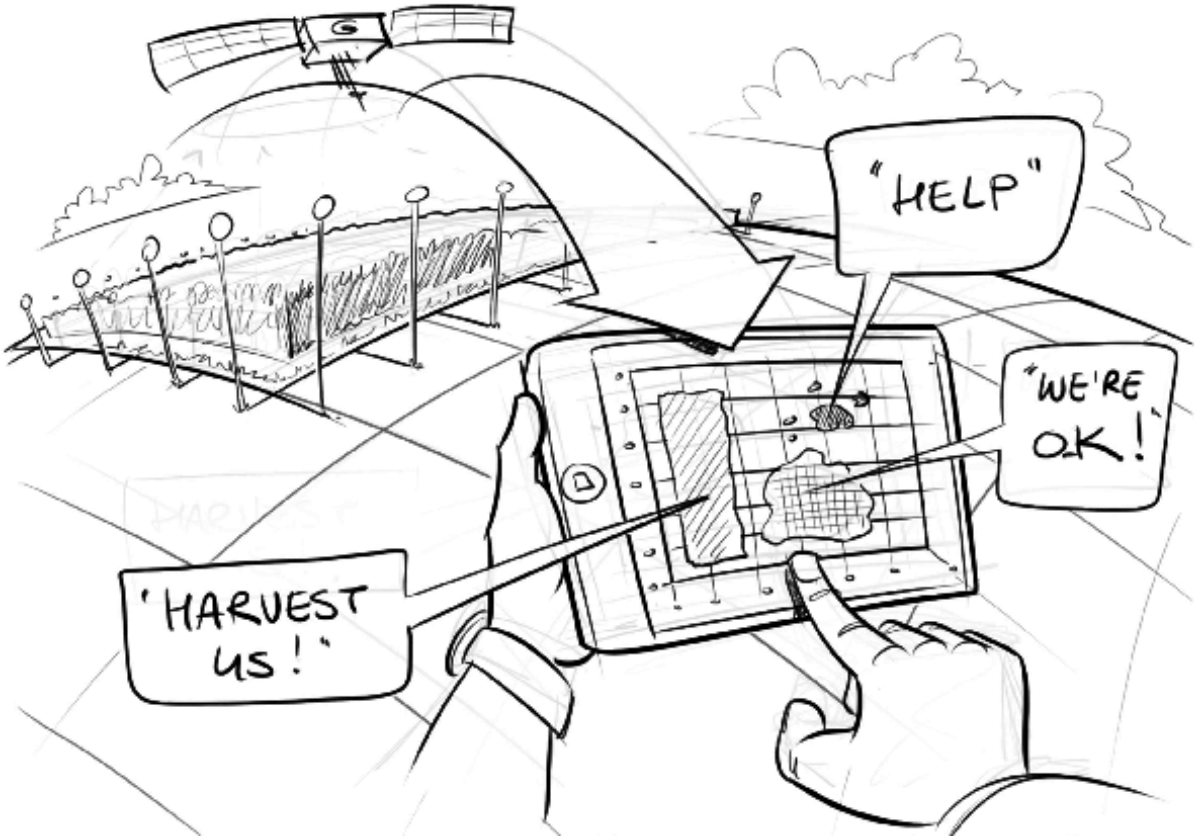
[1]Wageningen Livestock Research, Netherlands, The; [2]Farm Technology Group, Wageningen University & Research, The Netherlands

The Galápagos Islands are well-known because of their ecosystems and wildlife, however less attention has been given to the livestock production-systems that (partially) sustain local food chains. Industrialized livestock production-systems co-exist with small-scale traditional ways of animal husbandry. In this context, various stakeholders perceive the current situation (e.g. invasive species, introduction of pathogens, nutrient losses) in different and, sometimes, even contradictory ways, and have different long-term goals.

There are many challenges ahead for designing livestock production systems along socioecological sustainability lines. Here, we introduce an initiative to redesign the livestock (i.e., pigs and poultry) production systems on the Galápagos Islands (i.e., on Santa Cruz Island). Moreover, the analysis is based on the concept of knowledge-practice interfaces. The design process is organized through the reflexive interactive (re)design approach.

This paper focuses on the first phase of this redesign process that we have recently concluded, i.e., the interactive system analysis. We address the experienced problems, contradictions and shared long-term goals of stakeholders concerning local livestock production in Santa Cruz, Galápagos. Moreover, we present specific redesigning strategies that enable change towards socio-ecological sustainability. Among these strategies we find, for instance, the restoration of rural land. Within this strategy livestock plays a key role to control invasive species and to revalorize abandoned rural areas. Other strategies concern manure management, animal feed production, or the creation of a ‘semi-creole’ production-system with higher biosecurity standards and high efficient food conversion, and similar cultural and culinary aspects of current creole production.

Our paper-approach is relevant to agrarian engineers because it introduces a participatory redesigning practice formed by inclusive, interactive and reflective knowledge arrangements in which different types of knowledge (both formal and informal) and types of actors (including and beyond scientists and policy makers) assume an active role and responsibility regarding biosystem engineering in environmental management.


"HELP"
"WE'RE OK!"
'HARVEST US!'

Topic 2: New Farming Management Systems (FM)

Ideas, designs of concepts and proofs of principle of new farm information and data management systems to enhance sustainability and profitability of farming. Examples are integration of multiple technologies in management and farming systems (big data, data hubs, standards), Internet of Things applications, data-based and model-based decision support.

General

Inspiring Students With An Introduction To Smart Dairy Farming

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Development of the concept of precision livestock farming and precision agriculture was mainly driven by research and development of research institutes and commercial companies. All kind of new sensing systems and decision support systems were developed and introduced in the market. Nevertheless one of the critical points in adoption is the integration in practical farming systems. The question arises then whether farmers are capable of understanding and integrating these concepts in their farming systems, and whether advisors are capable of understanding the pros and cons of smart farming. Education might play a role in this. Since 4 years the author is involved in an organisation where the dairy farmers and advisors of the future are educated. A minor on smart dairy farmer has been developed. However, it appeared after two groups of students that there was very little study material available for students. Therefore a book 'An Introduction to Smart Dairy Farming' has been written to inspire students and give an overview of different aspects that have to be taken care of when they will become involved in the field of smart dairy farming. The combination of using text and visualizations will be explained. The overview is not only interesting for student, but also for others stakeholders involved in smart farming (or precision livestock farming and precision agriculture).

Adoption of Precision Farming by Flemish Farmers

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The focus group of the agricultural European Innovation Partnership (EIP-AGRI, 2015) indicated that the adoption of precision agricultural technologies (PAT) in Europe is lacking behind. More recently, ABN AMRO concluded that "everybody is doing smart farming except the farmers". Although experts seem to agree on the limited uptake, clear recent figures are lacking, at least in Flanders.

Therefore, the objective of this study was to map the use of PAT in Flemish agricultural businesses. In the framework of the Flemish year of agricultural data, questions on the use of PAT's were sent out to participants of the Farm Accountancy Data Network, i.e. a representative for all Flemish agricultural and horticultural companies. 527/655 (80%) useful replies were collected.

57% of the responding farms apply PAT's themselves or through contractor, or will most likely do so within a period of five years. In arable farming, dairy, pig and poultry sectors, this percentage is even higher than 66%. This mainly concerns GPS in crop farming and yield registration in livestock farming. A management information system is often lacking. Half of non-users thinks their farm is too small to invest in PAT. Drivers to adopt PAT's are clear costs/benefits, a substantial price reduction and positive experiences from fellow farmers. More accurate daily management and improved insights into technical results are mentioned as the most important benefits.

Concluding, today the use of PAT's is often limited to rather simple technologies like GPS. Yet, a fast majority of farmers shows great interest. The next step, using the generated data for data-driven management decisions is yet to be taken.

Connectivity of Agricultural Equipment and Applications - Strategical Approaches and Technical Standards

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Connectivity plays an emerging role in farming systems. It includes m2m, m2b and b2b communication in which business applications like farm management tools and also on-machinery applications are increasingly cloud-based.

Connectivity in a habitat of cross-brand machinery fleets and a heterogeneous tool landscape is challenging. After having solved this problem for wire-based machinery communication by defining the ISOBUS, we are now facing the challenge to let data flow between machines in the fields and all kinds of applications. The goal is to allow farmers to freely decide for equipment and applications based on their functionality and quality and not based on their brand while being able to easily connect everything.

One product approach for connectivity is to create an intra-brand habitat like some of the big Ag machinery manufacturers do. Some other players are invited to connect their applications, but there is no discrimination-free access guaranteed. Farmers can only use this connectivity platform with equipment of this brand.

Another approach is to create a platform for applications like some of the farm software companies do. Thus, different machinery brands can be connected using third-party communication devices or data-exchange standards. But on such a platform, only a limited number of applications can be used respectively there is no discrimination-free access for all software companies to connect.

The method to exchange data between different habitats is to create standards like it is done for instance by AEF with the "Extended-FMIS-Data-Exchange" standard (EFDI). But this still works with many point to point connections and requires a lot of test efforts.

A third approach is to create a brand independent connectivity entity like for instance the DKE "Agrirouter". This allows a non-discriminating access for all machines and applications but at the same time requires only one single technical interface which has to be tested.

The Analysis Of Tweets In French Agriculture Using OLAP Systems

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Last years some new technologies, such as blogs, wikis, RSS, social networks, etc., appear for sharing dynamic and personalized information content by means of the Web, enabling the knowledge production. This information can be used for several purposes, such as to understand consumers and their preference, health, etc. In the case of Twitter, users can post short-status messages with up to 140 characters and may include photo attachments, which are called “tweets”. According to Twitter, about 271 million monthly active users are generating an average of 500 million tweets per day. Twitter is more and more used in each application domain, and recently also in agriculture. However, to the best of our knowledge, there is not a study that investigates the usage of twitter in the context of agriculture. Therefore, in this paper we propose an OnLine Analytical Processing (OLAP) system to analyze tweets to answer to the following question: “Who and why people in French use twitter for sharing knowledge about sustainable agriculture?”.

Answering such a question is like collecting tweets, putting them in a form that can be manipulated by the machine, and finally exploring them to build such information. But collecting and preprocessing data from tweets present a real scientific lock. These are of textual type, the techniques to be used for their preparation must be adapted to their complex nature. Analyzing the content of social data from tweets requires approaches that combine different techniques from data mining, information retrieval and more. We used the LDA (Latent Dirichlet Allocation) method to extract topics related to agriculture. We have completed this study by OLAP analysis illustrating the various actors who use Twitter to exchange their information on agriculture. For this, we use 1,825,958 tweets . Analysis shows interesting results concerning the agricultural actors that really use twitter and their reasons.

Internet of Farming

Internet of Things Experiments in IoF2020 Dairy Trial

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The H2020 - IoF2020 project for a large scale pilot for Internet of Things started in 2017. The ambitions of the dairy trial, the way that they will learn from each other and their contribution to the fine tuning of technical IoT challenges, the measurement and monitoring of the business oriented KPI’s and the use of feedback by the involvement of end-users and co-creators will be explained in this paper. The dairy trial aims to implement, experience and demonstrate the use of real-time sensor data from ‘grass to glass’ to create value in the dairy chain. The trial will demonstrate, test and deploy IoT solutions for four user cases (Grazing Cow Monitor, Happy Cow, Silent Herdsman, Remote Milk Quality) that address different aspects of dairy farming and milk processing. The platform 365Farmnet will be used in all use cases to ensure seamless exchange of IoT data and services. The basic idea is that feeding individual cows and taking care of her individual needs can save up to 15% compared to feeding cows as a group. The neck collar sensors, together with the GPS location information, will deliver new insights and proxies for feed intake of grass and roughage. The same sensors will be used to improve oestrus detection, which will contribute to a longer life span of the cows. The feed information and cow behaviours will be used at the same time for early warning on animal health and welfare. Early warning will focus on feed related warnings like ketosis, but also on the issue of lameness and mastitis detection. Milk quality can be measured in different places in the production chain. This quality data will be used for a new concept of remote calibration and validation of sensors.

Internet of Food and Farms: Dairy Use Case 2.3

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The use of Internet of Things based technology to optimise the operational performance of farming practice is fast developing. In the present use case we are demonstrating the performance of SilentHerdsman accelerometer collar that measures neck motion on an animal and translates this into behavioural features that can assist in daily farm management functions. The initial objectives were to optimise herd fertility by alerting farm operatives to the onset of oestrus in cattle. This enables timely insemination so that herd productivity can be maximised. In addition to the above, the collar provides an indication of feeding and rumination time budgets which give an insight into animal welfare. The performance of the collar as a heat detection system is established and, once the system parameters are adjusted to suit the on farm conditions, farm operatives report a strong reliance on the system outputs. Presently we are exploring the interaction between the feeding and rumination signatures and other on farm measurement available through, for example, milking robots and other sensors accessed remotely in order to identify the early onset of illness in a robust manner. Integration of multiple sensor streams offers the potential to calibrate systems against each other thus reducing instances of false positives.

Determining Valuable Variables To Design An Early Warning System For Individual Fattening Pigs, A Pilot Study.

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Internet of Food and Farm 2020 (IOF2020) is a large-scale project funded by the European Union aiming at an accelerated adoption of Internet of Things (IoT) within the European farm and food production. The project consists of 19 use cases, organized into five different trials, including Pig Farm Management. One of the aims of this use case is to create early warning systems for possible health and production problems in individual fattening pigs. A pilot study to test the technical performance of several different sensor systems was recently concluded. Data from 119 fattening pigs (60 boars and 59 gilts) were collected. The barn was divided into 8 pens, with 14-15 pigs of the same sex (either gilts or boars) per pen. The pigs were checked for health problems daily by caretakers and twice a week by a trained observer. Each pen was fitted with a flow meter and a HF RFID-antenna near the drinking nipple. A conventional round feeder, mounted with a HF RFID-antenna was used in 4 of the pens. In the other 4

pens, a Nedap feeding station with weighing scale was used. All pigs had 2 high-frequency (HF) RFID tags, one in each ear. An extra low-frequency RFID tag was added to the right ear for the pigs in the feeding station pens. With these systems, data on feeding and drinking patterns, water consumption and, in half of the pens, feed consumption and body weight was collected on an individual pig basis. Several individual cases that died or with other types of health problems, such as lameness and illness, will be analysed to determine whether the health status of the pig was reflected in the data and if so, which variables are most promising to detect specific health problems. These results will be presented at the conference.

Meat Transparency and Traceability in the IoF2020 Project with EPCIS

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We present the information model we developed for improving transparency and traceability in pig and pork supply chains. Our information model is developed on top of the standard EPCIS traceability data model and aims to enable the capturing and sharing of information related to meat quality, animal welfare, and provenance of meat products. The focus of this work is on the upstream side of the supply chains, i.e. at farms and slaughterhouses. The information model is, however, easily extendable to the downstream side of the supply chains so that the sharing of such information is possible across entire supply chains. By employing the widely adopted EPCIS standard we are able to use EPCIS-compliant software solutions that provide diverse information extraction and processing facilities. In addition, EPCIS-compliance guaranties that the software solutions provide standard interfaces for integration with existing farm and supply chain systems, including farm management, logistics and retailer systems, and eventually with consumer applications. Our engagement with stakeholders demonstrates that, while customers at each stage of the meat supply chain increasingly demand information regarding origin, animal welfare and details about meat processing conditions, the main driving force for transparency seems to be the suppliers' objective in creating more value for their products through brand labels that are supported by trustworthy quality assurance schemes. In this respect, the solution we develop enables the producers of primary products, including farmers, to share information downstream the supply chain and build trust with their end-customers. Such an approach to transparency contributes towards improving consumer confidence in food products, and eventually, the European food market. In this respect, we aim to support the efforts of EU in realizing full traceability from farm to fork in diverse agrifood sectors by collaborating with other pilot studies within the IoF2020 project.

The Outlook of Big Data Application in Agriculture in China

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Big data has been highlighted as a national strategy in more and more developed and developing countries as they realized that big data is a huge "gold mine". Agriculture is the biggest playground for big data. The data ranges from soil, weather, water, seed, fertilizers, and pests etc. which generate volumes of data every day. Agriculture is a vital industry in China, employing over 300 million farmers. Despite rapid development of China's agriculture, it still faces several challenges from expanding population, low productivity, decreased arable land, and increasing labor cost etc. The only way to revolutionize China's agriculture pattern and current challenges it faces should be from technology innovation, especially digital technologies.Big data and the Internet of Things (IoT) platforms will be the key enabler to revolutionize China's agriculture. Firstly, various sensors, smart phones, drones and other IoT devices allow an ability to collect, manage and store an enormous amounts of data across the whole agricultural value chain. Secondly, big data technologies and techniques could be used to better monitor agricultural information at the field level, provincial level and even national level to help decision-making. This paper gave a brief outlook on China's agriculture from the area of crop, livestock, orchard, fishery industry with the application of big data.

Farms, Fogs and Clouds: Data open-architecture for optimal crop growth control for IoF2020 project

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In farming systems much attention is now focused on the introduction of technology in each one of the phases of the crop growth, connecting systems so as to allow an integrated, multidimensional view of farming activities, data sharing and enabling deeper understanding on how the whole ecosystem works. This intensive use of ICT (Information and communications technology) involves a large number of sensors, control loops, models and optimization techniques, forecast, vegetable production, energy costs, etc. In this ecosystem situation, 'fog computing' based control systems arise as a solution to improve system efficiency by reducing the amount of data transported to the cloud for processing, analysis, and storage. We focus on a model-based greenhouse control system using hierarchical architecture. Common fog computing applications include smart grid, smart city,… In our control algorithm structure, the first layer (upper layer, the timescale of weeks/months) takes into account the long-term objectives and data obtained and long-term predictions of the growth using a growth model (production estimation) and energy consumption models. The IoT (Internet of Things) supervisor receives the data necessary for decision-making from the local units and other agents (mainly public agencies) like weather forecast, market price fluctuations, energy prices, etc. which help the next layer, the intermediate, to optimize crop growth, modifying the control decisions (crop conditions) of each greenhouse to improve different objectives: water/energy/fertiliser/efficiencies. With this architecture, supervision and control of each greenhouse polygon are carried out by the local supervisor and the data storage is established using 'fog computing' technics. This The IoT-based hierarchical crop-growth system, which combines publically available and farmer data, is used as a multiobjective optimization solution to satisfy the objectives inherent in control system design and the data sharing/interoperability available for the different users: farmers, technical engineers, production planners and public administrations.

Design and Implementation of a Platform Based on IoT-cloud and Image Processing for Hydroponics Applications

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This paper proposes an internet-of-tings (IoTs) based cloud system with image processing technique for agricultural application. The proposed platform employs the Zigbee and WiFi wireless transmission protocol for receiving multiple data which form the different micro-electromechanical systems (MENs) sensor module. Each sensing module receives the environmental and image data, including the temperature, humidity, carbon dioxide, light quantum, air pressure, conductivity, pH, dissolved oxygen, etc. and send it to the embedded platform. Besides, the camera devices capture the plant image and store it into the platform. The image processing techniques is utilized to conduct morphological measurement, including area of leaf, number of leaf, and color level, etc. The fuzzy inference technique has applied to find the relationship between the growth status of plant, water quality, and environmental data. The decision results provide the suggestion and information for user to enhance the quality of plant. The proposed platform has been verified and evaluated in a greenhouse. The experiment results are also depicted in the paper.

IoT Architecture For Digitalization Of Silage Bale Life Cycle Management

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The research is conducted as part of Digibale project, which studies and conducts trial to evaluate the effect and benefit of digitalization for silage bale production and post-harvest management. By introducing sensors, RFID technology and digitalized services into silage bale farming and logistics, farmers would gain significant benefits and information, namely bale quality and history, thereby enhancing their customer's trust and increase the value of their products.

The focus of this paper is the research on information system architecture for management of silage bale life cycle, based on cloud infrastructure to provide data management and access services. The project aims include identification of silage bales using passive RFID technology, with the hardware implementation planned to be built separately or integrated to bale wrapper. The data collected contains identity of bales and additional information such as weather, GPS data and bale measurements, which will be transferred to the cloud-based information system.

In this research, the backend system is developed on cloud premises and include essential components for data exchanging and provision, such as database; device management and information provision using web services. The decision of developing the solution system on cloud infrastructure was based on three reasons: the abundance of cloud service providers, high availability and fast trial. The research aims to establish the trivial software structure for agricultural digitalization applications, e.g. data schema, data ownership, user management and data access. User input from participating farms will be the focus of the development cycle, to maximize the usefulness of the system for farmers and their customers. Finally, the operation cost for the cloud-based system could be derived and compared between different cloud service providers. The resulted information system architecture serves as a reference model, technically and economically, allowing interested parties to develop new business models from the project results.

Akkerweb, A New Platform For Use of Spatial And Temporal Data In Precision Farming.

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Farmers need simple, user-friendly and safe geo-information systems to apply precision farming, which is doing the right thing at the right time and right place, in the right amount. Akkerweb is a new geo-information system for farmers that want to apply variable rate technologies in their crops. The URL of Akkerweb is www.akkerweb.eu. Akkerweb is a public-private data platform. It allows data-based and model-support based decision support on variable rate plating density, weed control, fertilizer use and disease management. The interface and the basic tools in Akkerweb allow farmers to manage private soil, crop, climate and management data, and to connect with external data-bases and web-service. Over 10 validated decision-support apps are available on Akkerweb to apply variable rate technologies on different crop management activities. Most apps have been developed for potato crop management, but apps can also be used for management of other arable and vegetable crops, and pasture land.

The basics of Akkerweb will be explained and results of application of different decision support tools in on farm research will be presented. Platforms like Akkerweb are likely to speed up adoption of precision farming.

Internet-based Harvest Fleet Logistic Optimisation

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Harvesting operations of cereal crops in a modern farming context often involves multiple vehicles, which can lead to inefficiencies and increase operational costs if they are not used appropriate. Large distances from depot to the field, pronounced field topographies or visual barriers, e.g. hedges, can limit the operator's decisions on when and where an offload is taking place, and consequently make the operation less efficient. Moreover, the operation manager, who may be at the farm, does not have a clear overview of where the machines are at the moment, or how far the operation is.

Therefore, the harvesting operation of cereal crops is an obvious case for utilizing the potential of an internet-based harvest fleet logistic optimisation system - an application that assists the operators and manager in the harvest for optimising the farm's operations. The harvest fleet logistic optimisation system created gives the user a live overview of the operation and vehicles involved, it assists the operator on where and when to offload, and optimises the path in the field to reduce the operational time.

The concept system is described with focus on its architecture, its data flow and communication technologies used. The architecture is divided in three layers: sensor layer, communication layer, and application layer. The sensor layer consisting on a load cell, that measures the grain mass flow, and a GNSS receiver. The communication layer comprising the gateway. And the application layer covering the database, the data analysis and the interfaces. The system is based on Bluetooth communication between sensors and gateway and 3G/4G communication between the gateway and the cloud. Android-based mobile devices (tablets) act at the same time as gateways and interface.

The system is manufacturer independent and allows any machine to be connected, so it supports the interoperability that many farmers are seeking today.

Fruit 4.0: Towards data-driven fruit production

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Modern fruit production is not possible without reliable and up-to-date information. Fruit companies are getting bigger, the market requires increasingly detailed information about cultivation processes and there is a lot of data exchange required for regulatory and certification purposes. These developments pose ever higher demands on fruit growers' information management.

This paper investigates how the concepts and technologies of Industry 4.0 can be applied to fruit production to meet these demands. The so-called fourth industrial revolution is changing production processes radically towards flexible and seamlessly integrated systems based on recent technological developments in the field of the internet, sensors and robotics, among others. More specifically, the paper aims to propose a high-level information systems architecture for data management in fruit production and to analyse to what extent existing data management solutions can enable this architecture.

To do so, first the requirements were defined based on 12 interviews with growers, cooperatives, advisors and sector associations, and a validation workshop. Next, existing systems were investigated based on desk research, 10 interviews with vendors and a validation workshop. A long-list of 75 data management solutions was identified and 21 solutions were analysed according to a standardised questionnaire.

The resulting information architecture for Fruit 4.0 comprises three layers: i) sensing, actuation, data exchange via (wireless) networks and data processing in a Sensing & Control Platform; ii) farm management and supply chain information systems; and iii) support for decision-making.

The investigation shows that especially an operational Sensing & Control platform is currently lacking in the Dutch fruit production domain. The paper addresses three approaches to overcome this situation:

1. Extend existing farm management systems with a Sensing & Control layer;

2. Adapt platforms from adjacent sectors, especially arable farming, to fruit-specific requirements;

3. Implement generic IoT platforms in the fruit domain.

Systems of IoT systems for smart food and farming

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The Internet of Things (IoT) is expected to be a real game changer in food and farming. However, an important challenge for large-scale uptake of IoT is to deal with the huge heterogeneity of this domain. This paper proposes a systems of systems approach that combines flexible customization with efficient standardization in the design, development, implementation and deployment of IoT systems for food and farming. To do so, the research started with the architectures of 19 European uses cases of the IoF2020 project from multiple views (including domain, business process, data, and deployment diagrams). These use cases reflect the diversity of the food and farming domain, including different sub sectors (i.e. arable, dairy, fruits, vegetables and meat production), conventional and organic farming, and different supply chain roles. They follow a demand-driven philosophy in which IoT solutions for specific business needs are developed by end users and IoT companies, supported by R&D organisations. Next, the commonalities and synergies of these use cases are analysed and validated. Main common technologies include connectivity (e.g. Lora/Sigfox), localization (e.g. GPS, beacons), and data management (e.g. FIWARE, 365Farmnet) solutions. Main logical commonalities include animal and crop features, outdoor and indoor conditions, and soil characteristics. Most cases focus on information-centric control (47%), followed by task-oriented decision support (37%) and automated control (16%). Furthermore, location (granularity) and time (continuous, discrete) appeared to be essential dimensions for reuse. Finally, an architectural approach was developed in which autonomous IoT systems function as interoperable nodes in a software ecosystem and in which users can configure customized solutions from standardized components. Main elements are: a common reference architecture (adapted from IoT-A), catalogue of reusable system components, IoT lab that provides a testbed environment, and a Collaboration Space in which services and data can be shared among IoT systems.

Precision Farming

Enhanced Vineyard Descriptors Combining UAV 2D and 3D Models

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Precision viticulture has been assumed as an essential approach to optimise crop-managing practices and to improve the quality of food products. To deploy proper site-specific management, addressing the intrinsic variability within a vineyard or a parcel, reliable methods for features extraction and mapping of crops must be developed. The introduction in agriculture of Unmanned Aerial Vehicle (UAV), equipped with sensors able to acquire fields planar images at several wavelengths, makes available huge amount of data with high-resolution, in terms of both spatial and temporal dimension. Recently, in addition to well-known 2D mosaicked images, innovative features leaded by modern photogrammetry allowed accurate three-dimensional models of crops (ex. 3D point cloud datasets) to be generated.

The proposed new approach is aimed at defining enhanced crop descriptors by exploiting information provided by both 2D and 3D crop models. Crucial phases of the procedure are the proper management of data provided by several sources, in order to achieve high consistency of the obtained huge dataset. In addition, the detection of vine rows, discriminating them from all the other elements of rural areas, plays a crucial role. The developed algorithm, being not based on the straightness of vine rows, can profitably manage models of vineyards with curvilinear rows, also on steep terrains. Specific computing optimisation have been defined in order to process big data.

Four 3D point-cloud models and aerial images, acquired during UAV flights over a set of parcels of a vineyard in Serralunga d'Alba, Italy, have been profitably processed by the developed algorithm. The integration of 2D-3D information allowed to obtain good performance also in the presence of dense inter-row grassing which, usually, slightly differs from vine canopies in terms of reflectance.

A Territorial Services Platform for the Sustainable Precision Agriculture Applied to the Viticulture and Olive Growing Companies.

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The improvement of environmental and food quality and safety, simultaneously with the pursuit of common and economic activities based on knowledge and innovation supported by an environmentally sustainable development, represent the new community guidelines (Horizon 2020). Within this new approach, the aim of the research was the development of a territorial services platform for the sustainable precision agriculture applied to the viticulture and olive growing companies of Montalcino district (OENOSMART project). The activities were aimed to create an innovative territorial system and promote a multi-service platform for the effective, profitable and inclusive application of sustainable precision agriculture.

The platform, based on Geoserver with db PostGIS, was designed in five phases: structuring of the Web platform, data collection agro-meteorological parameters and aerial images, data processing, organizing of layers and subsequent decision supports. The study involved eleven companies for a total area of 250 hectares (vineyards) and 80 hectares (olive growing) respectively. Data, shared between the farmers, were acquired both remotely by airplane (RGB, multi and hyperspectral images and gamma rays) and with proximal measurements (physiological measurements, soil conductivity, soil profiles, meteorological data).

Collected data were processed by geostatistical analysis, interpolated between them to make thematic and prescription maps shape files as decision support systems (e.g. crop defence alarms, meteorological map), but also for the implementation of variable rate management (spreading of nutrients, selective harvesting). Moreover, the cadastral data (surface, national references, particel type) were included for the intercommunication with the regional delivering body in charge of the decoupled payments by common agricultural policy (CAP).

The developed platform constitutes a first example, on large area, of sustainable precision farming for the agricultural companies of a territory and provides an opportunity for a profitable management of big data that nowadays, represents a mandatory medium-term target for the smart management of agriculture sector.

Low Cost integral system for irrigation remote management based on a communication nodes network with sensors, weighing lysimetry and supervision of the vegetative state for hortícultural crops

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The purpose of the research project combines two main parts. In a first phase is to design and develop a hardware of communication systems and nodes of low cost and on the other hand a corresponding software meshed networks to complement commercial solutions that exist in the market. Field trials will be conducted based on the current SIGFOX and WASPMOTE technologies, to establish the weaknesses and strengths of each potential solution. Once the deficiencies are identified, the project will allow to establish trials at different geographic scales and variable conditions of the Valencian Community. A wide range of applications would be sought, from data collection for irrigation programming to precision telecontrol and real-time management. In parallel, a low cost system will be developed and validated, for commercial use in horticultural farms, which measure and manage irrigation accurately, in real time, according to the water balance obtained through varied sensors and compact weighing lysimetry, remotely monitoring the vegetative state of the crop through the use of digital cameras. Data and images will be sent wirelessly to a compact controller in the irrigation head, which will house irrigation management algorithms and process information in real time, and will give irrigation control orders according to the real needs of the crop. The information is sent by an ESP8266 wifi system to an external hosting where it is stored and displayed in an orderly manner, with a friendly user interface, accessible from any web browser or specific mobile applications, providing the services associated with any SCADA (historical management, warnings and alarms, changes of slogans, crop supervision, etc). The system will be linked to the hardware and software developed in the first phase and will allow obtaining specific agronomic data for large-scale applications.

Virtual fence, GrazeGuide, opens possibility of new grazing routines

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Dairy cows may use grassland more efficiently when allowed grazing in predefined areas with predictable sward height and grass quality. Separating High- and Low yielding (HY and LY) cows may have advantages for grassland use optimisation, by allowing HY-animals to graze on a new grass strip first. In the control group 8 cHY and 8 cLY cows were grazing on a fixed area with daily a fresh grass strip. In the experimental group 8 eHY- cows (matched with cHY) were also free to graze in the same fixed area, but 8 eLY cows (matched with cLY) were potentially stopped at a virtual fence (GrazeGuide) and reduced the grazing area. GrazeGuide consisted of underground wires signalling a boundary that was received in the collar, producing a warning signal when approaching the boundary and a correction signal when crossing it.

Wageningen Livestock Research tested the GrazeGuide applicability on its Dairy Campus. Cows were tested in three periods of 3 days: P1 (learning), P2 (basic) and P3 (crossover, ie experimental and control group switched). Cows quickly learned how to adequately react to the signals, and remained within the borders of the area allocated to them. High yielding-cows (23.5 l/day) and Low Yielding-cows (19 l/day) continued to give their pre-experimental milk yield in P1, P2 en P3 (all P=0.000) and no effects of the virtual fence on milk yield were found. Low yielding cows with a virtual fence had a slightly lower Locomotor activity in P1 and P2 (Yield* Fence interaction P = 0.028). However, in P3 this effect is not found.

The research concluded that GrazeGuide offers farmers the possibility to use efficient grazing routines in a labour extensive way. It allows the use of new grazing routines, e.g. give top producing cows in a group priority access to a fresh grass strip.

Application of Precision Viticulture for Thematic Maps Production

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The innovative technologies of precision agriculture offer today new solutions for the wine sector in line with the current demands of the sector. Income maximization in viticulture can be achieved by reducing management costs or by increasing the value of the product, or its quality. Viticulture in hilly areas is characterized by different composition and soil structure, humidity, nutrients and microclimate within the same plot. As a consequence, the vine responds by revealing different states of physiological expression resulting in different production per plant. The aim of this study was the quantification of grape production per plant within a vineyard plot with the same variety and year of planting in order to allow the realization of thematic maps useful for vine growers in order to eliminate the critical issues of the plot and allow them to manage the vineyard applying differentiated cultivation techniques with cost reduction and environmental protection. The experimental tests were carried out in Tenute Rapitalà farm, Camporeale (Italy). The vineyard, is trained with hedgerow system. The Catarratto lucido vineyard, 7.70 hectares wide, exposed to South-East, was hedgerow trained with 4000 plants/ha and Guyot pruning. The self propelled harvester Braud 9060L was used to mechanically harvest the grapes. The machine was equipped with a platform able to monitor and continuously record the quantity of grapes harvested by the machine. The platform was programmed to record grape weight data entering the hoppers every 10 seconds. GPS “STONEX S5" with differential correction and sub-centimeter precision, was used for geo-referencing. The study allowed to obtain a thematic map of the entire plot with different classes of yield. In this way, it will be possible to identify the critical aspects of the vineyard thus increasing quantity and quality of grapes, through the application of focused cultivation techniques, also reducing management costs.

Analysis of Vine Vibration Conditions and Grape Harvest Quality in Spain under Actual Mechanized Harvest Conditions

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Grape harvest mechanization is taking place worldwide since the 90s of last century. However, little effort has been made in the systematic definition of Key Performance Identifiers (KOIs) for the characterization of the quality of mechanized tasks. Moreover, standardized automated procedures are required for the comparison of mechanized tasks irrespective machine manufacturers, field conditions, operators or many other local conditions. This study aims at providing a KPI for the characterization of vibration conditions (by means of accelerometers) as well as the quantification of grain and must losses, in this last case by means of making visible those losses that are invisible to the naked eye. To this end georeferenced data from 19 plots (42.3 ha) have been gathered in order to characterize mechanized work performance, together with corresponding grain and must losses. On the other hand, vine vibrations have been analysed by placing 4 accelerometers (6 channels) in dedicated positions of the vine, and computing the time and frequency response, as well as the power spectra normalized in terms of vine productivity (kg). The results indicate that outliers found in grape losses (must and grain) can be explained in terms of the power spectra information, pointing to deficient regulation of the machines under daily circumstances.

Development Of A Sensing Platform For Agricultural Water Management

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Water limitation not only affects industrial production but also puts pressure on irrigation systems to produce more with lower supplies of water in Taiwan. To improve the efficiency of irrigation in agricultural production, this study developed a sensing-based platform to simultaneously monitor the environmental factors of a greenhouse and the growth status of *Brassica chinensis* Linn. The sensing platform comprised an environmental monitoring platform and a wireless imaging platform, which were deployed in the greenhouse. The environmental monitoring platform comprised six wireless sensor nodes and a gateway for measuring temperature, relative humidity, and illumination. The wireless imaging platform comprised a set of embedded boards with cameras to capture images of *B. chinensis* Linn, and all the sensing data and captured images were stored and estimated using an image processing algorithm. Our experimental results indicate that the daily average growth rate and color visibility of the leaf of *B. chinensis* Linn are a slight difference between full watered and reduced watered plants. The sensing data will be examined to determine the relationship between the environmental factors of the greenhouse and the growth of *B. chinensis* Linn under various irrigation conditions with the same type of fertilizer management. Finally, the statistical analysis and long-term monitoring data will be used to build water management systems for prescriptive cultivation decisions.

Application of Drone-Based Maps in Planning Farm Operations for Sward Management in Silage Production

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Experience and expertise, or tacit knowledge, traditionally have a very significant role in farm management. This is especially true on smaller farms, where the scope of the farm’s operations isn’t necessarily overwhelming without external planning tools. However, the ongoing digitalization of farming is bringing increasing amounts of data into farm decision making. Simultaneously, the rapid decrease in the prices and significant improvements in the usability of new technology and new analysis tools are making them viable alternatives for an ever-increasing number of farmers. Thus, in the future, traditional farm management will be increasingly supplemented – or even replaced – by management methods based on data gathered by various systems. In this work we examine how using drone-based mapping of agricultural fields can affect decision making in silage production for cattle. Our work covers four important field operations: overseeding, application of both organic and industrial fertilizers, weed control, and timing of harvests. We examine how drone data can be used in planning silage farming operations, and formalize planning processes that take advantage of field maps created from the data. We will compare the drone-data utilizing process to

traditional decision making to see how the drone-based data will supplement – or replace – the traditional decision making. Based on this, we will discuss how this can affect the tacit knowledge of farmers in the future, and possible implications for these changes in the expertise of farmers. The work will both demonstrate the effect of new technology on farm management processes, as well as contribute to research on knowledge management in agriculture.

Design and Performance of an Unmanned Aerial System for Precision Pest Management

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The use of small-unmanned aerial vehicle retrofitted with spraying systems allows precision aerial applications on smaller targets.. These precision applications can result in significant savings if agrochemicals are applied only in affected areas and can contribute to avoid soil compaction caused by machinery or risks such as the exposure of operators to pesticides during treatments.

In this context, this work aims at the design and development of a small application system capable of being mounted on an unmanned aerial vehicle for agrochemical spraying tasks and the subsequent analysis of the quality of the application and economic costs compared with a conventional treatment. .

Once the equipment was developed and verified its response during flights, field trials on super-high-density olive orchards were performed to evaluate spray deposition at different spray heights, flow rates and nozzle settings. Spray deposition efficiency, droplet diameter and population and drift caused by the spraying system were analysed using water-sensitive papers at different positions on the tree structure. For the comparison with a conventional spraying equipment tasks, field tests took into account parameters such as the applied volume rate, the time performance, equipment costs and depreciation, etc.,

The first results obtained indicate that there is no great difference in the application costs between the one realized by the aerial vehicle and the conventional equipment. It is hoped that the conclusions of this work will serve as a basis for a debate about the existing legislation, in which this type of aerial works, which can be beneficial in specific cases, can be carried out under safe and legal conditions.

CasNet – A Decision Support System for Yield Prediction of Cassava to Develop Inventory Planning Model in Indonesia

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As an essential source of food, feed, and fuel, cassava has the potential to become a promising crop that can adapt in changing climatic due to its low water requirement and drought tolerance. Despite the potential, cassava production has the constraints by several factors, including farm management, yield prediction, and supply chain. Inappropriate decision could limit yield production and increase associated production cost with less profit margin to farmers in Indonesia. This research presents a decision support system integrated with geospatial technologies such as remote sensing (RS), geographic information systems (GIS), and global positioning systems (GPS) for cassava management and cassava monitoring information. In the methodology, multi-source database was built using the fuzzy membership of expert knowledge integrated with the application of spectral reflectance of satellite image and mapping system. The decision scheme presented the farming practices including assessing suitable land, managing pests, and predicting the economic benefits. Performance evaluation of CasNet was conducted by the agricultural experts and farmers for yield prediction and inventory planning in the supply chain management of cassava in the Banten province, Indonesia. A suitability map for cassava production was created. It was mapping for the production and also the distribution of the cassava. Furthermore, the prediction yield model was done from the application of remote sensing vegetation index. In further research, the fuzzy-based expert systems will be extended to develop food nutrition security model in Indonesia for diversified crop production with best possible decisions for sustainable intensification of farming practices.

Animal Welfare Adjustment Real Time Environmental Condition of Housing (AWARTECH Project) - Living Lab Setup

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AWARTECH aims to create and develop a precision animal husbandry tool that supports the sustainability of the swine value chain. The intention is to create a platform for the collection and organization of data, that allows the evaluation of a set of environmental and physiological variables and to act in real time on environmental conditions. The first test to validate the equipment and methodology for collecting and monitoring information, related to animal welfare indicators, occurred between October 2017 and January 2018.

The environmental data were collected by sensors of temperature, relative humidity, air velocity and gas concentration, which are integrated in a environmental control system (Webisense) and a platform (Nidus). Webisense controlled the ventilation system, the cooling system and the heating system.

Physiological data (rectal temperature, body surface temperature, α-amylase and cortisol concentrations) were collected manually and analyzed. In order to monitor the behavior of the animals, video cameras and microphones were installed. The component of analysis of video and audio is in development, through the video and audio captures already made. This analysis aims to detect abnormal behaviors such as crowding/spacing of animals and vocalizations above certain frequencies.

An individual feeding machine equipped with a scale has been installed. That allows, through an RFID system, individual monitoring and control of the quantity of food supplied and ingested; number and duration of visits; and the weight of the animals. This information allows the analysis of productive data of animals.

The development of AWARTECH platform results from the integration of physiological data manually supplied and real-time data provided by Webisense, Nidus, feeding machine, video and sound analytics, that allow the control of housing environmental conditions in order to promote the animal welfare.

Traceability and Decision Support

Development of a traceability system for Agri-food supply chain based on Blockchain technology

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Agri-food supply-chain have been extensively studied and several researchers are considering the application of advanced technologies in supply-chain-management. Indeed, technological developments in the area of networking devices, sensors and communication technology can play a significant role in sustainability of animal product.

A new-technology called blockchain has drawn much attention from researchers in many different domains. Blockchain is a distributed database that maintains a continuously-growing list of data-records secured from tampering and revision. It consists of blocks, holding batches of individual transactions. Each block contains a timestamp and a link to a previous block. Blockchain could guarantee the security of the whole network by using mathematical algorithm mechanism.

The purpose of this study is to evaluate the possibility to establish a conceptual framework to support and guarantee supply-chain traceability. The system takes advantage of blockchain technology, which has the potential to enhance food safety and quality and, at the same time, to significantly reduce losses during the logistics-process. Such approach can cover the whole process of data gathering and information management of every link in the agricultural product supply chain, supporting monitoring, tracking and tracing "from farm to fork".

Specifically, the study takes into consideration supply-chains with different levels of complexity and analyses strengths, weaknesses, limits and opportunities in the implementation of this new technique. It is shown how blockchain can be particularly advantageous not only in the case of direct supply chains (one-supplier to one-customer) but also in the case of multi-entry-exit chain (multiple-suppliers for multiple-customers), allowing time saving ranging between 30% and 70%, and costs reductions comprised between 60% and 90% in the analyzed case studies.

Feedback Grading Information For Insight In Variability In Yield And Fruit Quality Of Elstar Apples At Sub Orchard Level

Pieter Van Dalfsen, Peter Frans De Jong, Dirk De Hoog

Wageningen University & Research, Netherlands, The

Fruit growers gather their fruit production information, such as yield and fruit quality, mainly at the level of the whole orchard. When, after harvest, fruits are graded by a machine at fruit sale organisations much data is gathered, but this information is unused by the grower because the exact picking position in the orchard is not known. Using this data by the grower would give more detailed insight in variability in yield and fruit quality and could be used to apply better management strategies to optimise fruit production. The picking platform Pluk-o-Trak was equipped with a GPS system in order to georeference the position of the full bins of picked apples in the orchard. Therefore the route per bin was tracked at three picking moments in an 'Elstar' apple orchard. The full bins were labelled and stored in cold storage. Next, the labelled bins were taken out of storage and graded on an Aweta grading machine which determines 13 different parameters per apple trough sensing and vision techniques. This data was available per bin and then linked to the GPS coordinates of the picking area for each picking moment. The cumulative yield and fruit quality and also per picking moment were presented in a geo referenced map. This method makes differences visible in yield and fruit quality at sub orchard level. Combining the three picking moments, the yields varied from 8 up to 23 kg/m of tree row. Areas with high yield (weight and number of apples) generally had a lower individual fruit weight. Some areas have less than 1% fruit rot, whereas other areas have more than 3%. To get feedback from grading information to sub orchard levels a chain approach is needed with fruit growers, sales organisations and technological suppliers.

Site-Specific Management of Pastures Based on Soil Apparent Electrical Conductivity Survey

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Fertilization is the main cost of maintenance of permanent pastures. Its incorrect use results in important direct economic loss and in environmental polluction. Usually, soils utilised for pasture and livestock production in Southern region of Portugal have high spatial variability. In consequence, it is necessary to determine the spatial patterns of the main soil properties as the first stage to implement site-specific management. However, this has to be performed using an inexpensive technique because the profitability in these types of farm are very low, so owners need a cheap, effective, and reliable method to know which zones have similar potential management. The use of soil apparent electrical conductivity (ECa), as it integrates many soil properties affecting crop productivity (for instance, soil texture, organic matter and cation exchange capacity), constitutes one of the most appropriate soil variables to characterize the management zones of a field. In the present study ECa measurements obtained with a Veris 2000 XA contact-type sensor and soil samples taken at 0-0.30m depth in three permanent pastures were used. The aim was to assess the spatial pattern of some soil properties, based on many ECa measurements as ancillary information and a guided sampling taking into account the spatial distribution of ECa. Relationships between ECa and some important soil properties were analyzed and, later, some maps were produced to visualize the spatial variability of the soil properties. Finally, homogeneous zones were delimited for attaining a site-specific management of the fields. Results showed that ECa is associated with some important soil properties and, consequently, can be considered as support information with the aim of obtaining low-cost data to be used to implement site-specific management (intelligent soil sampling or differential and optimal fertilization), in soils with permanent pastures and to contribute to the increased sustainability of the pasture grazing systems.

Application of a Modified Mckendrick-Von Foerster Equation to Predict Beetle Population Dynamics (Xyleborus Affinis) under Artificial Medium in Growth Chambers

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Augmenting accuracy and reliability of predictions in the woodboring beetle population dynamics is worthy information to anticipate potential plagues or extinctions, ensure sustainable ecosystems and estimate impact at new environmental scenarios due to climate change. This study focuses in the genus Xyleborus by rearing the beetle X. affinis, a species that can be found in United States and Mexico, such ambrosial beetle has potential to bore and disseminate fungus in trees of the Lauraceae family. In specific, it was investigated population growth rates for the X. affinis in four life stages (egg, larvae, pupae, adult) under three temperatures (20 C, 26 C and 32 C). The growth of the population was identified through sampling counts conducted every four days. Sampling counts of the population served to estimate the average time of development for egg life stage from 6.4 days, to 5.7 days, and to 5.6 days for 20 °C, 26 °C and 32 °C, respectively; whereas for larva life stage was found from 8.3 days, to 6.2 days, and to 5.2 days for 20 °C, 26 °C and 32 °C, respectively. Also, estimation of the average survival rates from eggs to larva were 37.1%, 56.9% and 4.5% for 20 C, 26 C and 32 C, respectively; whereas from larva to pupa were 6.7%, 32.9% and 0% for 20 C, 26 C and 32 C, respectively. Finally, the time of development was subjected to variability, which was deduced from the experimental data at each treatment, and was used to predict the expected population density using the modified McKendrick-von Foerster equation in order to recommend the periodic sampling counts accordingly to the change of life-stage, when X. affinis is subjected to a constant temperature.

A Systems and Control Approach for Integrated Pest Management

Simon van Mourik, Koen van Dinther, Johan van Riel

Wageningen University, The Netherlands

Poultry red mite (PRM) is a common pest in the poultry sector. The mites hide in the laying houses and they feed themselves with blood from the birds. Infestation of PRM in a laying hen house can lead to irritation, restlessness, anaemia and even mortality. As these symptoms are associated with a lower production, poultry red mite may cause considerable financial damage.

We investigated the added value of precise timing and dosage for PRM pest management with a modelling and control study. We designed a model based optimal control strategy for the timing and dosage of treatments. The optimality criterion used here, was defined as a minimized treatment input under the constraint that the mite population does not exceed a certain threshold. For this, we integrated a population dynamics model with a mite monitoring and scoring model.

The optimal control treatment strategy showed a potential saving of 52% of pesticides, compared to a conventional treatment strategy. The main difference between the optimal and conventional treatments, is that the optimal strategy prescribes a continuous-time treatment input, whereby the mite population is held at a constant level. The conventional strategy consists of 8 separate treatments during a production round of 70 weeks.

We found two main issues with the optimal control strategy. First, in case of chemical treatments, a continuous-time dosage might lead to resistance development. Second, model based control without sensor feedback might be sensitive to errors in the model that describes the dosage response. In an approach to deal with these problems, we approximated the optimal control strategy with a sensor based threshold controller that applies single separate dosages using the scores of a mite counter.

Performance Evaluation of Passive Radio Frequency Identification Technology in Silage Bale Application

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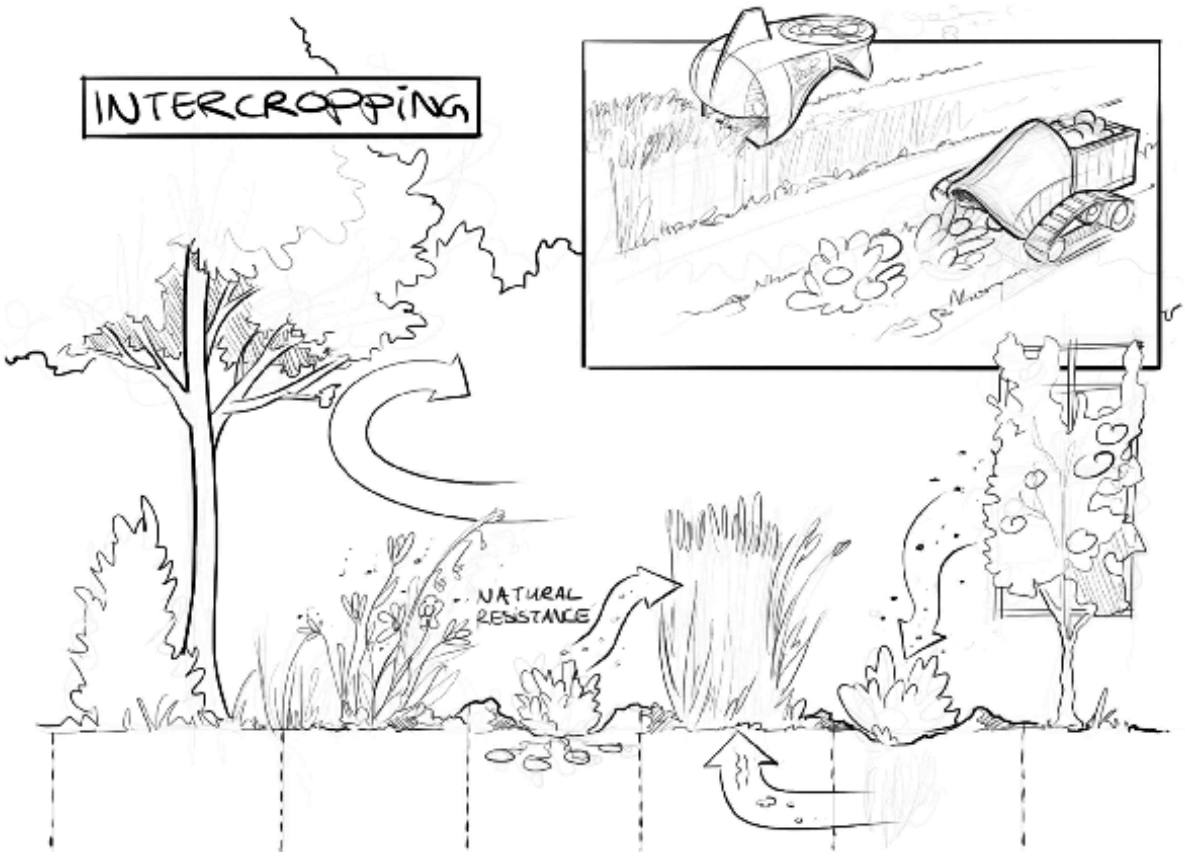
Digitalization in farming sector has raised interest nowadays. By increasing knowledge and enabling unique identification of harvested crop, farmers gain relevant business profit. At present, most of silage bales are stored in stacks on the edge of field or near cowshed without any special tag identification. In some rare cases spray paint are used for identification, but real-time and unique tracking is impossible. The need for weatherproof and automated identification, combined with microclimate and geographic information offer valuable information to farmers. Research work presented in this paper presents the first steps to achieve unique bale identification and related data management.

This research is focused on the utilization of passive radio frequency identification (RFID) for silage bales in stationary conditions. Passive RFID is wireless, non-line of sight identification technology, with free-air identification distances over 10m. When installed to application, distances decrease based on material's electromagnetic properties. As conservation of silage is based on lactic acid fermentation, with pH around 4 and dry matter variation between 20 and 45%, the challenge to achieve sufficient distance raises. RFID operation principle is based on reader command and transponders' passive backscattering, where transponders harvest all their operational energy from reader's communication signal. As maximum communication signal strength is limited by telecommunication standard regulations (e.g. ETSI), transponder type plays a crucial role to guarantee adequate signal strengths to achieve sufficient communication distances.

In this research, the applicability of RFID technology is measured in a silage bale of 160cm in diameter, covering 360 degrees around the bale. Measurements are conducted as identification distance [meters], and transponder population [number of tags]. Based on the results, the most suitable tag for the application is chosen, and the applicability is proven. The project next steps will be on-site testing, integrating RFID reader to baler and evaluating the performance in action.


INTERCROPPING
NATURAL
RESISTANCE

Topic 3: Co-Production and Implementation of Technology in Food Production Systems (FP)

Experiences and research into systems addressing the human aspects for farmers, workers, consumers and society involved in the development, implementation and use of new technology and systems in food production and processing. Examples include acceptance/rejection, safety and risk and management thereof, responsible development and democratization.

Promotion of Circular Economy in Alentejo's Agri-food Sector

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In a world of increased lack of resources, it is imperative to promote the transition to a more circular economy, seen as an alternative business model to promote competitiveness, reducing simultaneously the consumption and dependency of raw materials and energy.

The main goal of "Alentejo Circular" project was to raise awareness and mobilize Alentejo' s agrifood sectors to adopt the circular economy model, aiming to create value for enterprises, and consequently for the region, by transferring knowledge on the best practices and technologies for efficient resource use and waste valorisation. The work was focused on the wine, olive oil and pig farming industries, due to their current and growing importance for the regional economy.

Through national and international technical site visits and bibliographic research, a current diagnosis of circularity in the addressed regional industries was as carried out, as well the assessment of circular economy best practices, at national and international level. The resources and wastes were characterized and quantified improving the knowledge of recovery cycles with a list of best practices being gathered as priority for actions to be taken by the regional stakeholders, in order to support the transition towards a circular economic model.

As a result of this study, it was possible to conclude that the best available practices in these sectors, such as, smart farming and the use of renewable energy are already in use across the region, however these practices are only implemented by a limited number of the regional companies.

By means of several public sessions across the territory and a web 2.0 based platform, the interaction between stakeholders, including companies, public authorities and the scientific community increased, resulting in shared experience and knowledge on alternative use of resources, thus settling the conditions for the development of future synergies.

A Technical–Economic Analysis Of Precision Spraying In Vineyard And Apple Orchard

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A technical–economic analysis was conducted considering three different technological levels of spraying equipment for specialty crops case studies, using the results of precision spraying technologies reported in scientific literature. The application scenarios were referred to general protection protocols against fungal diseases adopted in vineyards and apple orchards in Central-Southern Europe. The analysis evaluated the total costs of protection treatments (equipment and pesticide costs), comparing the use of conventional air-blast sprayers (technological level L0), of on–off switching sprayers (L1), and of canopy-optimised distribution sprayers (L2). Average pesticide savings from 10 to 35% were associated to equipment L1 and L2, as compared to conventional techonology L0. Within the assumptions made, on grapevines, the conventional sprayer L0 resulted in the most profitable option for vineyard areas smaller than 10 ha; from 10 ha to approximately 100 ha, L1 was the best option, while above 100 ha, the more advanced equipment L2 resulted in the best choice. On apple orchards, L0 was the best option for areas smaller than 17 ha. Above this value, L1 was more profitable, while L2 never proved advantageous. Finally, in a speculation on possible perspectives of precision spraying on specialty crops, the introduction of an autonomous robotic platform able to selectively target the pesticide on diseased areas was hypothesised. The analysis indicated that the purchase price that would make the robotic platform profitable, thanks to pesticide and labour savings, was unrealistically lower than current industrial cost. The study showed that, in current conditions, profitability cannot be the only driver for possible adoption of intelligent robotic platforms for precision spraying on specialty crops, while on–off and canopy-optimised technologies can be profitable over conventional spraying in specific conditions.

Management System of Small Farm Machinery Hiring Business for Rice Farming Operations in Kampar Region, Indonesia

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Development of using farm machines for agricultural operations has created business opportunities for smallholder farmers in rural areas. Custom hire offering machinery services for farmers is one of business models at the farm level which has been adopted widely in many developing countries with different management system and economic benefit depending farming practices. This paper attempts to examine the management system of small farm machinery hire businesses for rice farming operations in Kampar Region. We have surveyed and purposively selected as 20 groups of hire service providers of small farm machinery in the region. Group managers and machine operators were personally interviewed using questionnaires to collect primary data during September – October 2017. The results showed that the small farm machinery hire services were small businesses managed by farmer groups and operated within village area. They managed 2 - 4 kind of farm machines and offered hiring services for their group members according to machine owned with a lower charge rate. The businesses became sources of increasing and diversifying family incomes for smallholder farmers in the region. Moreover, the availability of the farm machinery hire businesses was helpful stallholder farmers to access farm machinery for being mechanized their rice farming operations.

Automation And Robotics Examples And Way of Working Of Collaboration Between Industry And Research institutes,

Rick van de Zedde[1], Bram de Vrugt[2]

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Collaboration between SMEs and research institutes have launched successful high-profile examples of agro food robots. This way of working will be analyzed and explained. How can we translate progress in technological research & development into a suitable solution for, among others, SMEs. How must we lower the threshold for participation in these developments. In this joint presentation we will show how we build the bridge between science and industry, by discussing applied examples of vision-guided robotics for food inspection and handling.

What Are Driving Factors and Barriers of Organic Rice Production in Iran?

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The main objective of this study was to investigate the driving factors and barriers of organic rice production in Guilan province, Iran. This research used a three round Delphi technique to identify the factors reached in a consensus among 21 experts. The Kendall's coefficient of concordance was the basis for evaluating the experts' consensus at the end of the third round. Results showed that "generally informing on the benefits of organic rice consumption" and "issuing an ID card for organic rice and its eco-labeling by governmental regulatory bodies" were the driving factors of organic rice farming. The main barriers of organic rice farming were found to be "the high cost of inspection and supervision by Iran Organic Association for the farmer" and "inattention to the role of branding in promoting organic rice consumption". Additionally, "risk aversion of farmers due to their reliance on rice as the only source of annual income" and "their economic dependence on rice was another inhibiting factors".

Spatial Distribution of Mechanization Levels in Italian Greenhouses

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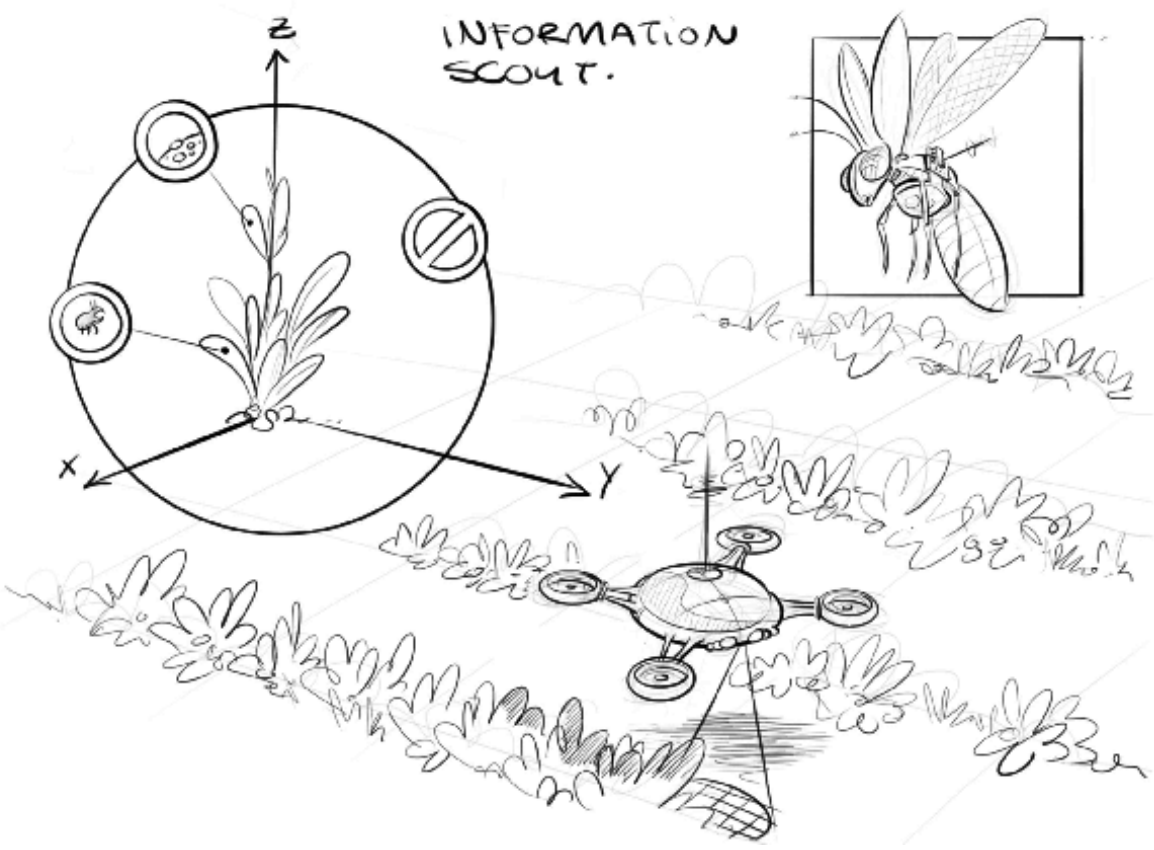
Greenhouse cultivation in Italy represents an important production sector within the horticultural sector, with a strong economic importance. Protected crops in the Mediterranean basin cover more than 40,000 hectares (ISMEA2016). In terms of volume, the regions that play a predominant role in Italian greenhouse cultivation are Campania (25.74%), Sicily (23.54%), Lazio (19.53%). Then follow Veneto (9.45%), Sardinia (6.80%) and Lombardy (6.21%). Greenhouse distribution in Italy covers different latitudes and the cultivations conducted provide different management with very different technologies and materials. Also the mechanization of the production structures is very varied and foresees different degrees of use.

The mechanization in greenhouses can provide for the various operations and are conditioned, as well as by the characteristics of the species in cultivation, vegetables or flowers, the type of greenhouse used and the type of cultivation adopted.

The present study has the main objective of observing the distribution of current mechanization levels in protected production companies and to verify any influences from income or from the surface and structure. Therefore the data of the Italian agricultural accounting information network (R.I.C.A. - Rete di Informazione Contabile Agricola) was studied, which is an annual sample survey established by the European Economic Commission in 1965, with the Regulation 79/56 and updated with the EC Reg. 1217/2009. The RICA sample allows an average national coverage of 95% of the utilized agricultural area (UAA), 97% of the value of the Standard Production, 92% of the Work Units.

The available data have therefore been studied for the spatial distribution of the farms, their mechanization in terms of kW used in the production process and for the interaction with the net income obtained, the company surface and the manpower used. Furthermore, a statistical analysis was developed to verify the possibility of an effect of proximity between companies towards mechanization.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Topic 4: Robotics and Sensor Technology (RM)

Research and development of mechatronic and (semi-autonomous) robotic systems and machine vision for agricultural applications, from breeding and seeding to monitoring in primary production and post-harvest processing. Contributions may include sensing technology such as 3D vision, hyperspectral imaging, spectroscopy, acoustics, use of satellites and drones, classification techniques including use of artificial intelligence for e.g. phenotyping and 3D reconstruction of plants, animals and environment.

Robotic Systems in Orchards

Orchardmapper: Application for Creating Tree Scale Maps FromfHigh Resolution Orthomosaics

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The availability of georeferenced maps of individual trees and their characteristics such as position in the orchard, canopy area and vegetation indices provide valuable information about spatial varability and crop status for plant-scale precision fruticulture and viniculture.

The OrchardMapper desktop application was developed to detect trees and derive individual tree variables from orthomosaics created from high-resolution images obtained using unmanned aerial vehicle (UAV) platforms. The application is currently being used as part of a precision agriculture service at the commercial scale. Applications have included mapping of spatial variability of tree vigour for precision canopy management, derivation of tree sampling protocols, tree inventories and detection of missing plants.

The algorithm is general enough to permit detection of trees under a wide range of crown coverage structures, ranking from closed carpet-like canopies of overhead trellis systems, to almost or fully discrete canopies characteristic of some fruit tree orchards. It also estimates portions of the canopy under shading or overexposure (situations resulting in loss of information pixels).

We present an overview of the software and algorithm and an evaluation of its performance, in terms of processing times, row and tree detection rates (close to 100% and better than 98%, respectively) and scale-dependent canopy segmentation performance for multispectral orthomosaics of tablegrape and winegrape vineyards, and fruit and nut orchards under differing conditions of canopy closure and weed pressure.

We also discuss some of the anomalies and special considerations that must be dealt with when working with high resolution images at different scales and how these affect individual tree canopy detection.

Comparison Between Four Navigation Algorithms For Autonomous In-row Navigation In Orchards

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Increasing labour scarcity puts pressure on labour intensive tasks in agriculture, such as crop management and harvesting. Agricultural robots have the potential to execute agricultural tasks unattended. These robots often rely on Global Navigation Satellite Systems (GNSS) for autonomous navigation. In environments where GNSS localization is unreliable, for example in orchards, alternative sensors and algorithms need to be used for navigation. Scientific literature indicates a lack of consensus on which alternative navigation algorithm should be used in an orchard. This research presents a comparison between four in-row orchard navigation algorithms under constant conditions; the Hough transform, least squares line fitting, the Kalman filter and the particle filter. All algorithms relied on 2D LiDAR data and included the extraction of line features in the laser scan image. Two experiments were executed in a Dutch apple orchard, using a robot platform equipped with a 2D LiDAR, inertial measurement unit and wheel encoders. The first experiment assessed the navigational accuracy by traveling two paths of 500 m at two velocities, while registering the robot's position and orientation using an RTK-GNSS receiver. Average lateral deviations from the centreline between two tree rows ranged from 0.05 m to 0.12 m, while extreme lateral deviations ranged from 0.12 m to 0.23 m. The particle filter showed the lowest average and extreme deviation from the centreline. The second experiment assessed navigational robustness by artificially removing trees from the sensor measurement and registering the navigational response of the robot. The Hough transform and particle filter steered the robot on collision course in case of missing trees, while the Kalman filter and the least squares line fitting only showed a marginal increase in lateral deviation. The last showed the lowest lateral deviation, indicating the highest degree of robustness.

Reliability of Autonomous Guided Systems for Vineyard Monitoring

Dionisio Andujar, Jose Bengochea-Guevara, Angela Ribeiro

CSIC, Spain

Homogeneous use of pesticides in the majority of the cropping areas is the most common method for pest control. Intra-plant variation is not considered which leads to the use of a non-adjusted dose. These facts demonstrate that the dose of sprayed products should be adapted to the growing state at each location. Information about crop status is of high value for agricultural management. The use of plant models allows site specific management and yield estimations. The models can be analyzed to obtain information such as height of tree-row-volume, which is used to determine the amount of agrochemicals, nutrients or grow regulator to apply at each location. The use of new technologies is of high impact in agriculture, and viticulture is the agricultural sector with more technological advances. The creation of spatial variability maps for site-specific management is still a challenge. The use of 3D structural maps can adapt the application of inputs within the fields. This work assess the reliability of 3D models using large maps of vineyards for site-specific management and explore the economic profitability of its usage. A mobile platform, based on a commercial electric vehicle, was developed and equipped with different on-board sensors for crop monitoring. The platform based on RTK-GNSS receiver and IMU information allowed operating in autonomous mode for vineyard monitoring. A low-cost RGB-D sensor, Microsoft Kinect v2 sensor was installed on-board the platform for construction of 3D crop maps. The reconstruction of the field objects was fully automatic based on ICP algorithms for 3D reconstructions of large areas, such as a

complete row crop. The experiment showed that the use of robotic platforms would reduce the operational cost and it would increase economic savings.

Field Robot to Detect Plants Infected by Candidatus Liberibacter solanacearum in Horticultural Crops Using Multispectral Computer Vision

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A low cost field robot has been built capable of transporting a series of sensors through horticultural fields, with the aim of early detecting problems in the crop by means of proximal sensing techniques. The robot is operated by remote control and is driven by two electric motors coupled to the wheels and powered by batteries. The sensors include different thermal, colour and multispectral cameras in the visible and the near-infrared range that are synchronised with the advance of the robot by means of an encoder coupled to the axis of the motors. The position of each image is geolocated using a GPS. An industrial computer receives the encoder pulses and triggers the cameras, also receiving and storing the images and GPS information for further processing. The inspection area is located beneath the robot with the cameras focusing downwards (to the crop). To avoid the negative influence of direct sunlight, the area had been covered with a canvas and illuminated artificially with four-spot halogen lights. A telescopic extension system between 100 and 200 cm allows the robot to adapt to crops with different row widths. The first trials were carried out in a carrot test field located in Villena (Spain) to detect plants infected with *Candidatus* Liberibacter solanacearum. The crop was inspected every month from sow to harvest. Labels were placed on 100 plants to guarantee their individual identification in the images. During the harvest, these plants were collected separately, identified and analysed in the laboratory using molecular techniques in order to determine whereas they were infected or not. Several maps of the field have been created using spectral indexes at very high resolutions between 0.5 mm/pixel and 2.5 mm/pixel depending on the camera.

Generation of Weed Cover Maps Using a SLR Camera

Karla Cantuña, Dionisio Andujar, Jose Maria Bengochea-Guevara, Angela Ribeiro

CSIC, Spain

Precision agriculture uses knowledge of spatial and temporal variations in crops for selective treatments. The case of weed management is of high importance because herbicides are the most used pesticides in the world. Weed mapping at early phenological stages is necessary to optimize herbicide application. The acquisition of series of high-quality overlapping pictures from autonomous platforms allows the reconstruction of accurate 3D models. The method needs of computer vision and digital photogrammetry such structure from motion (SfM) and dense image matching (DIM). It also needs of colour index-based segmentation algorithms to separate plant from soil to extract the vegetal cover from the digital images. This paper describes two aspects: 1) the generation of weed maps from images provided by an SLR camera (Single Lens Reflex, Canon EOS 7D) under real field conditions of uncontrolled lighting. All the images were georeferenced using the geographic location information provided by the RTK-GNS receiver. The data processing leads to an orthogonal projection (GeoTIFF image or orthophoto) of the sampled area. Lately, the best segmentation strategy was chosen by testing and adapting several methods. 2) Ten color-based segmentation strategies were applied to 313 random images. The efficacy of each segmentation strategy was tested by Jaccard's similarity coefficient. It estimates the percentage of similarity between automatically segmented image and its corresponding ground truth image. Following, Newman-Keuls test compared the averages of similarity percentages of the ten segmentation strategies to determine which strategy fits better. The results showed differential similarities: COM1 (53,01%), EXGR (52,08%), CIVE (50,52%) and automatic threshold (42,82%) were the most effective. Thus, the possibilities and disadvantages of different systems regarding their practical use in weed detection were assessed based on results obtained from field experiments. The studied strategies offers opportunities for automation of agricultural processes by integrating RGB cameras with fast algorithms.

The Electronic Smell of the Orchard Fruit

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Laboratory of Geo-information Science and Remote Sensing, Wageningen University & Research

Assessing fruit maturity when at the end of the season is a hard task for fruit growers. This is because this task is either made by visual inspection – which is tedious and time consuming - or using destructive procedures for measuring biophysical properties on the fruits, such as the sugar content.

An alternative to measure the ripeness of fruits is measuring the volatile organic compounds emitted by the fruits. An important compound produced by the fruits in this stage is ethylene (C2H4).

The recent advances in electrochemical semiconductors have enabled the rapid growth of electronic noses technologies and applications. Nevertheless, the research reported where its characteristics and limitations are explored only addresses experiments in controlled and indoor settings. Therefore, many questions remain regarding the electronic noses applicability in outdoor environments.

This work presents preliminary evidences that there are good chances that ethylene can be detected outdoors via an electronic nose placed within an orchard field. The results presented are measurements acquired in a Conference pear (Pyrus communis) orchard in September 2017. The measurements where acquired on several points within the field, and the maximum ethylene detection shows an increase of 10% over 400 seconds.

These results were contrasted with a theoretical study where gas dispersion patterns can be appreciated when subject to the wind speeds recorded in the field. The simulation results indicated a good correlation between the practical and the theoretical simulation results.

To the best of our knowledge this work is the first to report results from measurements using electronic noses in a non-controlled environment, and detecting spatial-temporal variability of natural gas sources.

Robotic Systems in Livestock

Decision-Tree and Support Vector Machine Algorithms for the Automated Measurement of Ingestive-related Cow Behaviours

Said Benaissa[1,2], Frank Tuyttens[2,3], David Plets[1], Luc Martens[1], Leen Vandaele[2], Hannes Cattrysse[2], Wout Joseph[1], Bart Sonck[2,4]

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Changes in ingestive-related behaviors (e.g., feeding and ruminating) are key indicators for assessing health and well-being in cattle. The aim of this study was to develop a decision-tree (DT) algorithm to classify neck-mounted accelerometer data for the measurement of feeding and ruminating behaviors in dairy cattle. The performances of the DT were compared with those of a support vector machine (SVM) algorithm. Ten multiparous dairy cows were used in this study. The cows were housed in an area of 36x13 m2 with individual cubicles and concrete slatted floor. The cows were fed roughage ad libitum. Drinking water was available ad libitum. Collar-mounted accelerometers were used to distinguish between three behavioral categories: feeding, ruminating and other activity (non-ingestive). The accelerometer (sampling at 10 Hz) was attached on the cow's collar. Direct observations (i.e., reference) were made from 09:00 AM to 03:00 PM (6 hours per cow). To classify the data of the three behaviors, a new DT algorithm was developed. The decision-tree algorithm was selected for its low computational costs, which makes it implementable on the on-cow nodes. The performances were calculated using leave-one-out cross-validation. Results showed that the DT algorithm nearly matched the performances of computationally intensive algorithms such as SVM (i.e., overall accuracy of 89 % for the DT and 92 % for SVM). The precision, sensitivity, and specificity measures were between 77 % and 94 % for the DT, and between 82 % and 96 % for the SVM. These preliminary findings illustrate the potential of the collar-mounted accelerometer to classify feeding and ruminating behaviors with a simple DT method. This would optimize the power consumption of the sensors by transmitting just the behavior of the cow instead of all the raw data to the backend system. Measurements are being continued in order to validate the reported results.

Automatic Body Condition Scoring of Dairy Cows Using Multiple 3D Cameras

Xiangyu Song[1,2], Eddie Bokkers[3], Simon van Mourik[1], Peter Groot Koerkamp[1], Rik van der Tol[1]

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Vision-based automatic body condition scoring for dairy cows offers a laborsaving solution to frequently assess the fat reserves of individual cows on farms. The body parts assessed in the existing vision-based studies include spinous processes, hook bones, pin bones, and the cavity between the tail head and pin bones. The manual body condition scoring used as references in these studies, however, often include four additional body parts: short rib, loin pit, thurl, and sacral ligament. We assume the conditions of all the additional body parts can be assessed automatically and the accuracy of the vision-based scoring improves when including all body parts. Our objective was to automatically extract the body-condition-related image variables of the eight body parts using multiple three-dimensional (3D) cameras to predict the body condition score (BCS). Forty-four lactating cows were recorded ten times in two consecutive days using three 3D cameras from the top-, right-side-, and rear-view. Each image was automatically processed to identify the projections of the anatomical landmarks on the body surface. The protrusion around the landmarks and concaveness between them were quantified as eight image variables for the eight corresponding body parts. Moreover, body condition was independently assessed by two trained assessors using a detailed protocol. Because the inter-assessor correlation coefficient was high (Spearman's $\rho = 0.91$), the BCS of the two assessors were averaged and used as the reference. To predict the BCS, a one-Nearest Neighbor classification model was applied using all the image variables as inputs. Using a 10-fold cross-validation, the model outputs were compared with the referential BCS, which yielded a mean absolute error of 0.15 BCS. So far, the smallest error obtained in referential studies was 0.26 BCS. Hence, we conclude that assessing all eight body parts in the vision-based body condition scoring increases the BCS prediction accuracy significantly.

Classification Method for Cows' Body Parts in RGB-Depth Images Based on Template Matching

Nan Jia[1,2], Peter Groot Koerkamp[1], Gert Kootstra[1], Zhengxiang Shi[2], Songhuai Du[2]

[1]China Agricultural University; [2]Wageningen University, Farm Technology Group

Body parts classification is a basic tool to distinguish body parts and to analyze specified fine features on each body part. Despite the fact that pattern recognition methods for human behavioral analysis have flourished in the last decade, computer vision analysis of cow body parts is scarce in literature, and most of cow body detection in video images recognizes and segments the cow as a whole, not using all of the body part information. This study presents a computer vision tool that automatically segments and extracts cows into 8 body parts: head, torso, udder, left foreleg, right foreleg, left hind leg right hind leg and tail. By doing so, more detailed information on e.g. cow behavior or cleanliness can be derived.

In this study, 1421 side-view images of 113 cows and 859 back-view images of 75 cows were collected in a Chinese research dairy farm using a Microsoft Kinect™ V2 RGB-depth camera installed at the side of the aisle in a barn; in all the frames the cows are walking or standing. We propose a method for body parts detection using an improved version of template matching. The entire image process includes automated video recording, image restoration and pre-processing, skeleton extraction, template matching, recognition of right or left leg, calibration, and body parts identification.

The average classification accuracies for body parts in side-view and back-view images were 87.96% and 72.95%, respectively. Results indicate that it is possible to automatically detect and extract body parts from RGB-depth images without any manual interference.

Lameness Recognition of Pigs Based on Skeleton Analysis and Gait Energy Image

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Jiangsu University, China, People's Republic of

Animal walking gait can reflect its health status. In order to identify the normal walking and lame walking of pigs, a lameness recognition method based on skeleton analysis and gait energy image was proposed in this paper. Firstly, the binary silhouette images of pigs were extracted, and the gait cycle of pigs was detected by the method of skeleton analysis. Then the gait energy images of pigs were synthesized in one gait cycle, and the gait features of pigs were characterized using the gait energy image (GEI). Two-dimensional principal component analysis (2DPCA) method was used to reduce the feature dimension of gait energy image of pigs. Finally, the nearest neighbor classifier was designed to recognize the normal walking and lame walking of pigs. In order to verify the effectiveness of the proposed method, the pig's gait image database was established. The proposed method were tested using the samples in the database. Experimental results showed that the recognition rate of normal pigs is 91.0% and that of lame pigs is 95.5%. The total recognition rate is about 93%. The main causes of the error in normal pigs are that some of them sometimes would walk or stop alternatively, and their heads would shake considerably. This study provides a new method for identifying pigs with abnormal gait and lameness using computer vision technology.

Robotic Systems in Open Fields

Automatic Detection Of Broccoli Heads In Open Field Using An Artificial Neural Network

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Visual observations to assess the quality of open field crops are labour-intensive and subjective. One instance of a crop which requires frequent visual observations for phenotyping, disease scouting and selective harvesting, is broccoli. In this research, an image acquisition module was built to acquire images from field grown broccoli. Computer vision software was developed to detect the broccoli heads in the RGB images as a basis for automatic and objective quality assessment. Object detection in these top-view images can be challenging as broccoli heads can be partially occluded by surrounding leaves. The goal of this research was to investigate if machine learning has the ability to deal with these environmental disturbances. As such, the object detection performance using machine learning was compared to traditional threshold based computer vision. A pixel-based artificial neural network, more specifically a multi-layer perceptron (MLP) with 40 hidden layers, was developed to classify image pixels in either broccoli or background. Five image features were used to train the MLP. Three features were colour-based and two texture-based. The MLP classifier was trained on 197 images which were randomly selected from a dataset containing 30.000 field images. The object detection method merged the connected MLP classified broccoli pixels into regions and selected the broccoli head objects with a threshold on the region size. The computer vision was validated on 295 independent images, containing 219 broccoli heads. 204 broccoli heads were detected, compared to 169 heads when a threshold based computer vision script was applied on the same test set. The corresponding false positive count was 2 versus 15. The MLP-based software showed a 94.8% detection accuracy, which was an 14.4% increase compared to the threshold based computer vision. The results show the potential of machine learning to detect crops in open field for automatic and objective quality assessment.

Virus Infection Detection in Hyperspectral Images of Potato Plants using Deep Neural Networks

Hendrik De Villiers, Pieter Marinus Blok, Gerrit Polder

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Virus diseases are one of the major problems in the cultivation of seed potatoes. Once found in the field, diseased potatoes lead to rejections of the tubers, resulting in a large financial loss. Much damage occurs when the disease is not detected in an early stage, which is often the case. Hyperspectral images provide detailed localized spectral information which could be useful in detecting regions of a plant which exhibit symptoms of viral infection. Deep neural networks have been shown to be effective in the process of simultaneously learning both informative features and the process of localizing these features within a given image. We demonstrate these methods on a set of hyperspectral line scan images of potato plants imaged under field conditions. Ground truth is based on GPS positions of diseased plants, marked by crop experts and provided on the level of individual lines. A fully convolutional neural network (FCN) architecture is employed to predict the health status of the plant at each given captured line. Tests on potato varieties other than that in the training data suggest the network partially generalizes to these other varieties. Results on the Vermont variety exhibit a high true positive rate exceeding 90%. An analysis of false positives shows that the majority of false detections originate from plants bordering known sick plants, possibly caused by the inaccuracy of the mapping between the images and GPS positions of the diseased plants. Testing on another variety (PCR11) produced similar results as the Vermont case in an earlier week, but showed poorer results in a later week with a 78% true positive rate and the majority of false positives lying in healthy regions. The results of a sensitivity analysis suggest that the network is primarily making use of spectral information, rather than spatial contrasts.

Agrosense, a Real-Time Height Compensation Mechanism for Crop Monitoring Applications

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Transferring sensing and monitoring technologies from applied research to practical applications is an important aspect of innovative precision agriculture. Until now several attempts can be found in context of automatic crop monitoring and proximal sensing. Various problems arise when adapting these solutions to real environments conditions, for instance to uneven and steep terrains in apple orchards and vineyards present in alpine regions such as South Tyrol (IT). Measurement data is influenced by shocks, vibrations and geometrical misalignments transmitted from the carrier vehicle or terrain, and can be improved with either Software or Hardware methods. ByeLab is a mobile laboratory, designed to carry out automatic crop monitoring tasks by applying techniques of ground sensing. It consists of an electric driven bins carrier and a support system for several installed sensors: 6 OptRx, 2 LiDAR, 1 RTK-GNSS. This paper presents an extension of this system with AgROSense, a sensor platform in

combination with a real-time height compensation mechanism for sensors. The feedback for the control algorithms is composed by an AHRS measuring angles and a laser-sensor used to gather the height reference from the moving sleigh of the mechanism to the ground. In order to overcome disturbances, the support system of the vehicle dampens high frequency vibrations whereas the mechanism evens out low frequency movements with high amplitudes. A controlled environment was used to validate the system whereas the uneven terrain was simulated using well-defined obstacles. The validation was carried out comparing LiDAR scans obtained by the system, with and without AgROSense, and the scans collected by a terrestrial laser scanner as a reference. First experimental results have shown the capability of the system to carry out more precise measurements than compared with those made without real-time compensation. Further investigations and real environment experiments are planned in future work.

Data Acquisition Platform for Collecting High-Quality Images of Cultivated Weeds

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In modern agriculture there is an increasing focus on a reduction in herbicide usage. As a result, machine learning algorithms is applied in several weed detection and classification applications. To make robust detection and classification, training data for such algorithms must include a wide variety of weed species and present diversity in the appearance of these. Ideally, training data should be collected in real-world fields to reflect reality most accurately. However, acquiring high quantities of in-situ images of all weed species plus annotation of these is time consuming and prone to human errors.

This paper presents a data acquisition platform providing a reliable and efficient way of collecting high-quality images of weeds, cultivated in a controlled environment. The platform is established at a semifield area at Aarhus University, Research Center Flakkebjerg. The platform itself consists of an imaging acquisition system mounted on a camera dolly that moves on a railing system above a set of pot experiment tables. The acquisition system is configured to automatically collect images when the dolly is moved above the cultivated plants. Each of the collected images covers approximately 0.28 m^2 and have a ground resolution of ~6.6 pixels/mm. The controlled environment makes additional annotation unnecessary, thereby reducing the risk of errors. Diversity in plant appearance have been achieved by applying different growth conditions. The platform has been used to acquire images each day of 39 different weed species, divided over two growth seasons: one spring and one autumn. The weeds are cultivated under three different growth conditions, from emergence to the 6 to 8-leaf stage. The spring season includes 18 weed species observed over a period of 36 days and the autumn season includes 21 weed species observed over a period of 60 days.

Design Of Simplified Optical Devices For The Agrofood Sector: Case Studies From Pre-Harvest To Post-Harvest

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The Italian agri-food system is mostly characterized by small and medium-sized enterprises (SME). Due to their size and the small possibility of significant investments in analytical instrumentation, they are characterized by the lack of crucial information for the management and control of their processes. The main parameters related to important information to better lead the decision-making stages of the production process (e.g. decide the harvest time, monitoring fermentations, monitoring shelf life and post-harvest life, etc.) need to be measured in a simple, quick and objective way.

From this point of view, the optical techniques based on visible near-infrared spectroscopy (vis/NIR) are an established, simple and rapid application for the analysis of many productions quality related parameters.

A number of vis/NIR and NIR optical systems are available on the market. These devices potentially represent a valid support to the various supply chains. Nevertheless, the available optical systems are complex and expensive devices and their real use in SME is still very limited.

The aim of the research was to design, build and test concepts and prototypes of low-costs and user-friendly devices useful for different applications from pre-harvest to post-harvest. Tests for the selection of specific wavelengths for the analysis of grapevine leaf water status, for grape and blueberry ripening evaluation, and for senescence monitoring of fresh-cut baby leaf salad during shelf life were conducted. In particular, for the grape ripeness analysis a Light Emitting Diode (LED) based prototype equipped with a customized optical fiber for the measurement of the spectral reflectance at four specific wavelengths (630, 690, 750 and 850 nm) was proposed and tested.

The use of these devices could be helpful for a more rational and objective monitoring of the products quality, leading to an optimization of the supply chains to provide a better product to the final consumer.

Implementation and Test of a Multi-functional Agricultural Robot based on Machine Vision in Nursery

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A high-performance farm machine can increase productivity. However, the current design of machine is single-functional and expensive in cost. Farmers have to rent multiple vehicles with different functions to accomplish tasks. Besides, each machine is different in its operation modes, which makes the operation time-consuming and labor-consuming. This paper aims to develop a multi-function intelligent agricultural machine installed with an embedded platform of a machine vision module to identify the location of crop and weed, soil moisture below the machine and perform the weeding, watering, and fertilizing. The platform also includes moisture sensor modules, multiplexing, decision making module, and fuzzy logic inference engine to receive the soil moisture so as to access degree of soil moisture and to define the operation procedures. The image identification scheme based on color space conversion and adaptive threshold selection are utilized to classify the weed, crop, and estimate the soil moisture. The automatic raking weed and watering device are utilized to accomplish weeding, watering, and fertilizing. The experiment results demonstrate that the machine can effectively identify different crops and weeds in outdoor filed, with an identification rate of each crop and make corresponding procedures based on image identification results, with accuracy rate up to 100%. In the future, the proposed machine can be combined with an autonomous agricultural vehicle to perform different farm tasks.

SPAD and Hyperspectral Images for Sensing Chlorosis Affection in Peach Trees

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The peach tree is one of the fruit species with the highest production in Spain. The nutritional diagnosis of the peach tree, usually based on the mineral analysis of leaves, is often late for the application of corrections before harvesting. On the other hand, the leaf diagnosis of ferric chlorosis is often imprecise, due to the narrow range of variation in leaf iron concentrations. SPAD measurements are commonly used for chlorophyll content sensing in leaves, showing relation with chlorosis development. However SPAD is measured locally. Hyperspectral images could be able to sense the evolution of ferric chlorosis on the leaf surface. Thirty-two trees, belonging to seven rootstocks, and three leaves per tree were considered for hyperspectral measurements. SPAD measurements were acquired from their leaves and flowers. Mineral composition (Al, B, Ca, Cu) was also determined. The SPAD appears correlated with several minerals in leaf: Ca, S, Fe, Cu and Sr, restricted to Ca and Sr when comparing the SPAD with the mineral composition in flower. There appears to be a very large dispersion among SPAD values for the same rootstock which points the existence of isolated individuals with leave chlorosis.

According to experts identification SPAD>=32 was set to sound trees, SPAD<24 was label as severely affected by chlorosis, and intermediate level in-between. Comparing the average spectra of sound leaves with affected ones, three features were observed; a) an increase of reflectance from 500 to 600 nm, with a peak around 550, b) a red-edge displacement to the left, and c) an overall weak decrease of reflectance at NIR range probably due to the increase of the chlorosis. Several authors notices that red-edge moves towards left with the decreasing of chlorophyll content. Besides, an increase in the visible range could be caused by a decrease in chlorophyll due to nutritional stress.

Robotic Systems in Pastures

Novel Systems for Pasture Characterization Using RGB-D Cameras and UAV-Imagery

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Reliable assessments of grassland growth and development enable accurate and timely management decision taking (e.g. application of slurry or grass cutting). In Norway, these assessments are commonly done by farmers, based on their experience, which is subjective and possibly erroneous. Current machine vision and geospatial technologies enable objective, time flexible and cost-effective plant monitoring, although, little implementation has been achieved for grasslands. Therefore, we evaluated the capability of two procedures to study and model pasture architecture in 3D, aiming at computation of grass height and biomass. Using the Microsoft Kinect v2 sensor, on-ground depth images were acquired on selected 1x1 m plots and reconstructed 3D point clouds via Kinect Fusion algorithms. Paralelly, a low-cost unmanned aerial vehicle (UAV) captured alongside a set of aerial Red-Green-Blue (RGB) images with 90% field overlap and the Structure from motion (SfM) technique composed the mosaic image, including also a 3D model of the study plots. Image data and 3D models were processed with object-based image analysis for estimation of grass heights and other parameters, to be compared with ground-truth observations (e.g, plate-meter measurements, manual cuttings and determination of dry weight biomass). A total of 20 sampling plots were measured in two experimental fields (10 plots per field) at the NIBIO Særheim Research Station, containing grass mixtures of importance for local farmers and of varying sward densities and plant heights. A higher accuracy of the Kinect-based procedure was reflected on the results to model grass architecture and compute plant height. However, the UAV-based procedure required significantly less time for data acquisition and elaboration of 3D models. We point out some advantages and limitations of each procedure. The use of UAVs facilitated operability and coverage of large surfaces, compared with on-ground systems. However, the on-ground sensing captured fine details of plants, producing more accurate measurements.

Estimating Pasture Nitrogen Content using Thermal Images

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This study was developed to explore the possibility of estimating nitrogen content in grasses using thermal images. The research was conducted in a farm condition and it is the first step ofusing (developing and testing) a smart robotic fertiliser (Nitrogen) spreader for dairy farms.

A farm experiment was conducted to determine if there is any correlation between leaf N content and the surface temperature of the herbage of the perennial ryegrass Lolium perenne. Using the thermal camera, periodic measurements of herbage surface temperature was made in conjunction with herbage cuts and analysis of dry matter for %N content. At the same time, other environmental factors such as humidity, soil temperature, and air temperature was measured.

Six treatments of soil N (0, 50, 100, 200, 350, and 500 kg N/ha equivalent) was created using urea mixed into a soil medium for this glasshouse pot experiment. Periodic measurements of herbage surface temperature was made using a mobile platform from which infra-red measurements of herbage temperature can be made from a consistent height above the pots.

For data analysis, the thermal images was analysed using Flir software to find the average temperature of the leaves. As data constitutes the core of the study, the database should be flexible, accessible and simple, for both data entry and data analysis. Subsequently, an MLR model was developed to predict nitrogen content based on herbages temperature and other measured factors. The result of this study will help to estimate nitrogen content of perennial ryegrass Lolium perenneunder different conditions, which is very critical to reduce nitrogen consumption on farms.

Challenges in modern automated Feeding Systems: Navigation Technologies

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Germany is a high-tech location, especially in agriculture with over 7.800 automatic milking systems (AMS) installed in Germany, with a clearly evident upward-trend [1, 2]. Based on the steep rise of AMS a similar development in AFS (automated Feeding Systems) seems likely. The technical advances are mainly attributed to time and labor savings for the farmer and the plan to meet nutritional and behavioral aspects of the cows. Recently Strautmann presented their study “Verti-Q”, a fully automated feeding system, on the Agritechnica 2017. Previously Schuitemaker, Lely, Hirl, LucasG and Siloking announced fully or partly automated feeding systems, so that self-driving, automatic feeding systems can be seen as a future solution in dairy industry. Challenging for most manufacturers is, that no standards for self-propelled AFS are existing, which are said to be the state of the art.

Especially the various environments on farms cause critical situations for machine operations, such as tough weather conditions. To reach the set safety level, durable sensing and a comprehensive safety concept are necessary. In preliminary tests a novel radar scanner and a laser 2D-scanner were tested. They proved to be possible solutions for navigational and safety tasks in AFS. The sensors gathered data of the environment of a farm. The acquired data were used to create digitals maps of the stable and showed the applicability of these methods. Quality data for mapping algorithms have been improved staedily with a self-designed high-complex physical system, where already Monte Carlo-filtered data has been processed with an Extended Kalman-Filter. With further progression concerning the prototyped radar-scanner and its data-processing, radar as well as laser will provide the sensory for a self-driving AFS. The next step will be a risk assessment based on the ISO 25119 for the Truckline AFS and further tests of the sensory under practical conditions.

Design of a Cruising Robot for Collecting Floor Eggs

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Current conveyor-type systems for poultry breeders and cage-free systems for laying hens can automatically collect eggs from the nests. However, collecting the floor eggs is a great challenge for the management and mostly require the labours to walk around and collect by hand daily. Facing the global stacked cage system is rapidly changing to cage-free systems, the challenge becomes event great. In this paper, an automatic cruising robot for picking up floor eggs was developed. It was comprised of egg grasping system, placement, driving mechanism, and UWB positing system. The detailed parameters were designed and perfected in different situations. The egg grasping system was used as the flexible material-paddle wheel, which can greatly reduce the broken egg rate. The placement mechanism was based on the vertical cross bars design, and the precision and completion rate were improved by a stepping motor. The UWB positing system can provide the position data, therefore, the automatic cruising robot would execute the stationary program. The surrounding information was precisely positioned by ultrasonic and infrared sensors, so the cruising robot can complete obstacle avoidance, collecting egg and placing them on the egg tray functions during the non-dead angle cruise.

Evaluation of Pasture Productivity and Quality in the Montado Ecosystem Using Proximal Sensors

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Montado is a silvo-pastoral system characterized by open canopy woodlands of mainly Quercus suber and Quercus rotundifolia, mingled in some areas with other Mediterranean tree species, with natural or cultivated grassland in the undercover and grazing animals. A decline of these ecosystems has been reported since the end of the nineteenth century in southern Portugal. In order to ensure a sustainable management, there is an urgent need to produce knowledge on the resilience thresholds of these systems. Monitoring of indicators for a timely evaluation of pasture variability in Montado is particularly complex and an important challenge due to the existence of different strata (soil, pasture, trees and animals). The conventional methods for determining key components of pasture productivity and quality are time consuming and expensive, hence the interest in evaluating faster and cost effective tools. Monitoring pasture productivity and quality over time is critical for defining the nutritional value of pastures and designing balanced diets for grazing animals. The aims of this study were to evaluate two proximal sensors with potential to monitor relevant variables in the Montado ecosystem and demonstrate their application in a case study: a capacitance probe and an active optical sensor (AOS). This work uses data of a dryland biodiverse Mediterranean pasture, collected at spring of 2016 and 2017. The significant and strong correlations between capacitance and pasture biomass and between normalized difference vegetation index (NDVI) measured by AOS and pasture crude protein (CP) and pasture fibre (NDF, neutral detergent fibre) can make an important contribution to determination of key components of pasture productivity and quality and to support decisions in the implementation of site-specific pasture and grazing management. This correlation can be used for the management of animal grazing intensity and calculation of feed supplementation needs throughout the vegetative cycle of the pasture.

Robotic Systems in Fruit Orchards and Vineyards:

Visual Feedback for Flight Control of an Autonomous UAV Operating Within Vineyard Rows

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In recent years there is a growing interest in the use of UAVs (unmanned aerial vehicles, “drones”) in agriculture. The common feature to all existing platforms is that they fly over the crop. Although for field crops there is obviously no alternative, the motivation of the proposed work is that in orchards and vineyards much more information could be obtained by flying the UAV within the tree rows. Accordingly, the present work focuses on the development of the sensing methodology and algorithms necessary in order to enable autonomous flight of a small UAV within rows of trees or vines. Such autonomous flight requires accurate estimation of the UAV position and heading relative to the tree/vine rows. Although ultrasound sensors which are commonly installed on small UAVs for obstacle detection work well for detecting large and strongly reflective objects, they do not provide reliable estimation of distance to sparse and irregular objects such as leaves canopy. In the present work we investigate the use of a simple vision system for this task. The system consists of a forward-looking and a backward-looking cameras. In each image each tree/vine row appears roughly as a trapeze whose properties depend on the camera position and/or orientation. Although one camera does not provide enough information for estimating both camera position and orientation, this can be

achieved by combining the information of the two cameras. The image analysis procedure we have developed is robust in respect to strong illumination variations and background changes, and the accuracy of the position and heading estimations appears to be satisfactory for autonomous flight control in vineyards.

Fruit Detection Using Mobile Terrestrial Laser Scanning

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The development of reliable fruit detection and localization systems is essential for future sustainable agronomic management of high-value crops. Up to date, most proposed systems on fruit detection and characterization are based on RGB cameras and thus affected by intrinsic constraints, such as variable lighting conditions and camera calibration. This work presents a new technique that uses a mobile terrestrial laser scanner to detect and localize fruits regardless of the prevailing lighting conditions and without the need of a previous calibration. An experimental test focused on two Fuji apple trees (containing 139 and 145 apples each) was carried out. A 3D point cloud of this scene was generated using a Velodyne VLP-16 LiDAR sensor synchronized with a RTK-GNSS receiver. A reflectivity analysis of tree elements was performed, obtaining mean reflectivity values of 28.9%, 29.1%, and 44.3% for leaves, trunks, and fruits, respectively. These results suggest that the reflectivity parameter can be useful to localize fruits in the tree. From this knowledge, a three-step fruit detection algorithm has been developed: 1) reflectivity thresholding to remove most of the leaves and trunks from the original point cloud; 2) statistical outlier removal to reduce noise; 3) connected components clustering using a density-based algorithm. By applying this algorithm to our dataset, a localization success of 85%, a detachment success of 78.8%, and a false detection rate of 15.2% were obtained. These detection rates are similar to those obtained by current RGB-based system, but with the additional advantage of providing direct 3D fruit location information (global coordinates) which is not affected by sunlight variations. It can be concluded that LiDAR technology and, particularly, its reflectivity information, might have potential use in fruit detection. Future work should include the application of this fruit detection technique on a wider range of crop types. add text in remarks!

Vibration Analysis and Canopy Adaptation of Citrus Tree for an Efficient Harvesting with Canopy Shaker Technology

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The mechanical harvesting of juice oranges can contribute to enhance profitability of farms and solve the problem of labour availability. The growing demand of the juice market generates the need for more efficient harvesting system. The canopy shaker systems are a current technology used to detach the fruit from the tree by means of the interaction of machine rods with the tree canopy. Since the most of citrus production is hand harvested, a mutual adaptation between machine and tree is requires for an efficient result. The objective of this work is to establish recommendations to reach high values of fruit detachment efficacy able to eliminate a sequent hand harvesting process. Field tests were carry out with a lateral tractor-drawn canopy shaker in four commercial plots of sweet orange in south of Spain. The canopy vibration during the harvesting process was measured with a set of triaxial accelerometer sensors with a datalogger placed on bearing branches in 90 trees. The vibration process, fruit production and branch properties were analysed. Vibration parameters showed a large variability in different points into the tree canopy. The harvesting efficiency values were reduced from an average value of 85% in zones of canopy in contact with rods to a mean value of 27% in zones without direct contact. The improvement of fruit detachment efficiency is possible if both hedge and machinery were mutually adjusted. The hedge should be training to facilitate the rods access and placing the fruit production on the outside of the canopy. The machine, working at mean frequency value of 4.1 Hz, must to produce a high level of resultant acceleration (100-200 ms-2) in the branches during a period of time higher than 0.921 s to reach a 100% fruit detachment.

A Study on Pick-Cycle-Times of Robotic Multi-Arm Tree Fruit Harvesters

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Robotic tree fruit harvesting is still at a pre-commercial stage, despite active research for at least 30 years. One reason is that fruit picking efficiency and fruit pick cycle times (PCT) are still inadequate for cost-effective operation.

This paper studies PCT as a function of the number of robot arms used for picking. A simulator modeled the kinematics and dynamics of a harvester comprising identical, independent, non-interfering arms. Each arm moved inside a ‘cell’ in an array configuration and picked fruits only from the canopy volume allocated to it, in a sequence that minimized arm travel time. Each tree was harvested independently, while the harvester was static in front of it. Digitized models of fruit-bearing, high-density trellised pear trees were used. Individual fruit distributions were non-uniform and varied significantly among trees. Such yield variation can introduce significant inefficiencies in multi-arm robot harvesting. Two scenarios were considered: A) all arm cells had the same size; B) cells were unequal and optimally sized to contain approximately the same number of fruits. Scenario (B) serves as an ‘upper bound’ on performance, since all arms harvest the same load and finish almost together.

Results showed that in both scenarios PCT followed a power law; it did not drop linearly as the number of arms increased. Overall, the PCTs of scenario A were three times worse than the corresponding PCTs of scenario B; this is the result of non-uniform fruit distribution. A ten-fold decrease in PCT (from 4.6 s to 0.46 s) was only possible with optimally sized cells and at least 14 arms. Achieving such low PCT with uniform cells required more than 40 arms. These results indicate that achieving low PCTs for cost-effective fruit tree harvesting requires many arms that must be carefully load-balanced in the presence of changing, partially known fruit distributions.

Estimation of Vine Shoot Morphology and Volume Based on Computer Vision and Image Processing

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While various automated techniques exist for the assessment of vine vigour and vegetative growth (including remote/close sensing NDVI measurements and LAI estimation), manual ones (pruning weight, shoot count) remain the reference methods. However manual vigour estimation is a very time-consuming task that is usually limited to experimental studies and that cannot be carried out routinely for vigour mapping in a production context. This work presents an automatic method to estimate the vine shoot volume and pruning weight, based on an embedded computer vision system mounted on a tractor and image analysis algorithms. The algorithm can also determine vine shoots morphology i.e. diameter and length. The method can easily be implemented in daylight and it is fully automated.

The image acquisition system is composed of one camera, two synchronized flashes and a reflective panel designed to produce over-saturated images where shoots appear as dark objects over a quasi-uniformly white background, without shadowing problems. The shoots are segmented using grey level thresholding and morphology-based filtering. Metallic wires are removed using orientation information. The shoot axes and lengths are detected using skeletonization and the distance transform is used to determine the local shoot diameter and section area in every point of the shoot axes. The shoot volume is determined by integrating the local shoot section along the skeleton.

The method was tested on images acquired on a parcel of vines in the Pessac-Leognan area, France. A total of 300 vine plants were taken in photo. The estimated shoot volumes per plant were correlated with manual pruning weights and NDVI measurements made by remote sensing during the previous growing season.

The first results show a promising correlation between the estimated shoot volume and the vine vigour. Future work concern a more thorough characterization of shoot morphology.

Fast Method For The Weeds' Impact Evaluation On A Field Crop Using Smartphones.

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The quantity and type of weeds plants influence the grain yield and the quality of the wheat, especially in organic farming. The knowledge of type and amount of weeds and the availability of precise reading and decision-making tools are important factors for agronomic management both in conventional and organic farming. The information technology and technologies available today allows for cognitive investigations on various approaches. Promising studies are being conducted for the education of machine learning approaches such as neuronal networks or classification and regression trees for the recognition of the species. However, farmers presently lack of equipment for automatic weed identification and location and frequently use large amounts of active ingredients, or other mechanical means of weed containment, both of which have a high environmental impact and great economic commitment.

The goal of this work is to develop an assessment methodology for field crops, able to detect unwanted grasses from images taken by a smartphone. The methodology is based on the analysis of the RGB and localization information available on most of the smartphones available on the market. An image reading algorithm was set-up with the R statistical processing program (The R Foundation for Statistical Computing) through which the R, G and B matrices were studied, and the crop and weed' percentages were estimated. Sampling were carried out in various locations in three successive moments and, at the same time of the collection of picture, weed biomass and individuals were measured. The surveys were repeated on the same positions thanks to the smartphone geolocation.

The present work reports the results related to the processing of the pictures collected in the geo-localized sampling points and shows the correspondence with the on-the-spot evaluation, in order to indicate the reliability of this fast system to indicate the presence of weeds on the crop.

Robotic Systems for Plant Observations

Identification of Reflected Spectral Related to Plant Circadian Rhythm Using Maximal Information Coefficient

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Plant factories have attracted attention as a breakthrough to solve the food production crisis. In the plant factory, there is an advantage that the light-dark cycle can be flexibly controlled, so that the circadian rhythm in plants can be regulated by light conditions and plant growth could be maximized by matching the circadian rhythm with light-dark cycle. However, the circadian rhythm is difficult to measure without destruction of plants, e.g. analyze of gene expression. In this research, we focused on hyperspectral camera (HS camera) to measure the circadian rhythm nondestructively. HS camera is an instrument that analyze the reflected light from an object as high-precision wavelength information. In a previous study, we have found that the internal time of the circadian clock (circadian phase) can be estimated by combining HS camera and machine learning, but the effective wavelengths for the estimation has not been clarified.

Here, we identified wavelengths as indicators of circadian phase by analyzing all combinations of two different wavelengths. Green perilla (Perilla frutescens) was grown and measured every 2 hours for 2 days. Maximal information coefficient (MIC) was used for all combinations of 525 nm to 900 nm (25 nm interval) to evaluate the association between two wavelengths. Furthermore, we constructed timeseries data of MIC (timeseries-MIC) and figured out that the correlation between timeseries-MIC in 1st and 2nd days are maximized when two wavelengths were chosen from photosynthetically active radiation region (400 nm to 700 nm) and near infrared region (700 nm to 900 nm). This study suggests that the circadian phase can be measured by two different wavelengths of light reflectance on leaves.

Flower and Bud Detection of Gerbera L. Using Faster Region-Based Convolutional Networks.

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In flower production, the total number of flowers and buds are counted to obtain the plant load, which is an important indicator for the expected future harvest and plant health. For production of gerbera flowers currently this is manually done once a week by the grower, taking into account any bud or flower on a plant having a size above 20 mm. Due to the high labour intensity, only 4 plants/ha are currently monitored and results are extrapolated for the entire greenhouse. In order to have a more representative measure for plant load at lower labour cost, potentially a load for each individual plant, a machine vision solution was explored aiming at application in an autonomous mobile platform. To enhance the density of plant load determination, a measuring system was developed to monitor the crop on m2 level by observing the crop from above. An RGB camera (Posilica GT2050C, Allied Vision Technologies) was mounted on a mobile platform with a high intensity xenon flash light (MVS-5002, PerkinElmer). The mobile platform drives on the pipe rail system in the greenhouse, taking an image of the crop every 70 cm. Images were taken for 6 rows in 6 sections, acquiring 700 images of the crop. In the images all flowers and buds were annotated with bounding boxes to train a Faster Region-Based Convolutional Network (Faster-RCNN). The network was applied to extract the number of buds and flowers per image. Due to occlusions, a bud and flower visibility in the images of 87.4% was achieved compared with manual counting. Preliminary classification results of the faster R-CNN network show a precision of 0.92 and recall of 0.75. Results are an important step towards increasing labour efficiency and support improving yields for flower production.

Monitoring Crop Status Using Hyperspectral Imaging

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One of the challenges in modern greenhouse horticulture is to optimally convert light into a harvestable product, such as tomato fruits. Leaves are essential in this process, via (1) assimilate production via photosynthesis and (2) the temporary storage of assimilates before they are transported to the fruits. In order to apply the appropriate crop and climate management actions, greenhouse growers could benefit from knowledge about the assimilate status of the leaves. Currently, there is no monitoring tool available that can provide growers with these data. Therefore, we studied the application of hyperspectral imaging to monitor crop status non-destructively.

In a greenhouse experiment, 5 tomato varieties were grown using 9 different treatments resulting in a large variation in chemical composition. Leaves were harvested, and hyperspectral scans were made in the VIS/NIR (400-1000nm) and NIR (900-1700nm) range. Subsequently, ground truth measurements were performed, such as chlorophyll, sugar, acid, starch, dry matter content and nutrients (K, Na, Ca, Mg, N, P, Fe, Mn, Zn, B, Mo and Cu). Partial Least Square (PLS) regression shows high correlations ($R2 > 0.95$) for VIS/NIR and NIR hyperspectral images and dry matter content and for VIS/NIR images and chlorophyll. Starch and sugar contents can be predicted by NIR images ($0.74 < R2 < 0.90$). For nutrients, Ca and N had the best correlation in NIR ($R2$ of 0.78 and 0.82 respectively). These promising results show that it is possible to develop a tool that growers can use to monitor crop status instantaneously and decide on the proper cultivation actions and climate management in the greenhouse.

Comparison Of Different Approaches In Estimating The Leaf Biomass In Romaine Lettuce By 3D Imaging

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The evaluation of the plant biomass and leaf area growth-rate is a crucial indicator for feedback on the management of production process in vegetables especially aimed for the ready-to-eat salads market. The non-destructive assessment of growth-rate is based on top-view color imaging which enable to estimate the plant biomass by measuring the projected area of the canopy at different points in time. The obtained accuracy becomes more limited as progresses the stage of growth, due to leaves overlapping and to occlusions of plant's top-view. The recent introduction of cost-effective time-of-flight cameras with three dimensional (3D) capability may enable a valuable step ahead towards an accurate and fast technique for monitoring leaf vegetables growing at greenhouse and field scale. The experiment consisted in an in vivo 3D imaging technique on undisturbed Romain lettuce potted plants at different growing stages. Top-view color and depth images (RGB-D) were obtained with a Kinect V2 (Microsoft, USA) in a greenhouse setup. Immediately after the acquisitions, each lettuce plant was destructively harvested to determine the total area of detached leaves and the corresponding fresh weight of the biomass. The RGB-D derived point-cloud of each plant was processed to extract the canopy volume and to estimate leaf area and biomass with two different approaches. In one case, single leaves were segmented with a region growing algorithm based on surface smoothness and colour similarities in the point-cloud. For all the single leaves the area was then calculated considering local surface orientation and finally added to obtain the plant leaf area. The second approach, based on concave hull volume, enabled to obtain the smallest polyhedron containing the canopy, and to compute its surface area and volume. The results obtained with the two methods correlated fairly well with fresh biomass, even at more advanced growing stages with $R2=0.77$ and $R2=0.84$, respectively.

A 3D Low-Cost Photogrammetry Method for Weed Plants Modelling

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New methods for plant phenotyping are crucial nowadays in basic and applied plant research. Plant phenotyping allows gathering information about plant architecture, which is fundamental to improve plant characterization, plant selection, treatment or agronomical management. In this sense, 3D processing algorithms and new devices for plant modeling are continuously arising and they are expanding rapidly to morphologically characterize plants. However, there are still some technical aspects to be improved, such as an accurate reconstruction of the end-details. The proposed study adapts low-cost techniques, i.e. Structure from Motion (SfM) and MultiView Stereo (MVS) for the 3D reconstruction of plant models. Different weeds with differential shape and architecture were selected for modelling. The capabilities and limitations of these methods were compared to accurately extract various parameters related to the morphology of these weeds. Plant reconstruction was made applying SfM to an input set of images covering each individual weed. Two rounds were done during the image acquisition process which guarantees a minimum overlapping between images of 90%. After acquiring the images, the actual height of plants was measured. The images were processed to create a dense point cloud using MVS to obtain a 3D polygon mesh. The created models were compared with

ground truth data of plant height and leaf area index. The results showed that each individual plant was reconstructed properly, with only small parts missing. Some errors at the end of the leaves and branch borders occurred and some part of the reconstruction did not show end details, mainly in the monocot weeds. The analysis of estimated and measured plant heights and LAI showed good values in every case.

Evaluation Of The Potential For Automatic Herbicide In Wheat Crops

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In wheat crops, the weeds produces losses of production which, depending on the degree of weeds can be up to 70%. Weed control is a component of the technology of any crop, and the share of these costs in the production expenditure structure is 15-20%. In conventional farming, weed control is done by uniform application over the all surface of the herbicidal mixture. Although the herbicide is applied uniformly over the entire surface, the weed area is less than half. In this context, research was based on checking the automatic precision herbicide only where weeds are present, based on image processing. The research was carried out in the Romanian Plain where, in the wheat culture, because of the pedoclimatic peculiarities of the monocotyledonous species, it is insignificant. The objective of the research was to compare the conventional method of uniform application of herbicides on the entire surface with the automatic automatic method of weed control method, by applying herbicides only where the weeds are present on the basis of image processing. For automated combat was used a mobile platform on with was mounted on which a Raspberry development board was mounted to which a PI Noir camera was connected for image acquisition.

After processing the image according to the presence of the weeds, an electrovalve is actuated, which will administer the herbicide. The OpenCV (cv2) library was used to analyze and process the images, so Excess Green was used to separate the green background color. Image segmentation is done by detecting contours of green areas (plants) and Canny for contour detection. Hough transformation (cv2.HoughLines standard) was used to trace the lines. In order to correlate the moment of image acquisition with the moment of nozzle opening, the data from a Hall sensor mounted on the wheel with optical corrections.

Robotic Systems for Remote Sensing in Open Fields

Weed and Maize Classification in Early Growth Stages Based on Near-infrared Snapshot Hyperspectral Imagery

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This study explores the potential of a novel hyperspectral snapshot mosaic camera for weed and maize classification. The image processing, feature engineering and machine learning techniques were discussed when developing an optimal classification model for the three kinds of weeds and maize. A total of 185 spectral features including reflectance and vegetation index features were constructed, and feature selection algorithm was used for screening important features to classify weeds and maize plants. Furthermore, the performance of support vector machines (SVM) and ensemble classification models with different feature combinations were compared for obtaining optimal classification model. The results of testing set showed that the optimal of SVM model with just 10 features selected by ReliefF algorithm could achieve 81.0%, 75.7% and 96.2% for model accuracy, overall weeds recognition rate and maize recognition rate respectively.

Robust Online Soil Roughness Measurement Using Stereo Vision

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Soil Roughness is an important agronomic soil parameter. It influences plant emergence as well as plant growth and plays an important role in soil erosion. The main goal at point of seeding is to get a good settled seedbed which is not to rough crumbled for good plant emergence and not to fine crumbled to avoid soil erosion and silting. These agronomic properties at seeding can be determined by soil roughness.

Thus, a robust method for soil roughness measurement is needed for mapping the soil roughness on fields and to control machines according to the site specific roughness. Tillage machines might be controlled online during field work to get more homogeneous and more efficient working results. Furthermore, roughness maps, generated with overlapping GNSS data, might be used for later precision farming applications, for instance site specific fertilizing.

Our proposed method is based on cost-effective stereo cameras and mobile processors. The method can be implemented in real time on a moving machine. Challenging environmental influences, like dust, lighting and vibrations, have been taken into account. The resulting roughness indices consider directional roughness, like stripe patterns. These constant soil patterns are generated by the directed movement of the tillage machine.

To evaluate the method, the roughness measurements and aggregate size of the soil were compared in different field tests. The robustness of the method was investigated in various tests under different soil conditions. Also machine parameters which influence the resulting roughness, like driving speed or PTO speed, were evaluated. Finally, the influence of soil roughness on the plant emergence was evaluated.

Towards Automated Field Detection Of Alternaria Solani Using Hyperspectral Imaging

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Alternaria solani, which causes early blight, is a pathogen notorious for its economic damage in potato cultivation. Crop protection products need to be applied regularly, may have an environmental impact and imply a considerable cost to the farmer. Localized treatment has been reported to reduce the application of crop protection products and hence lessen the environmental and economic burden. In this paper, hyperspectral imaging is proposed to automatically detect A. solani in field conditions to allow the generation of task maps for site specific spray applications. A proximal sensing platform (hypercart) was constructed for fully automated acquisition of hyperspectral images in the field under controlled light conditions. A protocol was created to normalize the acquired hyperspectral images. During the growing season of 2017, 32 potato plants in four field plots were inoculated with A. solani and monitored before and during visual disease expression over a period of seven days after inoculation using hyperspectral imaging. A variety of statistical analysis methods such as partial least squares – discriminant analysis (PLS-DA) and soft independent modelling of class analogy (SIMCA) were applied on the dataset to demonstrate the potential of hyperspectral proximal sensing for detection of A. solani in the field.

The variability in light intensity at leaf level resulting from the heterogeneity in leaf position made correct classification of pixels solely based on their spectra difficult. Less illuminated healthy leaves were regularly misclassified as infected or categorized as 'unknown'. Several pre-processing methods were investigated to deal with this variability in intensity, with varying success. An alternative method is to compare potentially infected spots and calculate the Euclidian distance of the centroid of infected pixels mapped in hyperspace to the centroid of the surrounding pixels. This distance could be a potential feature to distinguish A. solani lesions from artefacts and less illuminated leaves.

Sustainable Management and Yield Monitoring of an Annual Mixture Forage

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The need for sustainable intensification of fodder production to support extensive animal production systems in the Mediterranean regions requires new forms of mixtures, new forms of mechanization and the adoption of georeferenced sensory technologies that allow spatial analysis to mapping field and crop variations.

The objective of the present study was mapping a yield crop and chlorophyll indices measured by satellite of a mixture forage under no-till based on annual ryegrass and annual leguminous plants and through a soil survey attempt to point out site-specific management zones. The experiment took place in an area of 31 ha under a circular pivot in the Alentejo region, Portugal at the coordinate's 38° 53' 39''N 7° 03' 03''W.

The field was mapped for soil apparent electrical conductivity with a Veris 2000 XA sensor combined with the use of a global navigation satellite system, soil and crop samples were georeferenced in 16 different locations and normalized difference vegetation index (NDVI) evaluated by remote sensing using Sentinel -2.

Data were processed by linear model and geospatial ArcGIS software. Statistical analysis resulted in significant correlation coefficient values between biomass, dry matter yield and plant species composition and, spatial auto correlation to NDVI along the crop cycle was found. The survey carried out with the Veris sensor showed that there was spatial auto correlation for soil apparent electrical conductivity (ECa) and topography and two different areas of high and low ECa were identified. Although there was not spatial auto correlation for biomass suggesting that crop yield could be affected by other factors than soil, plant species composition concerning legume percentage was different ($p = 0,0039$) between these two areas, even though no statistical differences were found regarding grasses and other species.

Nondestructive Measurement of Soybean Vigor using Short Wave Infrared Spectral Imaging Analysis

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Shortwave infrared (SWIR) hyperspectral imaging (HSI) system was explored as a rapid and nondestructive method of soybean seed classification based on their vigor. Seed vigor is the proportion of seeds that can survive and develop into new plants under suitable conditions. Two hundred sample each of viable and non-viable soybean seeds were used in the study. The extracted SWIR data from 1000 to 2000 nm were analyzed by partial least squares discrimination analysis (PLS-DA) as a chemometric method for classification. In addition, various preprocessing methods and variable importance in projection (VIP) method as a variable selection method were applied to optimize the model performance. The PLS-DA showed the classification accuracies of more than 90% for the calibration and validation sets. The results show that the HSI technique is a promising method for nondestructive and rapid measurement of soybean vigor.

Robotic Systems: Various Topics

Smart Irrigation System for the Sustainable Watering of Urban Lawns

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The green spaces, gardens and urban grasslands play a very important role in big cities since they help the regeneration of air polluted by the peoples' daily activity. Although the automatic irrigation systems of these natural spaces are beginning to be improved, there is usually a fixed irrigation routine that does not take into account meteorological aspects such as the fact that it is raining or that the earth contains enough moisture to ensure the correct development of the grass. Taking into account these facts, this paper presents the design, development and test of an intelligent system for irrigation control of urban lawns. The system is based on the use of a multisensor node composed by humidity and temperature for soil and air, as well as a rain sensor. The multisensor node is controlled by an intelligent algorithm that takes into account the real time values provided by the sensors and the stored data of previous measurements. The intelligent algorithm is responsible for analyzing the data and deciding on the amount of water to be used in a given area. The multisensor node is integrated into a wireless sensor network that will allow us to control areas and specify different irrigation routines for areas with different requirements. Using actual annual meteorological values of Madrid (Spain) where different water requirements are observed throughout the year, the system's operation is simulated. The results show that for a landscaped area of about 140 ha, we could save approximately the 6% of the irrigation water we would use in a fixed irrigation routine which would be equivalent to about 22 million liters of water.

Structured Design of a Novel End-effector for a Bush Trimming Robot

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The European TrimBot2020 project researches the robotics and vision technologies to prototype the first outdoor garden trimming robot. The robot navigates over different terrains, approaches boxwood plants and trims them to a desired shape. The robot platform is based on a modified Bosch robot lawnmower, which navigates autonomously using 3D-based vision scene analysis. During trimming a robotic arm is controlled by visual servo in order to trim the bush. A novel end-effector had to be designed to guarantee flexibility of the manipulator, precision of trimming and smoothness of the trimmed bush surface. This paper describes the structured design of this bush trimmer.

When faced with a design problem with many interconnecting system elements, structured design is a tool to be used to iteratively and step by step guide the designers in making the right design choices at the right moment during the different design phases. First, preliminary research is done to analyse the problem and to assess the goals of the bush trimmer. Second, the functions are determined and working principles are found and put into a coherent structure. Finally, this leads to a composition of several preliminary designs of which the most promising one is determined. This design is built as a working prototype. Next to this, 3D-CAD tools and rapid prototyping is used to test ideas along the design process.

The final design, based on contra-rotating blades, was discussed in terms of how and to what extent it met the requirements, objectives and functions found during the structured design process. Moreover, the results of lab and field tests have shown the first functional results and improvements have been identified.

A novel trimming method, by contra-rotating blades, has been found using structured design which meets the demands and limitations of other system components of the robot.

Vision-based Robotic Bush Trimming Evaluation

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Trimbot2020 is an EU project that aims at automatizing garden maintenance. The maintenance of a garden is a labor-intensive task, that is difficult to automate because of the variation in a natural environment. To the best of the authors' knowledge, there is currently no robot able to trim bushes of arbitrary shapes.

In order for a robot to handle generic garden trimming tasks, an evaluation mechanism to decide whether a given bush has been properly trimmed is needed. As the trimmed bush has a complex 3D architecture, evaluating it is not straightforward. Furthermore, trimming evaluation is inherently a subjective process, as the opinion of users on a trimmed bush is dependent on personal preference and present-day gardening fashion. Evaluation can be used as a way to improve the trimming system, or as a way to provide closed-loop feedback to modify the trimming plan. Especially the latter leads to the requirement that evaluation should be automated, to prevent that for each trimming execution a human judge is needed.

This study proposes a novel automated system for the evaluation of trimmed boxwood bushes. Our system exploits a camera and a rotation table to collect a sample of snapshots of the bush before and after robotic trimming. This allows to downscale the 3D bush analysis into a 2D problem. A framework of metrics and assessment methods was devised to evaluate the quality of the trimmed bush with respect to a target shape defined over the untrimmed bush. The proposed framework was used to evaluate the shape result for some real robotic trimming tests. Results show that that our approach allows to capture a mathematical description of the trimming quality of a bush that can be correlated with the opinion of a human observer.

Robotti – A Generic Arable Automated Tool Carrier

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The Robotti is a low cost, light weight modular platform targeted for low cost crops like maize or sugerbeat. The low cost, compared to other robotic-platforms, enables the farmers to use robotic technology in crops where the return of interest until now has been too low. The modularity allows the farmers to use the tools and implements they already have at their farm. The width of the Robotti is customized for each farmer so it matches the working width of the existing row widths.

The safety system designed for the Robotti, allows an agricultural robot to operate autonomously in the field with limited or no supervision by a human operator. The goal of operation without human supervision has currently not been achieved because, as with self-driving cars, in the case of an accident the responsibility must be placed somewhere. The Robotti toolcarrier is classified as a machine according to EU legislation and standards.

The control system consists of a multi-layered control system where safety is an inherent part of the system. The path planning algorithm takes soil-compaction into account when planning the route in the field, along with other parameters as execution time and fuel consumption. The high-level control of the movement of the robot is being developed based on design space exploration to find the optimal trajectory algorithm for robot. Initial tests based on Active Disturbance Rejection Control in the trajectory algorithm is showing promising result in challenging agricultural environments compared to well-kown control algorithms, like PID control, since the system dynamics might change.

On-the-track of Soil-borne Pathogens Using Electronic Noses

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Banana's are one of the most demanded food items in the daily human being's diets, and one of the most important crops in the world with high economic impact.

The most grown banana species in the world is denoted as Cavendish. This banana replaced the Gros Michel (GM) variety that was wiped out in the last century due to Fusarium wilt. The causal agent of Fusarium wilt is the soil-born fungus *Fusarium oxysporum* f. sp. *cubense* (Foc). Whereas GM was conquered by Foc Race 1, Cavendish banana is now threatened by Foc Tropical Race 4 (TR4). A decease that originates from Southeast Asia but is spreading towards Latin America, where most Western consumers obtain their banana from.

Geneticists have been researching for many years in trying to obtain a resistant banana variety but so far not a commercial accepted variety is identified. Due to the rapid spread of Foc TR4, a new crash in the banana industry, fully dependent on Cavendish banana, is dawning at the horizon.

This work discusses the idea that electrochemical sensors (aka, electronic noses) might be able to detect chemical compounds emitted by infected banana's plants. This hypothesis is based on the fact that infected bananas emit for instance more odours, and that stressed plants tend to release more ethylene.

To address this hypothesis a novel remote sensing system is proposed for non-invasive real-time monitoring of banana plants and infected patterns recognition. This system combines low-cost consumer electronics boards with an electrochemical sensor. Two prototypes are placed in two different greenhouse rooms with infected and non-infected banana´s plants for 24h. Preliminary results, validate the conceptual sensor framework.

Potential of a LiDAR-based automated system to reconstruct vineyard crops

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LIDAR sensors have been widely explored for the geometrical characterization and measurement of biophysical parameters of tree plantations. They are low cost and simply to operate to scan their surroundings. They are able to measure the distance between the sensor and the objects around them, providing a large spatial density of points at a very high sampling frequency with a resolution of some millimeters of error. They reconstruct 2D planes and 3D information can be acquired by displacing the sensor perpendicularly. The use of plant models allows site-specific management at different crop stages. The study evaluates of the accuracy and performance of a light detection and ranging (LIDAR) sensor for vegetation characterization using distance measurements aiming to detect and reconstruct of 3D maps of vineyards. The maps were created during winter when only branches were present and leaves fell down. The models can be used to obtain information such as height and branch volume in order to make an automated prune or relate this parameter with future yield at each location. LiDAR sensors were installed on-board of a mobile platform equipped with RTK-GNSS receiver and IMU sensor for crop scanning. The 3D map was correlated with actual, manually determined, rest of pruning weight. The result indicate that LiDAR sensors are a promising tool for vineyard branch detection with great advantages over other types of non-contact ranging sensors, such as a high sampling resolution and high sampling rates. Thus, this tool is of high interest for several scenarios even when only branches are present.

Robotic Systems Using Satellites for Yield Monitoring

Assessing the Spatio-Temporal Alfalfa yield variability Using Landsat-8 and Yield Monitor Data at field scale

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Yield mapping is considered as the first logical step in Precision Agriculture (PA). In this study a hay yield monitoring system was mounted on large rectangular baler to assess alfalfa yield while baling process. The first step was to calibrate the system under different baler working conditions (baler chamber pressure and forward speed). The system provided an average R^2=0.86. Secondly, the calibrated system was used to investigate the spatial yield variations in an alfalfa cultivated area of 23.5 ha located in the eastern province of Saudi Arabia, irrigated with a centre pivot system. The system was used to monitor harvesting during five alfalfa cuts, dated 20 Oct, 5 Dec, 16 Feb, 2 Apr and 6 May, in 2013-14 growing season. Yield monitor data were analysed by using ArcGIS software and classified into five zones (>2, 2.01-3, 3.01-4, 4.01-5, and <5 ton/ha). Additionally, the maps of the five cuts were combined in one composite map to estimate the seasonal impact of different yields.

Geospatial analysis of yield maps showed significant spatial variations in the study area while all agricultural practices (Irrigation, Planting, etc.) were kept constant. During the study period, 18 landsat-8 images were analysed and compared with yield monitor data. Results highlighted how highest correlation were for NIR reflectance, SAVI and NDVI with R^2=0.69, 0.68 and 0.63 respectively. The study highlights average yield temporally varying between cuts, but with systematic distribution trend for all cuts

within detected zones. Large yield seasonal variations, as big as 17 t/ha (almost 300% of the minimum), recall the need for an yield forecast model, to support proper agronomical input optimization, as proposed by this work.

Benchmark Of Satellites Image Service For Precision Agricultural Use

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Over the last years, the attention of satellites images providers on precision agriculture has increased, leading to an enhancement of features resolution. At present, several satellites images services exist, which provide very different products for different demands. Specifically, constellations of nanosatellites are now able to produce daily images all over the world with a spatial resolution as low as 3 m in the case of Planet Scope. Besides, Sentinel-2 constellation is now completely positioned, and it provides data free of charge with a revisit time of 5 days and spatial resolution of 10 m. The present work is aimed at comparing spatial, temporal, spectral and radiometric resolution taking into account the farmer's requirements to benchmark the major satellites images providers. Concurrently, the study analyses the computational power needs per unit of area, for each single downloadable product. Finally, the costs of single images related to the minimum purchased areas are considered.

The integration of satellite services with digital agriculture technologies could be profitable for both small and large farms. Small farmers require low-cost services, but with enough resolution to manage modest plots of land. On the other hands, big farmers, despite the possibility they have to make significant investments, can use low-resolution images, due to the relevant dimensions of the fields; additionally, big farms are more frequently equipped with variable rate technologies, and they can more easily take advantage of variability detection by satellites images.

Current potentials and challenges using Sentinel-1 for broadacre field remote sensing

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ESA operates the Sentinel-1 satellites, which provides Synthetic Aperture Radar (SAR) data of Earth. Recorded Sentinel-1 data have shown a potential for remotely observing and monitoring local conditions on broad acre fields. Remote sensing using Sentinel-1 have the potential to provide daily updates on the current conditions in the individual fields and at the same time give an overview of the agricultural areas in the region. Research depends on the ability of independent validation of the presented results. In the case of the Sentinel-1 satellites, every researcher has access to the same base dataset, and therefore independent validation is possible. Well documented research performed with Sentinel-1 allow other research the ability to redo the experiments and either validate or falsify presented findings. Based on current state-of-art research we have chosen to provide a service for researchers in the agricultural domain. The service allows researchers the ability to monitor local conditions by using the Sentinel-1 information combined with a priori knowledge from broad acre fields. Correlating processed Sentinel-1 to the actual conditions is still a task the individual researchers must perform to benefit from the service. In this paper, we presented our methodology in translating sentinel-1 data to a level that is more accessible to researchers in the agricultural field. The goal here was to make the data more easily available, so the primary focus can be on correlating and comparing to measurements collected in the broadacre fields. We illustrate the value of the service with three examples of the possible application areas. The presented application examples are all based on Denmark, where we have processed all sentinel-1 scan from since 2016.

Robotic Systems for Orchards and Vineyards

Comparison Between Ultrasonic Sensors And 2D LIDAR As Perception Systems For Autonomous Vineyard Robots

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The VineScout project aims to industrialize, demonstrate, and take to market an innovative expert field monitoring system (decision support system) embedded in a small-size and cost-efficient robot for the vineyard. Autonomous robots need agile perception systems for stoping the robot in critical situations and helping in navigation. This study focuses on obstacle and path detection in front of the robot. In a first aproximation to this problem, ultrasonic sensors were used for navigation and safeguarding. The suitability of the sonar network depended of sound cone dimensions and interference crosstalk errors. Due to echo interference, ultrasonic sensors had to be separated 90 cm, producing a gap in the central area ahead of the robot. As an alternative, a 2D LIDAR sensor was used to provide 11 measurements simultaneously. Both perceptive solutions have been compared to determine which one is the most appropriate as a safety system. Both types of sensors were mounted in the same support, measuring the range to several targets in static and dynamic tests. For the trials, the sensing frame was attached to a robot prototype, which moved over the field in real work conditions. Three types of target were considered in the trials, being the target A a cylindrical element, the target B a rectangular box and the target C a person. The results show that the 2D LIDAR complements well the deadzone caused by separating the sonar rangefinders because it provides an increased safety zone for the robot with redundancy from combining two different technologies. In all trials the LIDAR scan provided more reliable distance measurement than ultrasonic sensors regardless of surface texture and position. Further research is in progress to find out if the side sonars add reliability to the perceptive capabilities or on the contrary may be ommitted to reduce complexity.

Non-destructive Firmness Assessment of Avocado Fruit Using a Pneumatic Low Impact Device

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Avocado is one of the most rapidly ripening fruits. The decrease of fruit firmness is a physiological process that occurs during fruit ripening. Different methods have been developed and used for firmness measurement. The objective of this research study

was to test a developed laboratory prototype designed for the non-destructive assessment of avocado firmness. A set of 150 'Hass' variety avocados, size 16, were selected and divided in 5 sets of 25 avocados. Fruits were stored in the laboratory under room. In order to assess firmness decrease, every day measuring session a set of 25 avocados was measured, destructively and non-destructively. The non-destructive firmness measuring prototype was an impact device with a pneumatic low mass cylinder. The final rod of the impact devise has a vacuum jamming system capable to be adapted to the irregular fruit shape. The accelerometer located at the base of the rod registered the deceleration curve, three non-destructive parameters were obtained. Non-destructive parameters registered from the prototype were highly correlated to the destructive firmness. A multiple regression model explained destructive firmness according to the non-destructive parameters from the prototype (R2=77.4 %).The designed prototype is capable to assess avocado firmness without damaging the fruit. Further research should be done in order to improve the adjustment of the prototype to assess avocado firmness.

Comparison Between Different Spatial Resolution Satellites Images For Viticulture

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Knowledge of spatial variation of vegetative vigour is essential for site-specific management and variable rate application. Specifically, precision viticulture requires continuous monitoring of the vigour due to the mutable condition during the year and to frequent treatments (10 to 15) during the growing season. Over the last few years, several solutions for vegetation variability surveying have been proposed, mainly based on optical remote and proximal sensing. In precision viticulture, images from remote sensing are influenced by inter-row spacing, which can somehow mask or distort field variability. Analysis of high-resolution satellites or UAV imagery are not trivial, due to the computing power needs, however inter-row spacing can be in these cases recognized, segmented and eventually removed. On the other hand, medium resolution satellites imagery does not allow identification of single rows, while they can easily provide general averaged information. The spatial resolution of the images plays a preeminent role in vineyard variability sensing and understanding.

In the present work, vineyard variability is evaluated through vegetation indices, which were estimated taking advantage of multispectral images at different resolutions, from Planet Scope, RapidEye and Sentinel 2 satellites respectively providing 3, 5 and 10 meters pixel sizes. The experimentation took place in a 5 hectares vineyard located in Northern part of Italy. Data were compared with UAV images, opportunely re-sampled in order to fit the spatial resolution of different considered satellites. The comparison was carried out considering references statistical parameters calculated on the basis of spectral images. Fast Fourier transform, and root mean square was been considered to exploit differences and relation between sources images.

Data Management System for New Harvesting Technologies Applied to High Density Olive Orchards

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Olive harvesting is usually carried out by trunk shakers, mainly for intensive olive orchards. The lack of tracking systems adapted for olive harvesting purposes lead this crop to have a gap of information that makes difficult to develop new harvesting technologies based on knowledge. Machinery tracking provides a highly useful data flow that enhances decision making processes for olive growers and technicians but gathered data should be automatically processed. Tests were performed on an intensive olive orchard 7 by 5 m spacing. Machine remote monitoring platform (MRMP) was mounted on a straddle harvester prototype based on trunk shaking. MRMP consist on pressure switch that detected when the harvester was shaking. This sensor sent information to a modem that includes GPS to determine harvester position sending information by a GSM/GPRS unit to a host control platform. Automatic time study methodology was also developed to analyze gathered data attending to time element size, harvester position or time element sequence. Based on these criteria, time elements were classified enabling harvester performance analysis. Basically, harvester work cycle consists on trunk shaking (13.4 ± 8.8 s), displacement between trees (30.8 ± 13.5 s), turnings (351 ± 187 s) and fruit unload (229.7 ± 116.5 s) (mean ± standard deviation). Moreover, time element size was mapped separating shaking time from other time elements in order to provide spatial information at a glance. Straddle harvester prototype showed a theoretical and effective field capacity of 0.46 and 0.23 ha h-1 respectively. However, it is expected that this harvesting system improve its performance after pre-commercial tests therefore, potential field capacity could reach 0.37 ha h-1 in optimal field conditions. Finally, olive integral harvesting could reduce labour requirements increasing olive sector competitiveness along with tracking systems, which make possible to enhance decision making processes for agricultural purposes.

Robotic Systems for Monitoring in Open Fields

Capturing crop height over the growing season from UAV based LiDAR

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Plant height is an important trait for agricultural crops and an indirect indicator of potential production. Especially when measured over the growing season it characterizes plant health in phenotyping or precision agriculture applications. Plant height can be defined as the distance from ground level to the tallest leaf. However, measuring crop height in phenotyping experiments is time-consuming and costly, so there is a need for new sensing technologies capturing plant height and other architectural traits in an automated manner.

In recent years, Light Detection And Ranging (LiDAR) systems have shown the potential to revolutionise crop structural characterisation by providing very high-resolution 3D data. LiDAR systems operated from Unmanned Aerial Vehicles (UAV) have now become available with sufficient point densities (up to 1000-2000 points per m2) to characterize the complex structure of agricultural crops. This study presents the first results of the RIEGL RICOPTER with the VUX®-1UAV airborne laser scanning system for agricultural applications. During the 2017 growing season we scanned a number of fields with different crops: wheat,

quinoa, grassland, and a fruit tree nursery. Some fields were scanned several times to capture the structural development of the crop. Around the time of LiDAR acquisition, manual crop height measurements were made for validation. From the point clouds of the UAV based LiDAR measurements, we derived Digital Terrain Models (DTMs), Digital Surface Models (DSMs) and finally Canopy Height Models (CHMs). In general, comparison of field measured canopy height and CHMS showed good agreement. In addition, the spatial datasets from UAV based LiDAR allowed characterization of height distributions within experimental plots and captured the spatial variation of crop height over the complete field. As a next step we are investigating opportunities to use the UAV-borne LiDAR point cloud for explicit 3D modelling of individual plants to characterize plant architectural traits.

Development Of Autonomous Robotic Platforms For Sugar Beet Crop Phenotyping Using Artificial Vision

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Phenotyping is a major challenge in international agronomic competition. In a perspective of modern and sustainable agriculture, understanding the relationship between genotype and phenotype according to the environment is one of the major projects of agronomic research. Artificial vision devices embedded on robotic platforms, working in visible or hyperspectral color fields permit to carry out many geometric and colorimetric measurements on crops. From this information, operations like crop varieties comparisons and disease detection are realized. For sugar beet crops, phenotyping operations are made from a two small leaf stage up to the final stage just before harvesting task.

Two robotic devices were used to make colorimetric and geometrical measurements on sugar beet plants. An autonomous mobile robot navigating in crop lines for little growth stages, embedded two cameras. A first one, with an oblique orientation permitted to realize autonomous crop raw tracking and the second one in a vertical position was used to record cartographic images and make detailed measurements on sugar beet plants. The second robotic platform was a manipulator arm with 6 degrees of freedom, fixed on a mobile linear axis to make measurements for advanced growing stages. Active perception operations realized with the embedded camera fixed at its extremity, consisted in locating by artificial vision the plant leaves in 3D environment and from this information, the camera was automatically positioned at various desired heights and orientations for each detected leaf, for carrying out, with accuracy, image acquisitions and measurements.

Experimentations realized with both robotic platforms, for various sugar beet growing stages, shown the interest of these devices for following and analyzing in detail the geometric and colorimetric evolution of sugar beet plants in the fields, in order to carry out some phenotyping measurements and particularly for detecting some diseases.

Optical Sensor For The Characterization Of The Agricultural Spraying Deposit

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In recent years, the use of phytosanitary inputs is a touchstone issue in the agricultural sector. The fact is, when pesticides are applied to crops, some spray drops fail to reach their target, which go on to contaminate the outer regions of the treated area. This off-target issue can cause environmental, health and economic problems.

By estimating off-target volumes, spraying quality could be optimized and thus help farmers improve their planting performances. This work purposes to develop an optical sensor based on a RIB waveguide design in order to characterize the quantity and distribution of a liquid spray deposit. We have assumed that the light guidance properties of these sensors would undergo a modification when spraying droplets are deposited on their surface. This phenomenon results from partial evanescent wave absorption by the water present in the pesticides which leads to a decrease in the transmitted intensity at the waveguide output.

Using different droplet volumes (0 to 10 µl), we studied the influence of a range of deposits at the guide center. The result was a gradual decrease in the output intensity signal due to the water absorbtion of the evanescent field, and this proportionally to the droplet volume; the bigger the droplet, the greater the loss in output intensity.

In addition, we performed a second test by successively adding 2.5 µl droplets on the waveguide to analyze their cumulative influence. The results obtained showed that the decrease in output intensity is also proportionally related to the number of droplets.

To conclude, these first results demonstrate the potential of RIB waveguide sensors to accurately quantify droplet deposits. Our future work should focus on improving the waveguide architecture in order to estimate deposited volumes and also the number of deposited droplets.

Inter-row Weed Detection of Sugar Beet Fields Using Aerial Imagery

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Early stage detection and the spread of volunteering plants play a crucial role for the yield performance in sugar beet farms. Relevant studies show that a delayed glyphosate application on sugar beet farms after the 8-to 10-leaf growth stage may lead to a significant yield reduction. Apart from this, inaccurate application of herbicides causes a substance-resistant behaviour from weed plantsand dramatically increases the environmental impact of agro-chemicals.

The rapid development of UAVs (Unmanned Aerial Vehicles) technology has transformed precision agriculture (PA) practices. Furthermore, digital image processing applications can offer innovative solutions to numerous aspects of arable farming.Therefore, these technologies combined can offer a Decision Support Tool (DSS) to the farmer.

This work aims to develop an automatic computer vision approach for weed detection from aerial imagery. It employs simple and affordable sensors (RGB camera) and processes raw images with scene perspective. The proposed approach combines colour-based segmentation, vegetation indexes and exploits the linear crop arrangement for detecting rows. In order to test the robustness of this approach aerial surveys were conducted over different growing stages and field treatments.

The results suggest that ExG and CIVE vegetation indexes combined with Triangle thresholding method can offer a reliable plant extraction while Otsu threshold struggles to perform under poor lighting conditions and dense vegetation. In addition, Hough Transformation method for row detection combined with optimization tools is able to yield an average of 87.3% Recall and 97.1%

Precision values. Finally, output weed maps manage to visualize accurately the weed expansion across the field in mature and low infestation crops, while some detections problems are identified in early-stage plants with high weed infestation.

Robotic Systems in Orchards

Apple-picking robot teleoperated with gestures - A proof of principle

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Dutch apple growing is expensive, impeding competition with cheaper markets. Labour is costly, physically demanding and increasingly scarce. Robotic automation of apple picking has been explored already for over 30 years, but is not sufficiently successful, economically nor technically. Since humans are still better at some tasks than robots, a human-robot collaboration could be a better intermediate approach. Orchards have evolved too, into thinner fruiting walls that are more suitable for mechanization. An aspect that has been often disregarded, and which may greatly contribute to ease mechanisation.

The objective of this research is to develop and test a proof-of-principle of a teleoperated apple-picking system. The resulting application consists, on one end, of a 3D virtual simulation of a multi-leader fruiting wall orchard, based on the innovative multi-leader trees architecture, and a picking robot. And, on the other end, a user interface that tracks users' hands and recognises specific hand's gestures as commands for the simulated robot.

The performance of the system was measured and compared against set requirements of picking performance (apple picking time), and of user experience like seamlessness and enjoyability, or low physical demand. The overall system approach proved rather interesting for testing users and a couple of growers and researchers. It was also seen as a potential mid-step to full automation. Quantitatively, an average of 10.33 seconds per apple were achieved with the system, far from the 5 seconds/apple objective.

Customisation to each user was conceived as an approach to improve performance. For which end, a series of biometrics measurements were carried out too, with the objective of finding an easily discernible pattern that could be later integrated as an algorithm into the system.

Preliminary Approach for the Detection of Olive Trees Infected by Xylella fastidiosa Using a Field Robot and Proximal Sensing

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A small field robot was designed and built within the framework of the H2020 project Xylella fastidiosa Active Containment Through a Multidisciplinary-Oriented Research Strategy (XF-ACTORS). The robot is remotely driven and provided with different proximal sensing equipment for the early detection of Xf in olive groves, including thermal, colour and multispectral cameras, and a 2D laser scanner (LIDAR) to obtain the 3D structure of the crop. The equipment is completed by a GPS to geolocate the data obtained and an IMU (inertial measurement unit) to correct the data captured by the LIDAR. An industrial computer triggers the sensors and controls the data acquisition, which is synchronised with the advance of the robot by means of a pulse encoder coupled to the axis of the motor. Then, crop maps can be created off-line after the analysis of the collected data to show graphically potential Xf infection in the trees. Owing to the height of the olive trees inspected, the cameras were placed on a platform that can be raised up to 200 cm. Two batteries power the electric motors attached to the wheels, thereby allowing a complete inspection of a field of approximately 4 ha. A series of tests have been carried out in an olive orchard showing slight symptoms of Xf infection in the region of Apulia, southern Italy. During the first tests, the robot inspected each row in both directions with the cameras pointing to one side, so as to inspect both sides of the trees. The tests were mainly focused on the development of the mechanics, navigation systems, sensors and data acquisition. Synchronised and geolocated images of the whole crop were also captured with the cameras in different climatic conditions, as well as with the laser scanner for later comparison to the in-situ observations.

Development of an Automated Apple Infield Sorting and Handling System

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In-field presorting of apples can provide significant economic benefits to the grower and packinghouse due to potential cost savings for postharvest storage and packing as well as for improved inventory management and postharvest disease/pest control. However, appropriate technology for apple in-field sorting currently is still not available, because of the technical challenges and high costs associated with the R&D. Recently, our research team developed a new cost- effective, automatic infield sorting technology for apple growers. This paper reports on the major features of the self-propelled apple harvest and automatic infield sorting machine. A new, compact, and low-cost machine vision-based sorting and grading system was developed, which mainly consists of a fruit singulating and rotating mechanism, imaging chamber, and rotary sorter. The sorting system is able to sort and grade apples for color and size (with the defect sorting function being incorporated soon) at a speed up to 9 fruit/s, and its singulating and rotating mechanism enables the digital camera to acquire 8-15 images for each fruit for complete surface feature analysis. Automatic filling of harvested apples into individual bins without causing bruise to the apples is critical to the overall system design. An innovative, simple bin filling system was developed, which employs a pair of foam rollers coupled with rotating soft panels for easy, gentle handling of sorted fruit in the bin. Laboratory and field tests showed that the new bin filler can meet the industry's requirement in minimizing bruising damage to harvested apples. Field tests and evaluation of the machine were carried out in the two harvest seasons of 2016 and 2017, and results showed that the machine has met our initial design goals in performance. Adoption of the technology will help apple growers achieve significant labor and production cost savings.

UAV and Machine Learning Techniques Applied to Yield Estimation of Orange Trees

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An accurate and early estimation of citrus yield is important for allowing both farmers and agricultural cooperatives to sell their products. Farmers require accurate yield estimates since such information is key for predicting the volume of stock necessary at the supermarkets and for organizing harvesting operations. In many cases, visual estimates of yield are done but these are not accurate. The main goal of this study was to develop an image processing method to detect and count the number and size of citrus fruits on individual trees using a machine learning algorithm and neural network. A total of 40 images (canopy left and right sides) were acquired from a commercial citrus orchard with an Unmanned Aerial Vehicle (UAV). The algorithm and neural network were tested on 20 citrus trees. The citrus yield estimations and actual mass of the fruit per tree were compared. The errors showed very promising values, and therefore, the method shows great potential for providing yield estimations for citrus and other types of fruits.

Robotic Systems General

Soil Organic Carbon estimation using proximal and remote sensing techniques

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Soil organic carbon (SOC) is considered as one the most important factors characterizing soils' quality and health and consequently affecting agricultural productivity. Additionally, soil is the second largest C pool with an estimated storage capacity of 1500 Pg C. Since soil is not a static reservoir, SOC estimation is of great use to ensure adequate agricultural production combined with sustainable soil management practices for climate change adaptation and mitigation. However, even if laboratory analytical methods for SOC content determination are considered more reliable in individual field level, such methods cannot be of use for large scale SOC measurements. To that end, more efficient, rapid, non-destructive and cost-effective estimations need to be developed and assessed. The challenges to measure and monitor SOC led to the need of (i) revised methodologies, (ii) updated remote and proximal sensing methods and (iii) simplified field information that could be used for SOC estimation, since there is still lack of a common measuring protocol with mutual acceptable results. The availability of hyperspectral data has led the scientific community to make a turn towards remote and proximal sensing techniques for estimating soil parameters. Hence, the aim of this paper is to review the studies that used remote and proximal sensing techniques for SOC estimation, highlighting the advantages and limitations of each approach. The focus is on hyperspectral sensors i.e. satellite, airborne and UAV based, and proximal sensing techniques in the visible and near infrared (vis – NIR; 400-2500) region in laboratory and in situ conditions.

PC Based Data Acquisition, Sensor Fusion and Data Syncronisation in Agriculture Based on an Example of Measurement of Soil Surface Roughness with a 2D LIDAR

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During the development of a device for fully automated attachment of supporting wires in hop gardens, a dependency between the area capacity, efficiency and roughness of the soil surface was analysed using a simplified 3D model of the device. Since most of the hop gardens are not designed for mechanised attaching of supporting wires, often prevail suboptimal conditions, causing difficulties during the application and consequently increasing the number of outages. The malfunctioning can be caused by the inertia of machine components as well as due the inadequate sensor technology. To solve this problem implementation of additional sensors and improvement of the mechatronic systems on the device can be striven for. Furthermore, the analysis of the working conditions, especially the preparation of the path including the soil roughness, which influences the achieved area capacity and the quality of the attached wires are required in order to achieve further improvements. In both cases, the documentation of the occurring errors and the failure reasons during the testing is necessary.

The paper highlights the design of an experiment in which a 2D LIDAR has been used for measuring the configuration of the terrain (fixed lanes) immediately before the application of the device for wire attaching. The questions considering the optimal position of the LIDAR, the measured data correction based on the information considering the roll, pitch and yaw angle of the LIDAR, as well as the measured accelerations will be analysed. Furthermore, the optimal way of data fusion will be analysed. It is expected that the data with adequate resolution combined with the information about the outage should provide more detailed insights considering the influence of the conditions which caused the outages and thus support the decision making to choose the optimal strategy concerning the further development of the device.

Design Space Exploration in the Development of Agricultural Robots

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Within the last decade, an increased focus in the agricultural industry is drawn towards autonomously driving field robots. When removing the driver from a field operation, the human sense of machine dynamics and operation accuracy must be replaced with a robust steering control system of the robot. The steering of an autonomously driving robot consists of a multiple of sensors and actuators.

To accommodate a wide range of field operations, a flexible design is preferable. Flexible in terms of changing width and mass due to the varying nature of the specific implements and tools within the working width of the robot. From an engineering point of

view, a flexible design yields changing machine and controller dynamics which has a significant impact on the performance in terms of following the desired path.

This issue is addressed by modelling and co-simulating a Continuous Time (CT-model) of the machine dynamics of the robot with a Discrete Event (DE-model) of the steering controller.

Initial simulations show that changing the parameters of the machine or controller directly influences the overall performance of the robot. This indicates that an optimized controller tuning can be found corresponding to the particular machine design. These optimized controller settings have been identified using Design Space Exploration (DSE) which provides a structured way of performing a large number of co-simulations. In this case, DSE is applied to investigate the performance of the robot by evaluating a number of simulated trajectories.

The results of this study show how a model-based approach to investigate such issues can be applied efficiently using DSE. This approach is shown to provide valuable results and knowledge about the robot in the early stages of the product development cycle.

Integrated Study of a Picking Robot for Greenhouse Grown Sweet Pepper

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National Ilan University, Taiwan

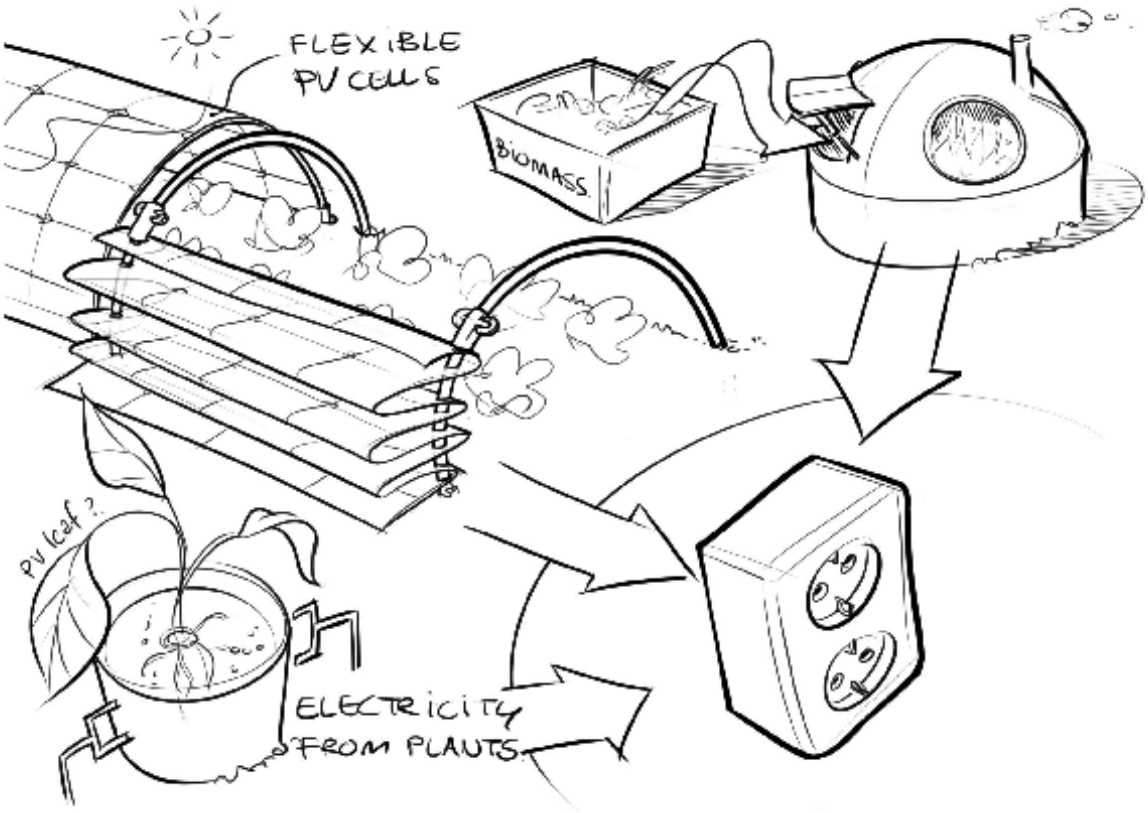
A robot was developed for sweet pepper harvesting in greenhouse. The robot has five major components: a six-degree-of-freedom robot manipulator, a harvesting end effector, a machine vision system, a mobile-platform which was modified from electric powered lift-platform-truck, and a control system which employs LabVIEW software package to control and monitor the harvesting processes. The machine vision system uses two color cameras to capture the image of targeted sweet pepper, and determines the position and orientation of its stalk through imagine processing techniques. The end-effector is a two-finger gripper installed with a set of cutting blade on one side of the fingers, and with sponge pads on inner side of both fingers. It was designed to grip and cut the stalk of the targeted sweet pepper, and secure the cut-off pepper between padded fingers with no damage. A primary test using 58 plastic sweet pepper models with 1500 x1500 mm simulated vertical harvesting zone and 500x500 mm imagine shot was conducted to check the essential functions of the developed robot. The success harvest rate was 93.7%. Another practical performance test which harvested 42 peppers with real sweet pepper plants in simulated greenhouse cultivating setup resulted in 81% success rate. Out of 8 failed cases, 5 was unable to accurately identify the position of the pepper stalk; 1 was cutting fail, and the other 2 dropped off when was transferred to collecting basket. The time for harvesting one pepper is about 21.8 seconds. The developed robot proved to be feasible and practical for automatic sweet pepper harvesting in greenhouse.

Development of an Agricultural Autonomous Platform

Pieter-Jan Note

Flanders Make, Belgium

This presentation is about the development of an autonomous platform at Flanders Make. Flanders Make is a Flemish research institute, aiming to bridge the gap between universities and manufacturing companies. One of our research domains is autonomous vehicles. The autonomous platform is used in several projects and implemented on different vehicles ranging from AGV's to On-highway car and bus and off-highway equipment such as a tractor. Today, we would like to present the development of our autonomous tractor.


FLEXIBLE
PV CELLS
BIOMASS
PV leaf ?
ELECTRICITY
FROM PLANTS

Topic 5: Energy and Greenhouse Gas Emissions (EG)

Reduction of environmental impact of operations in food and biomass production and processing by reducing energy demand, energy storage technologies, and new non-fossil energy sources. Examples are new implements and tractors including smart control, integration of energy from wind, bio-refinery and wastes, and reduction of emissions.

New Energy Sources for Agricultural Applications

Methanol As A Renewable Fuel From Surplus Electricity

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The further increase of wind power plants and PV-plants number in Germany and Europe is noticeable. However, further expansion of renewable energy leads also to a situation, when the grid is overloaded. Consequently, occasionally windmills or PV-plants in Germany need to be switch off due to the grid overload, still obtaining reimbursement, despite storing energy for seasonal fluctuations. On the other hand, looking at the current findings about diesel emissions, the conversion of a surplus of electricity into fuel, which is less toxic, would be very convenient. Methanol has already been proven to be less polluting and its´ energy density at ambient conditions equals to 4.4 kWh/l and in contrast to hydrogen, which energy density at 700 bar equals to 1.4 kWh/l, makes methanol an interesting alternative.

As a consequence, authors identify a need for a feasibility study of surplus electricity conversion into methanol at a farm, as a seasonal storage medium or as a fuel for tractors. Therefore, a technological, economic and ecological assessment will be presented in the presentation. Furthermore, a thermodynamic model was used to simulated methanol plant via ASPEN Plus®, in order to receive necessary inputs for design, for determination of related investment and maintenance costs, hence CAPEX and OPEX. Additionally, the emissions per 1 kg of methanol produced are used for a full comparative methanol life-cycle (cradle-to-gate) assessment, where production of the renewable methanol from the surplus electricity will be compared to a conventional process. In the presentation, the results of 11 impact categories will be presented, in order to identify eventual pitfalls of the methanol production. Furthermore, in the presentation, the utilization of methanol as a fuel or for generating electricity and heat is further discussed.

In-situ Evaluation of PV Pumping Systems for Drip Irrigation Use and Method for Yielding Hydraulic Performances

Abdellah El Aissaoui, Oudada Mohamed, Assia Harkani

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Photovoltaic (PV) water pumping constitute an innovative solution for sustainable irrigated agricultural in developing countries. This study treats technical and economic aspects related to actual use of PV pumping systems for drip irrigation in Morocco. An investigating on 14 farms was done to evaluate performance of PV pumping installation according to potential irradiance. Survey showed that farmers were interested to use of PV technologies but they cannot satisfy water irrigation requirements without use of both PV and diesel energy sources. Analysis cost of water cubic meter production showed the importance of PV system compared to the cost production using thermal (diesel) energy (differences ranging between 11% and 87% with an average of 61%). Reconversion of diesel based pumping systems to photovoltaic was tested and a power management method was proposed to set parallel pumps instead of using a single pump for the same installed equivalent power. The method improved performances of the PV pumping system as synchronization between hydraulic and actual irradiance behaviors were searched. Evaluation showed that use of three small pumps in parallel improved hydraulic performances and satisfied water requirements by 105% (against only 80 % by using one large pump). The proposed method showed that it is possible to design more economical PV systems as the maximum peak power demand can carried out using small power pumps in parallel and adjusting power switching to actual irradiance as a new technic of hydraulic MPPT. Using such method of yielding pumping capacity for drip irrigation is of importance to optimize design and performance of photovoltaic pumping systems.

Performance of a Direct Coupled DC Pumping Photovoltaic System to Drip Irrigation Network

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Renewable energy sources for irrigation have been widely used in recent decades. Performance of a direct coupled DC photovoltaic (PV) pumping system confronted to actual behaviour of incident irradiance was investigated. The system is based on a photovoltaic generator, a MPPT/ DC-DC converter, and a diaphragm DC motor pump connected to calibrated (Flow versus Pressure) orifices that simulate a small drip irrigation network, mounted in parallel scheme to vary the pump operating point according to daily actual irradiance. The result showed that occuring irradiance influenced considerably operating behaviour of the pump, consequently the performance of the standalone PV system is affected as there is inadequation between charges of the PV generator and the DC pump. Confronted to actual irradiance behavior and without energy storage option, The pumping system showed varying hydraulic performances (between 6% and 46%) and unstable operating conditions of connected network. A method of governing hydraulic performance is proposed to improve system efficiency and pressure stability as requirements for water distribution uniformity in drip irrigation network under by a standalone PV pumping system.

Modeling in Matlab of a Standalone Photovoltaic Pumping System for Drip Irrigation Use and Performance Analysis

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This study deals with simulation for optimal design of a stand-alone photovoltaic solar pumping system directly coupled to drip irrigation network in the context of arid climate of central region of Morocco. The simulation is done using Matlab/Simulink

environment. It provides theoretical study and modeling techniques based on equivalent electrical circuits to improve PV system design for optimal energy efficiency and cost of installation. The structure of the pumping system is presented using the mathematical models of different constituents. The modeling of the optimal operating point is done using the MPPT method based on the incrementing of the conductance. The assessment of the pumping system model is done using actual sunlight data provided by the meteorological station of the INRA center of Settat. One set of data is used as input for testing the model response in sunny conditions. The simulation results showed that the system is stable and reaches its equilibrium state in a relatively short time. The model is of importance to serve as tool for design of a standalone PV pumping system based on actual irradiance data. It allows possibility of studying influence of ambient temperature and solar radiation on the PV and hydraulic performances

Design and Evaluate a New Distiller for Seawater Desalination with Solar Photocells

Mohamed Nabih Omar, Abdellateif Abdelwahab Samak, Mahmoud Hassan Keshek

Menoufia University, Egypt

Water and energy are two very important commodities that govern the lives of humanity and promote civilization. In Egypt, there are a big problem in the fresh water and the energy due to a large amount of water are needed for the new land reclamation to meet the needs of the growing amounts of food. The main objective of this study was increased the fresh water produced from new design desalination seawater process using Solar Photocells with Solar Energy Collectors. For reach to the objective we used three types of distiller's units, the first part was the traditional unit, the second part was the traditional unit with solar heaters, and the third part was the new design unit with solar heaters. The new design of the solar desalination technology was based on separation the unit for vaporization and unit for condensation. To increase the efficiency of the evaporation process, electrical heaters was used within the evaporator, that powered by electricity generated from photocells as a renewable energy source. The measurements included solar radiation, inside distiller and ambient air temperatures, relative humidity, distiller efficiency, fresh water production and electricity generated from photocells. The results showed that, the maximum value of the produced fresh water was 3.74, 5.42, 7.15 L/m^{2}day for the traditional unit, the traditional unit with electrical heaters, and for the new design of solar distiller, respectively with solar radiation 1.1 kWh/m^2. The new design of distiller increased the amount of treated fresh water about 31.92 % and 78.75 % from traditional unit, traditional unit with heaters. The maximum efficiency was about 74.2% and 88.35% for solar collector and the new design of distiller, respectively. The results of study recommended to use the produced fresh water from the new design unit with highly efficiency within Hydroponics in the coastal area.

Biogas Production from Novel Substrates

Unutilized Silage as a Biogas Substrate

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Large amounts of unutilized silage are available in agriculture as well as from municipalities harvesting meadows and grasslands. At the same time, biogas plants with crop-based substrates are looking for alternative substrates to adapt to EU RED and to increase profitability. Unutilized silage that would not otherwise be used for feed can be an excellent biogas substrate, but the material is often coarse and pretreatment is necessary. This project was performed as a case study to substitute 20% of the crop-based substrate used today (maize, whole-crop silage and grain) with unutilized silage bales for the Jordberga biogas plant in the south of Sweden.

Three different mobile machines for disintegration of silage bales were used in practical trials to evaluate which was most effective at reducing particle length and damaging the structure of the grass for improved digestion. Two of the machines used a hammermill technique for disintegration and the third used knife rotors. Test results were evaluated regarding particle length, particle structure, energy consumption and capacity. Costs were calculated for the handling system of the bales from the farm or storage site to the processing unit for disintegration and then to the digester.

All three machines managed, to different extent, to reduce particle length and damage the structure of the grass. For a good estimation of the capacity and fuel consumption further tests are needed. The purchase of bales and transport to the plant are the largest costs in the system. It is therefore crucial for the interest of the biogas plants to use bales if they can have them delivered for free at the gate. If and how much the biogas plant is prepared to pay for the bales is also highly dependent on how the silage quality affects the methane yield potential.

Flexible Operation Of Biogas And Biomethane Plants To Cover The Residual Load Rises

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Limited fossil resources and the climate change make a more efficiently and environmentally friendly energy production necessary. Hence, the energy policy concept of Germany provides that in future the electricity will be covered mostly from renewable energies. Because wind and solar energy sources depend on climate conditions fluctuations in energy supply will occur. Energy storage systems and systems for demand-driven energy production will be essential to cover the residual load rises. Predictive models for the short-term residual load rises make it possible to adapt the operation of biogas plants to the demand. Actually the technical possibilities of flexible operation of biogas plants are underutilized.

Within the project a rigorous dynamic process model is used to analyze the flexible operation of biogas plants for covering the residual load rises. This model is optimized and an operation concept for a demand-driven energy production is worked out. For that the feeding amount and composition of available substrates is adapted to the energy demand. Within batch experiments the kinetic and degradation of different substrates are examined to identify the optimum feeding strategy.

The experiments will show that the substrates have got a different biogas production rate and reaction time. Also it will be presented that it is possible to cover the residual load rises with an intelligent feeding of a biogas plant. For these simulations a load profile of the region Emden was used. With adapting the substrate composition and amount this profile could be nearly completely covered. According to the substrate a contemporary increase of the gas amount could be reached. All in all the results show that it is possible to operate biogas plants flexibly with an individual and intelligent feeding program.

GIS-Based Biogas Potential Assessment of Anambra State of Nigeria

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The need and practice of reclamation of bio-wastes produced from animal waste is gaining approval from developed and developing countries of the world as a result of the impact of climate change on the human environment. The objective of this study is to estimate the biogas potential of agricultural wastes generated from livestocks in all the Local Government Area (L.G.A) of Anambra State of Nigeria using Geographical information System (GIS) capability. The result of the study indicates from the spatial density map of bio-waste of the study area, that Idemili North L.G.A has the highest spatial density, there is also a clustering of high spatial density of bio-waste in areas like Idemili South, Njikoka and Onitsha North L.G.A. The map for the gross electrical power production shows that Ogbaru, Idemili North, Njikoka and Awka South have the highest gross electrical power production of bio-waste. L.G.As in the Northern parts of the study area were characterised with low gross electrical power production. The availability of bio-wastes is the major premises on siting biogas plant, thus areas with high gross electrical production potential are suggested to be most suitable for siting biogas plant in the study area.

Anaerobic Co-digestion of Various Types of Agricultural Biomass

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The aim of this study was to determine the possibility of biogas production via anaerobic co-digestion of cattle manure and various types of agricultural biomass - sorghum KWS Tarzan and sorghum KWS Zerberus, sorghum-sudangrass hybrid KWS Freya, harvest residues of mungbean and chia plants, corn stover and corn cob, and to determine their biogas and methane yields and biogas composition. Anaerobic co-digestion process was conducted in batch lab-scale 1000 cm3 reactors under thermophilic regime during 40 days. Dairy cow manure was used as inoculum and substrate:inoculum ratio was 15:1 (based on total solids), while working volume of reactors was 250 cm3. The average biogas and methane yields after anaerobic co-digestion process were 361,6 and 243,4 cm3g-1 VS; 364,9 and 248,9 cm3g-1 VS; 360,9 and 240,8 cm3g-1 VS; 342,16 and 233,6 cm3g-1 VS; 313,0 and 210,6 cm3g-1 VS; 373,5 and 251,4 cm3g-1 VS; 397,7 and 274,1 cm3g-1 VS, respectively. If compared to anaerobic mono-digestion of cattle manure, only in experiment containing chia plant lower biogas and methane yields were determined. The highest biogas and methane yields were determined in experiment containing corn cob, which were higher by 20,5 and 22,6 %, respectively, if compared to anaerobic mono-digestion of cattle manure. Based on the results, it can be concluded that agricultural biomass that was used in this study represent suitable substrates for anaerobic co-digestion, particularly harvesting corn residues.

Climate Costs of Anaerobic Treatment of Food Waste Co-digested with Animal Manure

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Greve Biogass is a commercial biogas plant where they co-digest animal wastes and food waste. The aim of this project was to find out the climate costs of the plant. This was done by document mass – and energy balance, and economy. The biogas was upgraded and used as vehicle fuel.

The energy yield of the plant is based on mass balance calculations over 120 days in 2017. During this period, amounts of raw material into the plant were recorded. At the same time, samples were taken for analyzes of solids, organic solids and chemical oxidation demand. The amount and composition of biogas were also registered. During this period, 39 475 tonnes of a mixture of waste from swine and cattle, food waste, industrial waste and washing water were processed. The average solids content was 10%. The hydraulic retention time was 36.5 days. The organic load was 2.5 kg VS/m^3*day. The average methane yield was 453 Nm^3 CH_4/tonnes VS at a degradation rate of approx. 57% of VS. The methane discharge in the plant was measured at 2.9% of the biogas produced. The electric power requirement in the plant was 12% of the energy produced as methane, and heat recovery using heat pumps was equivalent to 37% of the power consumed. The production of methane for fuel corresponded to delivered energy of 16.2 GWh.

Calculations of the climate reductions for the Greve biogas plant in 2017 were estimated at approx. 11 748 tonnes CO_2 equivalents. When viewed in conjunction with investment economics and operating economics (including public support), a negative climate cost of approx. 15 EUR/tonnes CO_2 eq was calculated.

Energy Use and Efficiency of Tractors

Tractor Driveline Efficiency Evaluation Taking into Account Power Lost in Slippage.

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The primary purpose of agricultural tractors is to perform drawbar work that is mathematically defined by the pull force (kN) and forward speed (km h-1) of the tractor-tool assembly. An ideal tractor converts all the fuel energy into useful work at the drawbar: this implies the maximization of both engine fuel and drivetrain mechanical efficiencies allowing the optimization of tractive advantage by selecting an optimum travel speed for any given operation.

The adoption of OECD Code 2 for drawbar power and fuel consumption assessment if, on the one hand, allows obtaining comparable data (measurements are carried out at maximum engine power), on the other one opens the issue that tractors maximum drawbar power changes with gear or speed.

To deepen such knowledge, the data of 100 tractors of different power and weight, obtained following the OECD Code 2, were analysed with the aim of evaluating the specific driveline efficiency (the driveline power net to losses due to slippage). The whole dataset underwent Linear Regression Analysis (LRA) aimed at pointing out the relations between the power at the drawbar and the losses due to slippage in accordance with the following equation:

Pdb=α•PPTO-β•Pvd•-Ps

where:

– Pdb is the power at the drawbar (measured);

– α is the driveline efficiency coefficient (assessed);

– PPTO is the maximum power at the Power Take Off (PTO; measured);

– β·Pvd•defines the power used for the displacement of the vehicle (calculated as weight and speed): in it β is the motion resistance ratio expected to result ≈0.04 as reported in the ASABE standard;

– Ps is the power lost for slip.

According to results, driveline efficiency coefficient (α) turned out to be 0.93. This value was tested against an independent dataset pointing out that the model achieved optimal levels of efficiency and accuracy with R2 = 0.98.

Preliminary Study On Traction Efficiency of an Agricultural Tractor Equipped With an Extendable Ballast Holder

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In the last decades, agricultural tractor optimization was the main topic of countless studies. In fact, a more efficient tractor leads to higher durability and reduced energy losses, thus saving on fuel consumption. In particular, many studies were conducted on the optimal weight distribution among tractor front and rear axles because this aspect deeply influences traction efficiency. Therefore, in recent years some agricultural machinery manufacturers tried to develop innovative ballast systems to obtain the maximum traction efficiency in every field operation and soil condition. One example of these innovative ballast systems is a special ballast holder that could be installed both on front or rear three point hitch, able to move the ballast up to 1 m over its original position in the longitudinal direction. This movement is granted by a mechanical linkage actuated by the tractor hydraulic system. The aim of this paper is the tractive performance comparison of a tractor equipped with this special ballast holder between its two extreme configurations, device fully closed and device fully extended. Field tests were performed on a loam soil with a 4WD tractor with a maximum engine power of 194 kW and a ballasted weight of 9590 kg. With each ballast holder configuration, drawbar tests were carried out by towing another tractor with similar weight as a loading unit. Tractor operating parameters were acquired through a CAN-Bus data logger, while drawbar pull and speed were acquired respectively with a load cell and a GPS receiver. The analysis of the results shows that a higher traction efficiency was reached with the device in the fully extended configuration, especially in high slip condition. The obtained results confirm that the tractor weight distribution on the axles influence its traction efficiency.

Agricultural Tire Energy Efficiency Test Method and Dedicated Equipment to Compare and Improve Fuel Consumption and Traction of Agricultural Tires under Real Field Conditions

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Sustainable way of agriculture is one of the fundamental pieces of our viable future. Most policy makers, stakeholders, production companies, farmers have realized the importance of energy efficiency. The economic impact of energy waste is unambiguous. Fewer people understand or care its environmental aspects. The ENTAM as the European Network of Testing stations of Agricultural Machines and equipment has settled up a new ENTAM Technical Working Group in order to draft a common methodology to test the agricultural tire energy efficiency, in close cooperation with Michelin. The aim was to find an easy still a representative measurement method with reproducible records on real agricultural fields, in standardized soil conditions. A novel dedicated equipment has been built which uniquely provides the possibility to measure dimensionless tire performance indices in a standardized way. The prototype covers a wide range of tire dimensions and is capable of applying large vertical loads and drive torques. In the practice it will play a key role to determine optimal tire settings and can decisively contribute to the sustainable way of agricultural practice.

Fuel Consumption Analysis Of Real-World Measurements

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The trend in agriculture is toward more sustainable and efficient crop productions. The efficiency of a crop production can be evaluated as a ratio of between energy costs and crop yield. The highest energy cost is that of mechanization fuel consumption. This information is usually estimated with empirical formulas. The most commonly adopted formula was established by the ASAE and it was derived from the Nebraska Tractor Test reports. The procedure that developed those reports are based on constant load tests, but tractors, under real field activities, operate with variable loads and therefore, concerns can be made in using this formula. Nowadays, due to the widespread integration of CAN-BUS, much information is easily available from any modern tractors and they can be used for an exact estimation of tractor fuel consumption. The aim of this paper was the collection and the analysis of fuel consumption data acquired under real operating conditions. A large fleet of tractors of the same family were used in different farms for cultivation. Tractors operated with different cultivators (i.e. different working width and depth, tool type, etc) and worked on different soils and land profiles. On each tractor, a CAN-Bus data logger was installed and the following operating parameters were acquired: engine torque and speed; vehicle speed; and fuel consumption. For each tractor, data were acquired for an hour. From the acquired signals, power requirements and frequency plots were calculated for each acquisition and all the data were statistically analysed. The data analysis revealed that in-field average engine power is limited to the 75% of the maximum engine power due to the fact the implement draft is highly variable. Moreover, the in-field fuel consumption varies from tractor to tractor due to the fact each tractor was used with different power demand by the driver.

Greenhouse Gas Emissions from Milk Production and Slurry Application

Milk Transport Costs and Carbon Emissions of Various Triggered Milk Logistic Chains

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This paper copes with the full costs and the carbon emission rates of a milk supply chain between milk producers and dairy processor, where two different milk logistic chains and three different milk collection cycles are considered. The optimization triggered milk chain and its process variant requires a monetary valuation of the milk collection cycles and different milk logistic chains. This contribution aims at determining the full costs and the carbon emission rates of a milk supply chain during a period of six days for a one-, two-, and three-day triggered milk chain. Exemplarily, the various triggered marginal costs are estimated for two milk logistic chains and two milk draw areas. The cost calculation of various triggered milk logistic chains uses full cost accounting. The carbon emission rates are determined by the consumption-based method. The unique full cost accounting and carbon emission rates of the triggered milk chains and the various process variants differ. The analysis of the individual scenarios constitutes an indicator for the payment to the milk producer of a various triggered and processed milk chain from the viewpoint of a dairy processor.

Insights in The Carbon Footprint of Raw Milk From 12000 Individual Dutch Dairy Farms

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Raw milk production is estimated to contribute to 4 percent of global anthropogenic greenhouse gas emissions. As a result, global and national targets are set to reduce greenhouse gas emissions, including emissions from dairy farming.

The aim of this study was to explore greenhouse gas mitigation potential of the Dutch dairy sector by evaluating the magnitude and cause of variation in carbon footprints of raw milk from 12000 Dutch dairy farms. Carbon footprints were analyzed for individual Dutch dairy farms using life cycle assessment. Farm specific Life Cycle Inventory data were retrieved from a national database.

Results show that the average carbon footprint per kg FPCM was 1247 gram CO2-equivalents/kg FPCM, with 90 percent of carbon footprints ranging from 1014 to 1640 grams CO2-eq/kg FPCM. The distribution of all carbon footprints showed to be positively skewed. Stratification of data showed that this is caused by higher carbon footprints of milk from dairy farms with peat soils. On average enteric methane emissions, manure storage emissions, roughage production at farm and production of purchased resources accounted for 493, 186, 161, 406 grams of CO2-eq/kg FPCM respectively. The relative contribution individual processes to total carbon footprint of milk, however, varied between farms. The carbon footprint of raw milk was correlated positively and most strongly with the share of on-farm peat soils, the grazing period of dairy cows and soil nitrogen surpluses. Negative correlations were found with feed efficiency, milk production per cow and the amount of maize fed.

This study showed that large variation between carbon footprints of raw milk from individual Dutch dairy farms exists. Carbon footprint varies with soil type and individual farm characteristics. Results indicate that mitigation potential exist for all dairy farms and a farm system approach is needed to develop most effective mitigation programs for dairy farms.

Economic Comparison and Carbon Emissions of Payload Optimized Milk Logistic Chains

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This contribution copes with the optimization of the payload and carbon emission rates in milk logistic chains between milk producers and dairy processor by full cost accounting, where two different milk logistic chains and two different milk draw areas are examined. The use of a milk transport truck and its profitability requires a monetary and carbon emissions valuation between different triggered milk chains and its payloads. This contribution aims at determining the full costs and carbon emission rates for five different payload scenarios. Exemplarily, the various payload marginal costs are calculated for two milk logistic chains and two milk draw areas. The cost calculation of payload triggered logistic chains uses full cost accounting. The carbon emission rates are determined by the consumption-based method. Thereby, the full cost accounting and the carbon emission rates differ and increase with the decrease of the payload and increasing distances between milk producer and milk processing company. Studying payload triggered milk logistic chains and carbon emissions is beneficial for strategical consulting and decision-making when thinking of milk removers from the viewpoint of a dairy processor.

Technology for Efficient Application of Liquid Manure: A Comprehensive Modelling Approach on Greenhouse Gas Emissions

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The goal of this study is to describe all effects of liquid manure application technologies on greenhouse gas (ghg) emissions at farm level. A literature review showed, that despite the existence of a big number of research done in this field, there is still a lack of understanding overall ghg emission dynamics. As there is a big uncertainty in predicting nitrous oxide emissions and so far none of the field studies included the full set of relevant pathways of nitrogen loss and all influencing factors (e.g. location factors), the current work aims to analyse and describe coherences and the range of possible manifestations rather than derive absolute numbers for ghg emission reductions through liquid manure application technology. A modelling approach was developed to show self-enforcing and counteractive influences using values of diverse studies. The results highlight different forces that need to be considered to achieve a ghg emission reduction. Furthermore results show which framework conditions promote or hinder the implementation of liquid manure application technology at farm level. The liquid manure application technology provides a big potential to reduce ghg emissions. The efficiency of liquid fertilizers due to application close to the soil and roots can be expressed by the mineral fertilizer equivalent. Such high efficiencies can be accounted for in ghg modelling by savings of manure that are available for fertilization elsewhere and replace mineral fertilizers there. Our findings emphasise, that to ensure a ghg

emission reduction through the use of liquid manure application technology, it should go hand in hand with a reduction of manure input, being the biggest control variable in ghg modelling. From the found results the conclusion can be drawn, that ghg modelling needs to address manifold effects to develop functional ghg mitigation strategies and not to mislead by monocausal findings.

Energy Use and Greenhouse Gas Emissions from Various Systems

Sustainability Issues Related to Woody Biomass Supply From Fruit Tree Plantation Removal

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In Europe, there is a large surface of land cultivated with fruit trees (i.e. vineyards, olive and fruit plantations) providing valuable amounts of woody biomass from pruning and plant removal at the end of the plantation cycle.

Such biomass is generally burnt in open air or shred on topsoil. In few cases, this material is used as fuel for biomass power stations provided that harvesting technologies are adequate for costs optimization and product quality.

To assess and deepen the sustainability issues related to such a supply chain, a field survey was carried out on the various phases of biomass harvesting and transporting from the uprooting of a peach tree orchard placed in the surroundings of Ravenna (Emilia-Romagna, Italy).Trees were planted in a low-density orchard, spaced at 3.5 m along rows and 6.0 m between rows, at 476 plants ha-1 (the total area was 1.96 ha).The biomass collection chain foresaw the following phases: i) plant uprooting and windrowing, ii) biomass stacking, iii) lorry loading with and without compaction; iv) biomass transport to the power station.

According to results, personnel represented 18.8% to 30.15% of the total costs (€/ha) for phases i) and ii) while the kind of truck (articulated or not) was found to deeply affect the loading times (they doubled in case of articulated trucks) more than the compaction system that caused a +35.7% increase in working time. The collection system was also found to affect the quality of the supplied biofuel following the cleaning of root biomass from soil residues.

This study shows the importance of a specific set up of the logistic chain related to the recovery of orchards stumps that should be focused on both economic and technologic issues (e.g. reducing the topsoil pollution of the harvested underground biomass) to meet the needs of power stations.

Improvement of The Carbon Balance of Irrigated Arable Crops by Applying Bmps in Mediterranean Conditions

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One of the most important key points for agriculture in the next few years is to reduce its impact over the environment and especially in the climate change (CC). This work try to demonstrate how the applications of environmental Best Management Practices (BMPs) can improve the carbon balance of the arable irrigated crops in Mediterranean conditions.

This work belongs to the Life+Climagri project. It shows the results of three seasons carried out in the farm of the University of Córdoba. Different irrigated arable crops management were studied:

Treatment 1: conventional farming (CF) based on tillage

Treatment 2: same management of inputs but with No Tillage and Guide assistance systems

Treatment 3: treatment 2 plus use of fertilizers in the seeding line

Treatment 4: treatment 3 plus irrigation according to the real necessities of the crops

Treatment 5: treatment 4 plus site-specific distribution of fertilizers

The parameters on mechanized operations were logged using a remotely data acquisition system. The equivalent Carbon Dioxide (CO2) emitted was calculated by energy analysis. The CO2 fixed was a transformation of yields. Two parameters were defined: CO2 Efficiency (CE): CO2 emitted/CO2 fixed. Carbon Productivity (CP): Kg of yield/each kg of CO2 emitted.

The results showed how the applications of BMPs improved yields, which increased on average of 32% with respect CF. As more BMPs were implemented, the CO2 emissions were reduced. The higher diminution respect to CF was 32% (treatment 5), and the average of all BMPs was 13%.

In spite of the reduction of emissions, treatment 5 did not presented the best results for the CE and CP. Because a decrease in the yields owing to the site-specific distribution of fertilizers. Therefore, treatment 4 presented the best results, reducing these parameters with respect CF around 80%. The global reduction by applying BMPs was higher than 55%.

Energy Balance and Economical indices in Small-Scale Scallion Production System

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Modern agriculture relies on the fossil fuels consumption for food production. Reduction of non-renewable energy consumption in food production systems is critical in attaining a sustainable food supply chain. Hand-scale intensive food production systems can contribute to the reduction of non-renewable energy consumption and to increase the renewable human-based energy. Thus, this study was conducted to evaluate the energy balance and economical indices of scallion production in Golestan Province, Iran (as an example of small-scale food production system). Data were collected from 36 scallion producers through face-to-face

interviews during 2015-2016. The results showed that the average yield of scallion production was 11,148.78 kg ha-1. A total energy input of 21,325.77 MJ ha-1 was calculated to be needed for scallion production. Chemical fertilizer was attributed the largest amount of energy consumption. The economic analysis showed the total cost of scallion production was 4461.49 $ ha-1 and the highest cost of scallion production system belonged to the human labor. Moreover, the benefit to cost ratio was calculated to be 4.03. The energy indices of energy use efficiency, energy productivity, specific energy, and net energy were determined to be 0.84, 0.55 kg MJ-1, 1.83 MJ kg-1 and -3487.72 MJ ha-1, respectively. The amount of non-renewable energy consumption was higher than renewable consumption. The main non-renewable energy hotspots were chemical fertilizers and diesel fuel; therefore, management and improvement in the application of these inputs would decrease the amount of non-renewable consumption during scallion production system.

Assessing Water Supply Sources Using Life Cycle Assessment: Study Case of Lemon Crop in South-Eastern Spain

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The Segura River basin, in south-eastern Spain, is one of the areas with the highest water scarcity, not only in Spain but also in Europe. As a result, in such a region, farmers can have up to six different water supply sources for irrigation (surface water, groundwater, reclaimed water, desalinated brackish groundwater, desalinated seawater and inter-basin Tagus-Segura water transfer). Moreover, water reallocation by water trading between concession holders is also possible (i.e. water markets), which in practice represents an additional water supply source. Water markets are one of the most promising instruments for reallocating water resources in mature water economies since they are capable of increasing the economic efficiency of water use and reducing the economic impact of scarcity. This paper analyses the environmental impacts of production of a representative lemon orchard irrigated with each one of the water supply sources above mentioned. Lemon has been selected as it is the perennial crop with a greater area in the basin. A life cycle assessment was used to quantify the lemon orchard global warming potential, acidification of land and water, eutrophication potential, land use and cumulative energy demand. The system boundary was considered from raw material extraction to farm-gate based on lemon production.The results showed large variation in the indicators. As expected, irrigation with desalinated seawater showed the highest value of global warming potential and cumulative energy demand, which is justified by the high-energy requirements to produce desalinated seawater and also for higher implementation of calcium and magnesium fertilization. In addition, the analysed environmental indicators of water markets resources with the basin were similar to those of the inter-basin Tagus-Segura water transfer.

Modelling the Impact of Carbon Dioxide Emissions on Global Warming

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Global warming, also referred to as climate change, is an increase in the average temperature of the Earth's climate system and its related effects. During the last century, the rapid growth of technological advances in industrial societies has significantly increased the contribution of human intervention in climate changes, and climate and temperature changes caused by greenhouse gases are one of the major challenges in the present era. Carbon dioxide (CO_2) is considered as one of the most important greenhouse gasses, which plays a major role in global warming. This study aimed to model the impact of carbon dioxide emissions on global warming. To that end, we first collected the data and statistics related to the average temperature increase and greenhouse gas emission of Co_2 uses different sources in the period of 2000-2017 and then regression equations were used in the form of Two-way and linear logarithmic model for modeling the effect of Co_2 gas on ground temperature through normal least squares method. According to the two-way logarithmic model, the Earth's temperature increases an average of 1.06% with an increase of 1% in Co_2 emissions. As well as, according to the linear model, an average of 0.97 units (°C) is added to the average temperature of the earth with an increase of Co_2 emissions about 1 unit (Trillion tons). The results of this study showed that the modelling of factors affecting global warming can be applied to control, eliminate or reduce its causative factors.

Energy Use and Greenhouse Gas Emissions from Livestock Systems

Analysis of the Indoor Climate and Energy Use in two Animal Houses for Fattening Pigs

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In last years, the adoption of monitoring systems also in animal houses has increased the amount of data that are available for the farmers. A correct analysis of those data could mean more information about the farm that could help to improve the management of the production, to maximize the profit and to guarantee the animal welfare. The continuous monitoring of indoor climate conditions is interesting because the productivity can be strongly affected by environmental parameters that are not adequate to the reared species.

In this work, the results obtained from an environmental and energy monitoring campaign carried out in two fattening pig houses are presented. The measurements were performed during two production cycles and take about one year. For the environmental monitoring, the two buildings were equipped with temperature and relative humidity data loggers (10 minutes logging time) that were placed in various spots inside the house. Outdoor data (air temperature, relative humidity and solar radiation) were obtained through a weather station located next to the test site. Concerning the energy monitoring, 3-Phase kW Power Transducers (10 seconds logging time) were placed in the electric panel of each house in order to log the electrical energy consumptions of both the houses due to ventilation, lighting and automatic feeding. Data regarding the reared animals (e.g. final live weight, feed conversion ratio and mortality) were provided by the farmer.

The obtained data were used for mapping the temperatures inside the houses, for evaluating the electrical energy consumption related to indoor/outdoor air temperatures and for comparing the indoor air temperature values with values provided in literature. Furthermore, the obtained data were used for individuating potential heat stress conditions of the pigs that could cause production decreases (e.g. higher mortality and lower feed conversion ratio).

EPAnHaus: Energy Performance Certification of Livestock Houses

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The promotion of a sustainable agriculture is between the Sustainable Development Goals set by United Nations that should be achieved before 2030. To reach this target, particular attention has to be paid to the rational use of energy in livestock sector. Intensive animal farms are characterized by high energy consumption, especially for the control of the climate that can consume up to 140 kWhth·m-2·K-1 in broiler houses, representing 96% of the total thermal energy consumption. Even though energy needed for climate control entails a considerable energy consumption and running cost of livestock houses, currently neither legislation nor calculation methods about this energy consumption exist.

EPAnHaus project aimed at establish an energy certification scheme for livestock houses that considers the energy uses due to climate control (heating, cooling and ventilation). The objective was reached through three steps. First, an inventory of the energy uses for climate control of livestock houses in Europe was done to obtain benchmark values. Second, a calculation method in compliance with international standards on the energy performance of buildings was customized to develop a simulation model for the estimation of the energy consumption, in particular of broiler and pig houses. The developed models were validated using datasets obtained through measurement campaigns. Finally, a certification scheme based on the previous steps was developed.

The energy certification of livestock houses increases the knowledge of the energy amount needed for climate control and has both local and global positive effects. Local positive effects concern farmers and engineers, which can use the provided information, for instance, for better planning the production and for better evaluating retrofit actions. Global positive effects lie in proposals of legislations and funding that politicians could develop based on the provided information, with the final aim to reach a global reduction of energy consumption in this sector.

How 'CO_2 Smart' is the Dutch Agri-food Sector?

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Globally, throughout the total food value chain 33% of the produced food becomes waste. That is roughly 1.3 billion tonnes per year, and 3.3 Gt in CO_2 equivalent. The Netherlands is one of the countries introducing major innovations, such as with the first national food related network for the Internet of Things (IoT).

In this paper we discuss the influence of one relatively new paradigm that has proved to foster CO_2 reduction through "Smart Farming" (SM). The driving research question is: how does the Dutch Agri-food sector offer sustainable solutions to improve the problem of food waste (FW) and reduce $CO_{2\text{-eq.}}$ emissions through SF and related technological innovations?

A mixed research method approach was used to gather the information to answer this question, i.e. literature review and semi-structured questionnaires to interview key respondents. As part of the preliminary findings (from literature) an inventory is provided here of the effects (not exhaustive yet) of the technology associated to SF practices : (i) prevention of FW generation at different stages of the value chain; (ii) improvement of production efficiency by automated operations; (iii) valorisation of some perishable food stuffs (e.g. CO_2 absorbent materials). Further, the need to include other relevant aspects in our analysis, aspects that may have a crucial influence in the technology implementation and in the collaboration deployed among different actors of the Agri-food value chain, is acknowledged and explained. As the $CO_{2\text{-eq}}$ emissions reductions were derived from literature, suggestions are made as regards future research for their actual calculation in the context of SF practices.

The Effect of Gas to Liquid Ratio on Carbon Dioxide Removal and Heat loss across a Forced Ventilated Trickling Filter in Aquaculture

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High levels of CO2 in culturing conditions have negative effects on fish growth, physiology and behaviour which are serious problems when trying to achieve an intensification of aquaculture . The concentration of CO2 in the aquaculture recirculating system is usually controlled by trickling filter which also works as a degassing tower. Therefore, it is combining the nitrification process with the degassing of CO2 due to the structure of the media , ventilation and the height of the tower.

The goal of current research is to investigate the effect of gas to liquid ratio(G/L), on carbon dioxide removal and heat loss across a trickling filter, in order to reduce the heat loss by optimization of the ventilation rate for CO2 control. the trickling filter in the Aquatic Research Facility (ARF) was used for the experiment under different G/L ratio's. the ventilation fan (range 6 - 60 m3/h) mounted on the top of the trickling filter moving air upward through the filter. The CO2 concentration, temperature, humidity, flowrate,...of the influent and effluent water/air was measured using several sensors.

In this study the effectivity of 8 different GLRs (1, 2, 5, 7 ,10, 11, 15) on carbon dioxide removal and heat loss in a trickling filter was tested under steady state conditions. Test Results show when G/L is between 1~5, CO2 removal efficiency increasing rapidly with growing of G/L ratio's and it was effectively the same between G/L= 6~10. The heat loss will increase sharply for G/L=1~3 and then it rises slightly. Considering an energy saving aspect and removal efficiency, the ratio of removal percentage to energy loss, in G/L ratio of 4~5 is considered to be the best for CO2 removal.

Biomass Heating System with Kerosene Boiler for Green House Heating

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Biomass boiler system is important to substitute fossil fuel with woody biomass. Generally, the biomass boiler system has a heat storage tank filled with water in order to store hot water converted from combustion heat. With a heat storage tank, even a small burner can heat the greenhouse. However, according to the heating load, the biomass boiler is comparatively easy to control the quantity of woody biomass, but difficult to turn on and off; therefore, we developed a biomass heating system using a rotary kiln-type burner combined with kerosene boiler.

The Heat storage tank of our system contained 7 m^3 water, we kept the water from 30℃ to 40℃ using Kerosene boiler. Furthermore, we made the water temperature rising to 70℃ - 90℃ by the biomass boiler with the rotary kiln-type burner. For heating the greenhouse, we used the radiator which was made by automobile component, and it provided warm air converted from the hot water. The heat output of the radiator was about 20 kW with 60 - 80 ℃ water temperature. This system controlled switching on and off the fan of the radiator.

Field tests were performed by heating a strawberry-cultivation greenhouse in Japan from December 2017 to March 2018. The greenhouse was double layer greenhouse. Outside temperature was from about -10℃ to 10℃ ,and the ,minimum temperature was -17℃.

The Greenhouse was able to be heated to keep 10℃ or 18℃ at night, depending on the growing stages of strawberries. The temperature control accuracy in the greenhouse was ± 2 ℃ . When the water temperature was 70℃ in daytime, The total heat produced from calorie radiated was about 1,530 MJ from 5:00 p.m. to 8:00 a.m.

Groundwater Utilization in a Farm Heat Network

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There are various demands for heating and cooling in a farm. The dryer of grain, raising seedling and heating of greenhouse and farm office or working space in winter need heat source. And refrigerators for products and cooling of greenhouse in summer need heat sink. Our purpose is to reduce the energy consumption in a farm by building the Farm Heat Network (FHN) that is consisted of networks of hot and cold water and heaters and coolers. Hot water will be supplied to the network from biomass boiler, solar heater and other heat sources. Cold water will be supplied to the other network from heat pump or other cold sources.

As a part of that system groundwater can be utilized for both heat and cold sources. Because the temperature of groundwater keeps almost the same temperature throughout the year it can be utilized for cooling in summer and heating in winter.

We built a system to heat and cool green house for flower production utilizing groundwater. The capacity for cooling and heating of the system was examined as a part of FHN.

A result of heating trials of our system is as follows, the average temperature of input air to the heat exchanger was 0.4 °C, the output air 8.7 °C, the input groundwater temperature to the heat exchanger 10.1 °C, the output 4.6 °C and the average heating capacity 5.1 kW with the groundwater flow rate13.5 L/min. And a result of cooling trial is as follows, the average temperature of input air to the heat exchanger was 20.4 °C, the output air 17.2 °C, the input groundwater temperature to the heat exchanger 14.9 °C, the output 19.6 °C and the average cooling capacity 4.2 kW with the groundwater flow rate13.1 L/min.

Simulation Model of Using the Electricity and Exhaust Gas Heat Generated from Poultry Litter Waste in their House

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Menoufia University, Egypt

The poultry industry is an important industry in Egypt and consumes a large amount of energy. This study was done to estimate the renewable energy generated from the broiler waste and reused it in the broiler farm. A mathematical model consisting of algebraic equations was developed for broiler house heating by exhaust gas from generator engine integrated with a heater exchanger. The equations were activated by MATLAB program in four stages. The first one, calculate the required broiler house heating energy according to the recommended inside air, outside air temperature and heat transfer through the broiler house structure. The second stage, estimate the broiler litter waste produced from broiler house and calculated its bio-gas production in m3/day. The third stage, calculate the electricity generated and heat energy of exhaust gas from the generator. Finally, calculate the energy saved by balancing energy produced from wastes to the energy required for the broiler house. The results of the developed model show that, about 19.85 kWh/day of electricity can be generated from the bio-gas produced from the broiler waste and 32.28 kWh/day of waste heat energy recovered from generator exhaust gas. This adaptation would be a valuable addition of renewable energy in country existing energy system. The saved energy from broiler litter wastes was ranged about 45 to 53% of the total required energy. The values of thermal loss during the broiler cycle production from Transmission and ventilation were about 48.78 and 44.19% of total required energy. The minimum correlation coefficients between predicted and measurements values were 0.940, 0.9478 and 0.936 for inside temperature, bio-gas generation, electricity generation. Using the electricity and heat energy from exhaust gas which, generated from waste as an input for broiler house operations is a new approach for reducing operating costs and considering as a new application of renewable energy

Modelling of Energy and Greenhouse Gas Emissions

Sustainability Through Digital Agriculture - Analysis of Available Greenhouse Gas Emission Indicators in Farm Management Systems

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Technical University of Munich, Germany

The debate on sustainability is playing a more and more important role in European agriculture. The greenhouse gas emissions induced by production processes are a decisive factor in this process. On the one hand, they are a decisive factor in the commitment of individual states to reduce greenhouse gas emissions. On the other hand, there is an increasing demand for information about emissions by food retailers as these are a marketing instrument.

In general, farmers have to document a wide range of activities, so more and more farmers are switching to farm management systems. It will be investigated whether it is possible to calculate agricultural greenhouse gas emissions with the help of automated data from Farm Management Systems.

The calculation of greenhouse gas emissions in the soil and plants sector requires 40 different input data: 21 of these can be read directly, four of them have to be calculated indirectly and 15 are not available automatically. The calculation of greenhouse gas emissions from agricultural machinery requires 15 different input data: nine are directly readable, one input factor has to be

calculated indirectly and five are currently not digitized. For the calculation of greenhouse gas emissions from livestock (beef cattle and dairy cattle) 43 different input data are required: 26 are already directly readable via digital sources, two have to be calculated indirectly via several input data and 15 are not yet available automatically.

This thesis explains that it is possible to calculate greenhouse gas emissions in agriculture using digital sources. For some of the required values, however, literature values must be used. In order to further advance research in this area, it is recommended to examine the perspective of farmers regarding automated greenhouse gas calculation and to compare automatically calculated greenhouse gas values with average values.

Comparing the Artificial Neural Networks and Multi Linear Regression Models to Predict the Energy Output of Fruit Production

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Several researchers have used Multi Linear Regressions (MLR) or Multi-Layer Perceptron (MLP) artificial neural networks to model the energy audit of agricultural production. A literature review showed that no previous analytical work has been reported on the comparison of MLR and ANN models to predict the energy output of fruit production. Therefore, the main goal of this research is to compare the MLR with MLP artificial neural networks modeling and select the best one to predict the energy output of peach production in Iran. For this purpose, the same data were used to train the MLR and MLP models and thus, 60, 70, 80 and 90% of data were selected to train the models. Levenberg–Marquardt learning algorithm was employed to train ANNs models. The results showed that 3.41 MJ of energy was consumed to produce one kilogram of peach in Iran. The application of the models highlighted that the differences between the actual and predicted values for the two models were not statistically significant. The performance indices such as coefficient of determination (R2), Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), and Efficiency (EF) for the best ANN architecture were determined to be 0.96, 2297.75 kg, 11.79% and 0.96%, respectively. While, these indices for the best MLR model were 0.91, 3418.27 kg, 14.80% and 0.91%, respectively. Overall, it was concluded that the MLP models could better predict the energy output than those of MLR models and the performance of MLP highlighted that this model can be applicable to prognosticate the energy output of peach production.

Integration of Principal Component Analysis and Artificial Neural Networks to Better Predict Agricultural Energy Flows

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There are some studies regarding the prediction of agricultural energy flows using Artificial Neural Networks (ANNs). These models are quite sensitive to correlations amongst inputs. And, there are often strong correlations amongst energy inputs for agricultural systems. One potential method to remediate this problem is to use Principal Component Analysis (PCA). Therefore, the purpose of this research was to predict energy flows for an example agricultural system (Iranian tea production) via a novel methodology based on ANNs, using principal components as model inputs, not raw data. PCA results showed that the first and second components could account for more than 99% of variation in the data, thus the dimensions of the data set could be decreased from six to two for the prediction of energy flows for Iranian tea production. Using these principal components as inputs, an ANN model with 2-15-1 structure was determined to be optimal for energy flow modeling of this system. Results from this optimal model demonstrated that the difference between actual and predicted amounts of energy was not significant at the 1.0% level. Ultimately, these results indicate that a PC+ANN model could be used to reliably predict this agricultural system. To conclude, the results of this study highlighted that the use of PC as ANN inputs improved ANN model prediction through reducing its complexity and eliminating data colinearity. Many agricultural systems could benefit from using this methodology for modeling.

Development of In-House Lattice-Boltzmann Simulator of Anaerobic Bioreactors for Vinasse Treatment: Preliminary Dimensionless Modelling and Sensitivity Analysis

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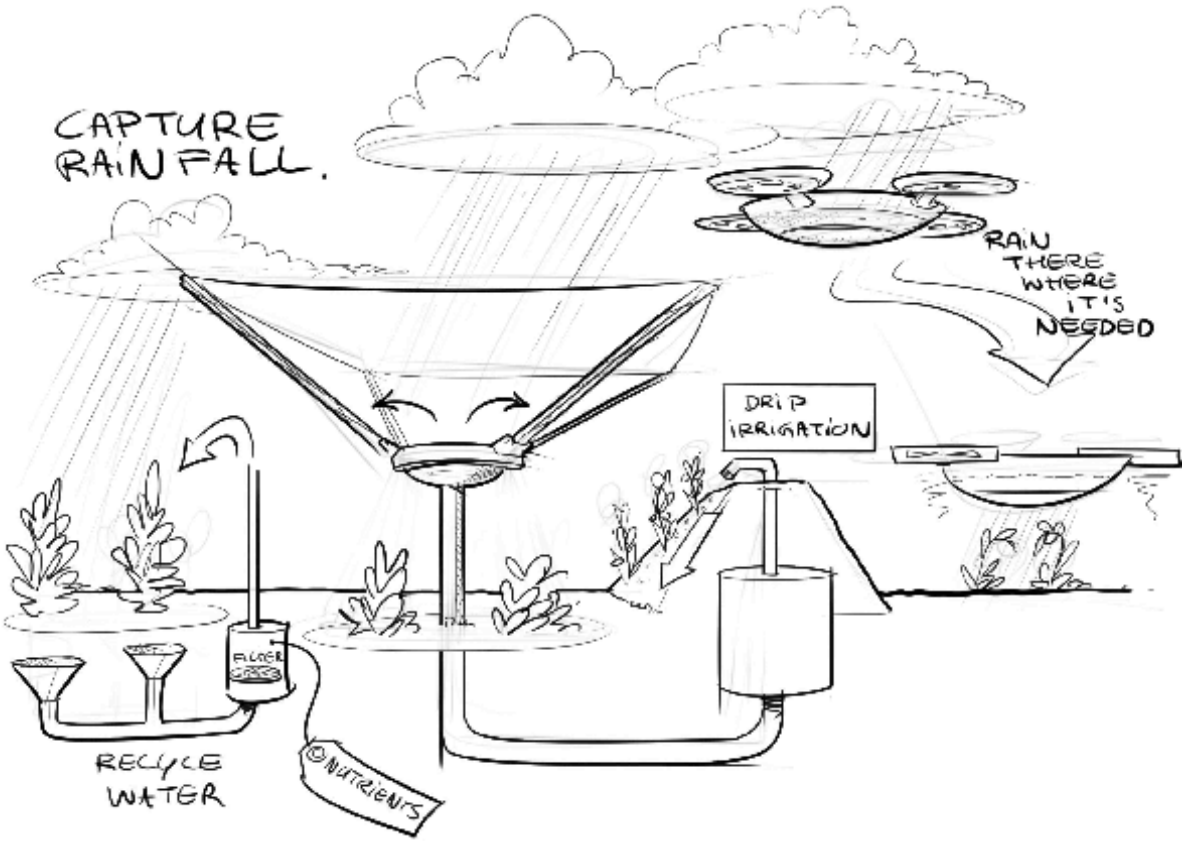
Sugarcane vinasse is a by-product from the ethanol industry whose large-scale exploitation has long pointed to ferti-irrigation in sugarcane crops after it undergoes anaerobic treatment. Anaerobic packed bed reactor (APBR) comes forward as an attractive treatment system so as to preserve vinasse quality as bio-fertiliser while allowing energy to be recovered as biogas, thus mitigating greenhouse gas emission as well as groundwater contamination. Bearing in mind the computational modelling of APBR towards cost-effective and sustainable operation, an in-house numerical simulator has been developed via lattice Boltzmann method (LBM). Claimed as a promising method, LBM has the ability of numerically simulating transport phenomena, fluid flow and moving boundaries without solving Navier-Stokes equations. Inspired by the Anaerobic Digestion Model Number 1 from International Water Association, such in-house LBM simulator has initially relied on a time-dependent one-dimensional model in primitive variables. In view of supporting (while simplifying) prospective scale-up, this work aims at casting this preliminary model and LBM simulator in dimensionless form. Original model parameters (e.g. interstitial fluid velocity, species diffusivity, kinetic coefficients, and reactor length) were successfully lumped into fewer dimensionless parameters (e.g. mass-transfer Péclet and Damköhler numbers). Computationally implemented in D1Q2 lattice, the LBM simulator remained fully operational in dimensionless form. A sensitivity analysis indicated that gradients of dimensionless species concentrations were smoothed not only with respect to axial variation but also in terms of time variation in diffusion-dominant APBR operation.


CAPTURE RAINFALL.
RAIN THERE WHERE IT'S NEEDED
DRIP IRRIGATION
FLOCK
RECYCLE WATER
NUTRIENTS

Topic 6: Soil, Land and Water Engineering (SW)

Technology and systems for management of water and nutrients in soil, soil quality and rural planning. Contributions can address irrigation and drainage, logistics of equipment in the field, losses and emissions, soil compaction and carbon sequestration.

Water Engineering

Integrated Bayesian multi-model approach to quantify input, parameter and conceptual model uncertainty in groundwater modelling

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Groundwater flow models are commonly used to understand and forecast groundwater flow under anthropogenic and climatic effects, but the reliability of the predictions is strongly influenced by different sources of uncertainty. The conventional treatment of uncertainty in groundwater modelling focuses on parameter uncertainty. Recent studies suggest that uncertainties on model predictions may be largely dominated by uncertainties arising from alternative conceptual model definitions. In this study, we present a flexible Integrated Bayesian Multi-model Uncertainty Estimation Framework (IBMUEF) to explicitly quantify the uncertainty originating from errors or simplifications in the model conceptualization, the input data, the parameter values and measurement errors of a fully distributed physically-based groundwater flow model. In the proposed integrated fully Bayesian multi-model framework, the DiffeRential Evolution Adaptive Metropolis (DREAM) algorithm with updated likelihood function is combined with Bayesian Model Averaging (BMA). This framework is applied on an overexploited aquifer in Bangladesh. Four alternative conceptual models representing different geological models have been developed. The uncertainty of the spatially distributed input of the model (recharge and pumping discharge) has been represented by multipliers. A generalized formal likelihood function is also included for hydrogeological modelling based on a new heteroscedastic error model to extend the applicability of our IBMUEF framework in situations where residual errors are heteroscedastic. The results of the study confirm that consideration of both conceptual model uncertainty and uncertainty of the input data are important to have confident parameters sets and better model prediction. The results also confirm that the IBMUEF framework is a useful tool and provides better model predictions than individual models. We conclude that an explicit consideration of conceptual model structural uncertainty along with model input, parameter and measurement uncertainty using the IBMUEF framework improves the accuracy and reliability of the model prediction and related uncertainty bounds.

Climate Change Effects on Groundwater Recharge and Yield in the Barind Region of Bangladesh

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Over the last three decades, groundwater resources in the north-western Barind region have been excessively exploited to irrigate high water demanding Boro rice crop therein. This leads to a declining trend of groundwater level (GWL) in the region. Therefore, a research study was conducted in three selected sites of Barind region namely, Bagmara, Mohadevpur and Nachole upazila to estimate recharge potentials and safe yields of the underneath aquifers; and, to project the likely impacts of climate change on recharge to those aquifers. Two recharge estimating approaches (i) GWL fluctuation and (ii) soil moisture accounting method embedded in the Hydrologic Modelling System (HEC-HMS) model were employed in this study.

It was found that rainfall is strongly correlated with groundwater recharge estimated by both GWL fluctuation (correlation coefficient = 0.61) and HEC-HMS (correlation coefficient = 0.83) models. The studied aquifers are mainly get recharged during June – October and about 23 –70% of annual rainfall can be converted into groundwater recharge. Safe yield analysis shows that both unconfined Mohadevpur and Bagmara aquifers are no longer suitable for further exploitation whereas the confined aquifer underneath Nachole upazila has still the potentiality to provide useable groundwater. The build HEC-HMS model was run with future climate forcings generated by the two Global Climate Models (GCM), GFDL-CM3 and MIROC-EMS, participated in the latest IPPC's CMIP5 project. Compared to the baseline period (1981 – 2000), an increased mean monthly rainfall (up to 60 mm/month) was projected during June –August in the future 2021 – 2040 period. Moreover, the studied areas are projected to experience consistent increased temperature for all calendar months (maximum increase 2.9 °C). Projected increasing rainfall and decreasing evapotranspiration altogether increase groundwater recharge (maximum 90 mm/month) of the aquifers for the future 2021 – 2040 period. Such blessing impacts of climate change will help conserve the country's groundwater resources.

Flow Simulation in a Phreatic Aquifer using Infinite Elements in the Finite Element Analysis

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Surface water and groundwater interaction is a challenging issue and special case studies are usually examined. Such a case is the seepage from a stream or canal into the adjacent phreatic aquifer. In this groundwater flow problem, the area of main interest is the soil zone in the vicinity of the stream while the aquifer is supposed to extend, particularly for the mathematical analysis, to infinity. In this paper, the problem is approximated as one-dimensional saturated groundwater flow described by the Boussinesq equation and as two-dimensional saturated-unsaturated groundwater flow described by the Richards equation. To solve numerically these equations, the finite elements analysis is applied by embedding special elements, called infinite elements, which extend to infinity in one direction based on the appropriate shape functions used to describe the infinite part of the element. Hence, the number of elements required to discretise the key subsurface flow region is substantially reduced compared to the elements required to discretise the flow region of the whole aquifer. Thus, computationally efficient and sufficiently accurate solutions are obtained both in terms of simulated water table and groundwater recharge or discharge. The computational schemes using infinite elements are calibrated by the corresponding schemes that discretises the entire flow region with common elements. The developed schemes are also applied to an agricultural area in Central Greece where the variation of water level in a drainage canal is closely associated with the variation of the water table in the phreatic aquifer.

Territorial Analysis and Hydrological Modelling of the Canale D'Aiedda Basin

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The Canale d'Aiedda basin, together with the other basins of the Jonico-Tarantino territory, is part of the environmental area of Taranto. This site is recognized by the Italian State as an area that requires remediation of soil, subsoil, surface water and groundwater, in order to avoid environmental and health damages. The Canale d'Aiedda has the largest extension among the basins in the area and flows into the Mar Piccolo. The results of the territorial analysis of the Canale d'Aiedda basin defined in detail its geological, morphological and hydrological features, as well as the main environmental and land use characteristics. The information produced by the data analysis and the surveys carried out on the territory were archived in a GIS environment. The results of the field and laboratory activities as well as of the modelling are related to three specific objectives: nitrogen and phosphorus balance; monitoring of streamflow and water quality; hydrological modelling. Results of the nitrogen and phosphorus show a surplus of these nutrients. The methodology used is based on official data and the results are indicative of a pollution of agricultural origin. The water quality monitoring activity confirmed the results of the nutrients balance and showed a specific type of pollution deriving from the wastewater treatment plants. Based on the information obtained from the surveys, as well as from monitoring, hydrological simulations were carried out through the implementation of two distributed models, SWAT and AnnAGNPS, for the estimation of water discharge, sediment yields and nutrient loads deriving from point and non-point pollution sources.

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Irrigation Performance of Soil-Moisture Based Automatic Irrigation System for Growing Soybeans in Korea

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Water management is important for growing soybeans in Korea, because they are easily affected by water stress. Although manual irrigation systems are very simple, they are labour intensive methods. Automatic irrigation system operates with no or minimum manual intervention. In this study, soil moisture content, water use, and irrigation efficiency were calculated to evaluate the performance of the irrigation system.

Three different irrigation methods (sprinkle irrigation (SI), surface drip irrigation (SDI), and fountain irrigation (FI)) were used in this study. Soybean (Daewon) cultivar was sown in June 20, 2016.

Soil water contents were measured at 10, 20, 30 and 40cm depths and irrigation efficiencies were obtained by dividing the water absorbed in the effective root zone by the total applied irrigation water. The automatic irrigation system maintained the soil water content at 10cm depth at constant value (30%) using a controller and solenoid valves.

The average soil water contents were 45.17% at SI, 46.03% at SDI, and 42.47% at FI for whole growth period. These values were higher than the control (42.09%, no artificial irrigation practice), but there were no significant differences between the irrigation methods. However, the total amount of irrigation water at SDI (47.3 ton/10a) was the lowest among the methods (60.4 ton/10a at SI, 92.6 ton/10a at FI). In addition, the irrigation efficiency at SDI (91.86%) was the highest among them, followed by SI (89.34%) and FI (78.92%).

Even though SDI requires higher initial investment, it turned out that SDI saves water and may improve yields by applying water more directly to the root zone. Thus, SDI would be a promising irrigation method for upland crops.

In conclusion, this automatic irrigation system can reduce the production costs of upland crops, thereby improving grain self-sufficiency in Korea.

Alternative Underdrain Designs for Reducing Pressure Drop across Sand Media Filters

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Reduction of pressure drop across sand media filters – which are broadly used for preventing emitter clogging – should help reducing energy consumption in microrrigation systems. Previous research has shown that most of the pressure drop is located at sand filter underdrain. In this work, the effect of the nozzle geometry on the pressure drop of a sand filter was experimentally studied. Four nozzles were analysed: one commercially produced with a conical shape and three alternative cylindrical underdrains that were built for the experiment and that differed in the location and the number of slots. Experiments in both filtration mode and backwashing conditions for a wide range of superficial velocities were carried out at the laboratory. The results reported that a reduction of the filter energy consumption greater than 20% could be achieved by simply modifying the position of the slots above the surface of the underdrain element. The effects of the nozzle were further investigated by means of an analytical model that predicted the pressure drop of the water flow through the filter. The model confirmed that the distribution of the slots in the underdrain was a critical factor for determining the length of the region with a nonuniform flow within the sand. When using the commercial nozzle at flow rates >0.85 l/s, this region produced the major contribution to energy losses in the filter due to increases in the tortuosity of the water path within the porous medium. From these results, it is suggested that an affordable way to increase the energy efficiency of already existing installations would be to replace the current underdrain elements with new improved designs that have 40% more slots in its cylindrical surface.

Coupling Water Saving Technologies and Wireless Sensor Network-based Information System for Efficient Irrigation Management Under Upland and Lowland Crop Production Systems

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Maximizing limited available water supply for crop production during drought occurrences in tropical and arid countries can be addressed using modern information and communication technologies. A collaborative project is developing and pilot-testing a wireless sensor network (WSN)-based water information system for improving water use efficiency under upland and lowland crop production systems in the Philippines. The upland pilot test site uses drip irrigation together with a network of soil moisture sensors and weather sensors that provide real-time monitoring of soil and weather conditions fed directly to a cloud-based water information system as basis for automated irrigation scheduling. The lowland pilot test site uses alternate wetting and drying technology (AWD) along with a network of water level and weather sensors for real-time monitoring of water management parameters, similarly fed directly to a cloud-based water information system as basis for automated irrigation scheduling. Biophysical characterization of the upland and lowland pilot test sites and design of WSN hardware have been performed. Field experimental plots under "with" and "without" wireless sensor network have also been established. Deployment of wireless sensors and accessories, low-level programming and testing will consequently be performed at the test sites. Significantly higher irrigation water use efficiency, water productivity and crop yield are expected to be observed under plots with wireless sensor network and water saving technologies compared to plots with manual irrigation without wireless sensors. Results of pilot testing could serve as basis for upscaling and commercialization and for policy formulation to address contemporary issues such as water security, climate change, sustainable agriculture and food security particularly in areas with limited water supply and regions often plagued by drought occurrences.

Artificial Ground Water Recharge Planning in Bijnor District Using Remote Sensing and G.I.S.

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With the increasing population and industrialization, water demand for various purposes is increasing, resulting in over exploitation of ground water. The water table in many parts of the India is declining. Keeping it in view, the present study was carried out to identify the groundwater potential zones for the artificial groundwater recharge planning with the help of Remote Sensing data of IRS-1D-LISS-III. Area selected for the above study was the Bijnor district of Uttar Pradesh state of India, covering an area of about 441980 ha. Satellite data were used to prepare geomorphological map of the district. Thematic map was integrated with the help of Geographic Information System to demarcate the poor to excellent groundwater potential zones. Water table depth variation contour map (for the period of 20 years) was prepared to delineate the maximum water table decline zones. The study has presented a synoptic view of the geo-morphology of Bijnor district. On the basis of this study, suitable sites for the construction of different structures for the artificial groundwater recharge have been suggested. Results showed that water table declined by 3 to 9 m in Old Flood Plain (OFD)–2, during the study period. The geomorphic elements, identified in the study area, suggest that OFP-1 land form is highly suitable site for percolation tanks. In OFP-3 land form, percolation tanks having larger width and lesser depth are suitable. Maximum water table declined in OFP-2 and OFP-3 land forms. Hence these areas need immediate recharge plan. Dug well recharge method can be powerful tool for the land form OFP-3 where the silt and clay contents in the upper surface are high, whereas OFP-1 and Young Flood Plain (YFP) -2 land forms are highly suitable sites for percolation tanks.

Effect of Irrigation Systems and Water Quantities on Corn Production under Partial Rootzone Drying Conditions

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Worldwide, Agriculture is consider the main user of water. In Egypt, Agriculture uses more than 80 % of the available water. In irrigated agriculture, the right way to save water is to increase water use efficiency (WUE) through better irrigation management like Partial Rootzone Drying (PRD). Partial Rootzone Drying is an irrigation regime, which increase water use efficiency without yield reductions in many different crops. Corn crop is one of the most important crops for human and animal consumption and planted for grain yield or for forage (FAO, 2018). Corn yield productions under surface and sub-surface drip irrigation systems and their responses to different irrigation water quantities was evaluated in 2016 and 2017 summer growing seasons. A field experiment was conducted using corn crop (Zea Mays) grown in northern Egypt at Shebin El Kom, Menoufia Governorate. A randomized split-plot design was used with irrigation system as main plots and different irrigation water quantities randomly distributed within either conventional or partial rootzone drying irrigation regimes. The irrigation water quantity was a fraction of crop evapotranspiration (ETc) as 0.6, 0.8, 1.0, 1.2, and 1.4 of ETc. The experimental treatments were replicated three times. The experimental results showed that, the soil water content significantly affected by irrigation regime and irrigation water quantities. Also, Corn grain yield was significantly affected by irrigation system and both irrigation regime and irrigation water quantity. Corn 100-grain weight and plant height were affected by irrigation system, irrigation water quantity and irrigation regime, respectively. Significant differences for the interaction between season and irrigation systems were only found for Corn yield production and 100-grain weight. Finally, the results from this small experiment should extrapolate to a large field to find out the optimal irrigation scheduling under non-uniform of irrigation applications.

Down the drain: A model based irrigation strategy

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Efficient irrigation strategies in soil agriculture are hard to predict. Ideally, the irrigation strategy a grower follows should prevent crop water stress while maintaining drainage to a minimum. Nevertheless, is not easy to measure drainage in soil. Lysimeters

are capable of measuring drainage, yet they are expensive and require maintenance. Model based scenario studies can run different case scenarios without needing to set-up numerous lysimeters in the field.

The purpose of this works is to find out how much drainage can be reduced without increasing crop water stress by using model based scenario studies.

The model consists of two integrated modules: The first module describes the water transport through the soil by Richard's Equation. The second module describes the plant water uptake by Penman-Monteith evapotranspiration.

The model was validated with experiment data from lysimeter drainage measurements. A one-at-a-time sensitivity analysis was used to find the robustness of the model in different soil parameters. The soil types ranged from light clay to sandy soils. Six different soil parameters were chosen. An algorithm was used to change the parameters stepwise and observe the change in drainage.

The model showed good prediction accuracy. The predicted total drainage was 250 litres per square meter, against a measured value of 260. The grower strategy did not result in crop stress according to our model, it required 1590 litres, and resulted in 250 litres drained. Strategy 2 did also not result in crop stress, with 217 litres drained. The third strategy resulted in only 164 litres drained, however here crop stress was predicted to occur.

The balance between crop stress and drainage is a delicate one. Drainage model scenario studies have potential to help in this balance. However, careful attentions in measured parameters needs to be considered for the model to perform accurate predictions.

Development of an ICT-based Groundwater Control Systems for Increasing Yields of Field Crops Grown in Paddy Fields

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In Korea, rice consumption has declined gradually recently and its self-sufficiency ratio maintains more than 90 percent. Other field crops heavily rely on imports from other countries, because of their low productivity domestically. Thus, crop production in paddy fields is critical for improving crop self-sufficiency ratio in Korea.

In this study, a wireless sensor-based irrigation management was developed for automatic irrigation control and field monitoring. At subsurface drain irrigation system, the underdrain pipes were placed at 3m and 6m apart, and the groundwater levels were 30cm and 60cm. In addition, the soil water contents and soil electrical conductivities were measured to evaluate soil's physical and chemical properties.

The soil water contents at the surface layer (0-10cm, 10-20cm) during the growing season were 0.253 and 0.316 m^3/m^3 respectively at 60cm groundwater level, which were 27% and 21% lower than the higher groundwater level. These soil water contents were affected by rainfall. In addition, the soil water contents at 30cm groundwater level were larger than 0.24 m^3/m^3, whereas these values at 60cm groundwater level were decreased to 0.16 m^3/m^3. The drain spacing did not influence the soil water contents; however, the drainage outflow at 3m drain spacing was greater than the one at 6m drain spacing, indicating that the narrow drain installation is more effective to drain the soil water. Electrical conductivity in soil was significantly greater with 30cm groundwater level because of the reduction of drained outflow volumes passing through soil profile. In conclusion, the high groundwater level (30cm) and narrow drain spacing (3m) is required for better water retention in soil and higher crop yield.

This smart irrigation system provides farmers with the efficient use of water resources for crop production in paddy fields.

Water Quality Correlation Analysis between Sewage Treated Water and the Adjacent Downstream Water in Nakdong River Basin

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The purpose of this study was to analyze the correlation between the effluent of the sewage treatment plant (STP) and the adjacent stream located downstream of the STP in Nakdong River. The flow and water quality such as BOD, COD, SS, T-N, and T-P data for 12 STPs and adjacent downstream monitoring stations in the main stream and tributaries of Nakdong River were collected from 2012 to 2015. As a result of correlation analysis between river flow and water quality at the river water quality measurement point, COD, SS and T-P were correlated positively with river flow rate at 6, 8, and 6 points, respectively. As a result of analyzing the water quality of sewage treatment plant effluent and downstream stream, BOD and COD were correlated at 2 and 3 points, respectively. T-N showed a positive correlation at 9 points, and 7 of them had a strong positive correlation, indicating that sewage treatment effluent had a large effect on downstream streams. In this study, we found that the correlation between river flow rate and water quality factors (COD, SS, TP) was high for river water measurement points, and the sewage treatment plant effluent was correlated with the T-N value of adjacent streams.

Soil Engineering

Differential Interferometry as a Tool for Localized Study of Runoff Erosion

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New space missions like Sentinel-1 (European Commission and European Space Agency Copernicus Programme partnership) are able to obtain SAR (Synthetic Aperture Radar) images with high frequency, resolution, range and, above all, availability, which allows the use of techniques like differential interferometry in new fields.

Interferometry technique is based in the accurate measurement of the go and back travel of electromagnetic radiation between a SAR Radar and the earth surface, registering intensity and phase of returning radiation into SAR images. Comparing two images of the same earth surface area it is possible to make an interferogram, in which the information of phase difference is highly related to terrain topography, and its deformations can be graphically represented through maps.

The aim of this study is to evaluate the possibilities of using differential interferometry technique for localized monitoring of runoff erosion studies, evaluating calculation parameters, use limits and results meanings.

Qualitative studies in a monitored basin in Daganzo de Arriba (Madrid) has offered good results: erosion proportional to the intensity of rain, use and landcover of each plot, and the results showed independence from crops activities as harvesting.

Quantitative studies in a pilot plot in El Molar (Madrid) was made comparing interferometry results with the deformation patterns obtained with direct measurements taken with a LIDAR and processed with M3C2 algorithm of CloudCompare software. Although results of both methods share the same order of magnitude and, in most cases, differences are within the RMS error, some of the measurements were not conclusive, probably due to the lack of horizontal accuracy needed to make a cell to cell comparison.

Next step of this investigation is to try to apply Persistent Scatterer Interferometry (StaMPS) to verify quantitative results and the best method of vertical correction factor determination: constant o geographically variable.

Impacts of Artificial and Natural soil Conditioners on Water holding capacity and Hydraulic Conductivity of Sandy soils

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In arid and semi-arid regions like the Kingdom of Saudi Arabia, efficient use of irrigation water requires adoption of appropriate agricultural practices of water conservation. Improving hydraulic properties of sandy soil to be as if that of loamy soils enhances soil available water and minimizes deep percolation. Addition of natural and artificial soil conditioners to sandy soils attested to be effective in rising water holding capacity and reducing saturated hydraulic conductivity. This study was to investigate impacts of addition of super-absorbent polymer (K- crossed-linked polyacrylamide), as an artificial conditioner on hydraulic properties of sandy soil, along with three natural soil conditioners; dry cattle manure, rich clay soil (silt clay loam soil), and date palm biochar. Water holding capacity of amended and un-amended sandy soils evaluated under selected low soil matric tensions (-0.2, -0.4, -0.6, -0.8 and -1 bars), while their saturated hydraulic conductivity assessed with TOP-Bench high precise digital apparatus. The results showed all conditioners enhanced the retention ability of sandy soil, but they had different impacts on saturated hydraulic conductivity. Water-holding capacity of amended sandy soils increased by about 379%, 200%, 74% and 32% with respect to effect of addition of 10% date palm biochar, 0.4% K-HCP polymer, 10% silt-clay-loam soil and 10% cattle manure respectively. On other hand, the date palm biochar, silt-clay-loam, and cattle manure decreased saturated hydraulic conductivity of sandy soil by about 74%, 59% and 47% respectively, while the K-HCP polymer incensed by about 31%. The date palm biochar has the highest potential to improve hydraulic properties of sandy soil; therefore has the potential to save irrigation water and reduce deep percolation water losses.

Effect of Sand Size and Inlet Pressure on Sand Media Filter Performance Using Reclaimed Effluents

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Sand media filters are specially recommended for preventing emitter clogging when irrigation water with high pollutant load is used in micro irrigation. The objective of this work was to assess those operational conditions related to media size and filter inlet pressure that could yield to a better emitter protection when wastewaters are used. So, an experiment was carried out in a micro irrigation system that had a sand media filter for filtering a reclaimed effluent. Two sand size ranges (0.4-1.0 mm and 0.8-2.2 mm) and three operating pressures (200, 300 and 400 kPa) were tested. Filtered flow rate and volume, pressure loss across the filter, inlet pH, temperature, turbidity and electrical conductivity and outlet turbidity data were collected every minute in a supervisory control and data acquisition system. Volume used for filter backwashing was also recorded after each filtration cycle. As the reclaimed effluent was supplied by a wastewater treatment plant, there were some variations in its quality across the experiment. Greater sand size significantly ($P<0.05$) increased filtered flow rate but reduced turbidity removal. On the other hand, operating pressure was statistically significant on filter flow rate, backwashing volume and turbidity removal. The effect of pressure was not the same on each parameter but, overall, a pressure of 300 kPa yielded higher filter flow rates and turbidity removal and required less backwashing volume. Although that for the 0.4-1.0 mm sand size range, inlet filter pressures of 300 and 400 kPa did not show statistical differences on turbidity removal, increasing filter pressure up to 400 kPa is not recommended because working at this inlet pressure caused higher pressure loss and, presumably, higher energy consumption.

Development of a New Subsoil Management Concept for Combined Deep Loosening and Incorporation of Organic Material

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Soil deterioration due to soil compaction and limited fertilizer application become increasingly significant. Concerning common tillage practices, deep tillage (subsoiling), is known to be beneficial for soil physical conditions and thus plant development. Subsoiled soils have lower bulk densities and increased infiltration capacities. A new subsoil management concept was developed to figure out its effects on plant development.

The concept operates strip wise and excludes the topsoil. The topsoil is removed in a strip of 30 x 30 cm (width x depth). Organic fertilizer is placed on the strip in a quantitative volume portion of 20 % and incorporated up to 60 cm. Afterwards the topsoil is laid back into the strip and reconsolidated.

The feasibility and value for plant development was examined by a two year field experiment and verified in comparison to a control treatment. The experiment covers effects on growth of spring barley on fallow land (FL) and at regularly tilled land (RT). A significant increase in straw and grain yield ($P>0.1$) was detected for subsoiling and subsoiling with incorporation of biological waste compost (Bio). The effect of subsoiling on yield is higher at the FL than at RT (28 % vs. 5.7 %), compared to control. While for Bio the opposite effect occurs (40 % vs. 73 %). The incorporation of compost from green cuttings promoted contrary results. For FL a significant increase in yield (11 %) occurs, while at RT a significant decrease in yield (- 32 %) is present. Plants of all treatments were significantly higher at FL, while at RT only subsoiling and subsoiling with Bio increased plant height.

Thus subsoiling and subsoiling with Bio increase overall plant development. The new subsoil management concept offers the opportunity for a sustainable increase in plant production that can secure stable yields during dry periods

Evaluation of Compaction in No-Till Vertisol Field Using Methods of Cone Index and Pedotransfer Function - Case of a Moroccan Semi-Arid Context

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This study aims to evaluate compaction of a fifteen years old no-till vertisol field crop (40.91 % clay 44.16 % loam 14.93 % sand) and find spatially potential correlation between compacted clusters and relative physicochemical properties. Measurements are done on soil strength (using vertical penetrometer), bulk density, organic matter, total limestone, and Atterberg limits to evaluate soil compaction and develop pedotransfer function. Experimental results showed ranges of the bulk density of [1.30 to 1.80 g/cm^3] in the boundaries and [1.01 to 1.40 g/cm^3] in the center of the field crop. The matter organic content averages are 2.23% and 2.91% for the profiles of 0-10 cm and 10-20 cm, respectively. Analysis of the total limestone content showed a spatial decreasing gradient situated between the ranges of [3.5-14 %] and [0.5-3%] for the soil profile of [0-10 cm]. The total limestone gradient decreased in the soil profile of [10-20 cm] within the range [4.5-21 %] and [1- 4 %]. Soil strength behavior showed relatively a decreasing gradient between the ranges of [11.5-19 MPa] and [0.1-11 MPa]. Atterberg limits showed that is of importance to respect delay intervention for avoiding compaction induction relative to soil plasticity state . The results showed an important compaction level in the extremities field due to importance of machines/tools traffic impact and intensity of tractor turning and operation number with no respect of soil plasticity during intervention in the crop production cycle. The compaction was also related to limestone gradient in the field. The limestone content affected soil strength and its susceptibility to compaction. Based on evaluated parameters, estimation of vertisol sensitivity to compaction was approached using a pedotransfer function (R^2=0.9039).

Novel in Situ System for Monitoring Soil Organic Carbon by Using Mobile Vis-Nir Spectroscopy and Machine Learning Techniques

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Recognizing the importance of Soil Organic Carbon (SOC) for effectively reorienting and transforming agricultural systems towards the perspective of climate smart agriculture, it is essential to perform in-situ measurements in a novel, efficient, and cost effective way. The objective of the present study is to introduce a Mobile Proximal Soil Sensing System (MPS^3) allowing in situ vis-NIR measurements independent of illumination and soil roughness restrictions. The MPS^3 towed by a tractor provides some advantages over conventional backpacker and soil penetrator systems such as the fast and high power data acquisition in a near- real time domain. The current study focused on integrating in situ measurements with machine learning methods and geo-statistics towards delivering quantitative and spatially distribution of SOC to support the implementation of informed decision making in the agricultural sector. Specifically, a set of linear and non-linear machine learning algorithms including the partial least squares regression (PLSR), Cubist, and Support Vector Machines (SVM) are utilized with leave one-out cross-validation in order to establish spectroscopic calibration models of SOC. A detailed in-situ dataset (100 soil samples coupled with in situ spectral and chemical laboratory measurements) was acquired in an experimental layout in Greece to test the performance of the MPS^3 under open field conditions. The results reached coefficients of determination values (R^2) of 0.68 and a residual prediction deviation (RPD) of 1.36.In this context, this study proves that the MPS^3 is a rapid and cost effective tool for precision agriculture applications and effectively monitoring of SOC stocks for accounting purposes. Further research should consider the improvement of signal processing and reconstruction techniques to address the effects of soil moisture aiming at the synergetic use of field acquired spectra with existing soil spectral libraries by employing spiking techniques.

Development of New Version of the Spiked Shear Vane for Measuring of the Peatland Top Roots Layer Strength

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Many wetlands in Poland require special care to restore them as breeding areas for endangered bird species. Using tracked snow groomers, tracked trailers and farm tractors is not eco-friendly practice and can conflict with conservation goals, mainly, through disturbance of the ground surface. To improve protection of these sites Industrial Institute of Agricultural Engineering (PIMR) developed tracked vehicles and technologies that will be more useful in formal paludiculture. To assess the quality of vehicles work and theirs impact on terrain the spiked device, developed by METLA from Finland, was built in PIMR for measuring the shear modulus of the ground. Tool is manually rotated using a commercial torque wrench equipped with gyroscopic sensor. Spiked tool is good but output of 13 spikes shear vane measurement only describes strength prevailing in very small areas. Manually operation sets also limits to the torque availed in the researcher hands but increasing diameter of the plate should yield a truer estimation of the top layer strength in the scale of track contact path. After field tests new version of the plate was build. In this version of the spiked plate its radius increased from 0.1 m up to 0.194 m, spikes length is almost twice shorter comparing with first one (0.16 m). Number of spikes was preliminary increased to 25 and in next step up to 45 spikes. The length of spikes (0.7m) corresponds to the height of the crossbars of the snow grooming vehicle. Volume of specimen rotated by spiked blades corresponds to ¼ of the volume of the top roots layer which is between the crossbars of each track of the PIMR's vehicle. Spiked tool is equipped with removable wheels for easier transport handling in the field. New version of tool facilitates relatively fast manual measurement of top root layer strength.

Analysis Of Tillage Operations With Variable Working Machine Parameters Using a Compact Disc Harrow

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During tillage operations a lot of factors are considered to achieve a high soil tilt for plant growth and reduce cost of operation. The purpose of this research was to establish the relationship between the working machine parameters of a compact disc harrow and tillage operational parameters under various soil moisture content. The working machine parameters were disc space and

ground machine speed. The tillage operational parameters were soil inversion, cutting depth and soil clod breakage. The results showed that disc space and ground machine speed all significantly affected soil inversion in the various soil moisture content media. The resulting data was statistically analyzed in one way ANOVA. The highest soil inversion was achieved when the ground machine speed was 0.2m/s with the disc space at 20cm. Also, at disc space of 20cm and the ground machine speed of 0.2m/s in the 26.5% soil moisture content, the highest soil breakage was achieved in this particular medium. According to the study, changing the disc space or the forward ground speed of the working machine did not have much significant effect on the tillage cutting depth. It was concluded that varying working machine parameters such as disc space and ground machine speed could significantly affect the soil inversion, and soil clod breakage.

Soil and Landscape Engineering

Delivery Rates during Retention And Transport Of Encapsulated Fertilisers In Porous Medium

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Fertilisers applied to soils commonly undergo a quick removal by leaching that greatly diminish nutritional benefits to the plant. To solve such problem, this investigation proposes augmenting effectiveness by means of a controlled release of the fertiliser. The present investigation suggests a process of synthesising particles that contain fertiliser and having an average size between 1 µm and 2 µm. For this study, a fertiliser (KH2PO4) was immobilised with chitosan, and later was evaluated with the aim to identify in first place efficiency of synthesis of micro-particles, and in second place delivery rates along time. The evaluation compared results between KH2PO4 and KH2PO4 immobilised with chitosan in order to know the capacity of retention and transport within the soil. To conduct experiments, soil was represented by a column length of 0.1 m with porous medium, which was constituted of silica gel with average size particle of 51 µm. Milli-QTM water was used for a series of experiments that assessed the micro-particles through induced leaching. It was found that 17% of the KH2PO4 was delivered during the first induced leaching, and corresponded to the KH2PO4 that was not immobilised with chitosan. Additionally, every 48h there was an induced leaching that was conducted 4 times, and delivered 69% of the KH2PO4. Then, the experimental rig was also modelled by means of the general rate model. The model included axial transport, convection, and accumulation in the mobile and stationary phase to get unidimensional predictions along the column. In this way, it was possible to predict the concentrations after water moved down through the column, as an indicator of delivery rates. Thus, presenting experimental and modelling assessment of the induced leaching happening in a column under specific operating conditions.

Soil Conductivity: Detecting Slurry Injection Depth With Minimal Effort

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Semi-liquid manure is a valuable fertilizer. Worldwide, pig or cattle slurry ensures efficient supply of plant nutrients in many crops. Current laws and future regulations demand to apply semi-liquid manure on soil surface or to inject the slurry immediately into the soil during application. The results are emission reductions and reduction of nutrient loss. Correct slurry application depth is a significant factor in each crop. If the roots reaches the injected slurry at the optimal plant growth, we observe a maximum consumption of nutrients and a suitable uptake.

In field trials and research facilities, the potentially successful slurry deposition depth after injection is checked by digging with spade. Depending on the structure of the soil and the presence of larger particles and stones slurry injection depth may vary. By a large number of samples, the variance depending on soil conditions, moisture and nutrient supply can be determined. This requires lots of work and much time.

For quick and reliable checking of the correct deposition depth of the semi-liquid manure, we present a measuring system based on conductivity. The system delimits the processed soil areas from the slurry, measures the vertical extent of the fertilizer applied and can make a declaration of the zone of mixed loosened soil and semi-liquid manure in deposition depth.

This results in a large reduction of spending time on field trials for the scientific staff. Fast data collection makes the measurement results comparably, since the environmental influences during data acquisition can change less strongly than over a long trial period.

NH_3 Emissions from Treated Buffalo Manure Application in Mediterranean Climate and Comparison to ALFAM Model

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Ammonia volatilization is widely recognized as one of the major environmental European problems, due to the increase in livestock farming activities. As a consequence, accurate ammonia assessment is needed in order to control ammonia emissions and to update national emission inventories. Besides some uncertainties still related to the measurement methods, another important issue is the necessity of investigating a different kind of fertilizers. In the last few years, considerable attention has been paid to many manure treatments prior to field application.

This study aims to assess ammonia emissions from the field application of separated buffalo manure digestate in the Mediterranean climate, in order to improve the emission inventory for this animal species, reared mostly in South Italy. Two measuring methods were used: wind tunnel (WT) and Integrated Horizontal flux (IHF). Moreover, ammonia emission measured were compared to those obtained running the statistical regression model ALFAM. This model based on Michaelis-Menten type equation is often used to predict cumulative ammonia loss and since it is based on a significant dataset is useful to discuss the effectiveness of the emission measured. The total ammonia losses measured in 7 days were 26.39 and 49.24 kg N ha^{-1}, for WT and IHF, respectively. Although the predicted total emissions were 40.99 and 36.56 kg N ha^{-1}, for IHF and WT, respectively, it is possible to observe the good accordance of the ALFAM model with the temporal pattern of both methods.

Landscape Fragmentation in the European Context: Outcomes from a Comparative Approach

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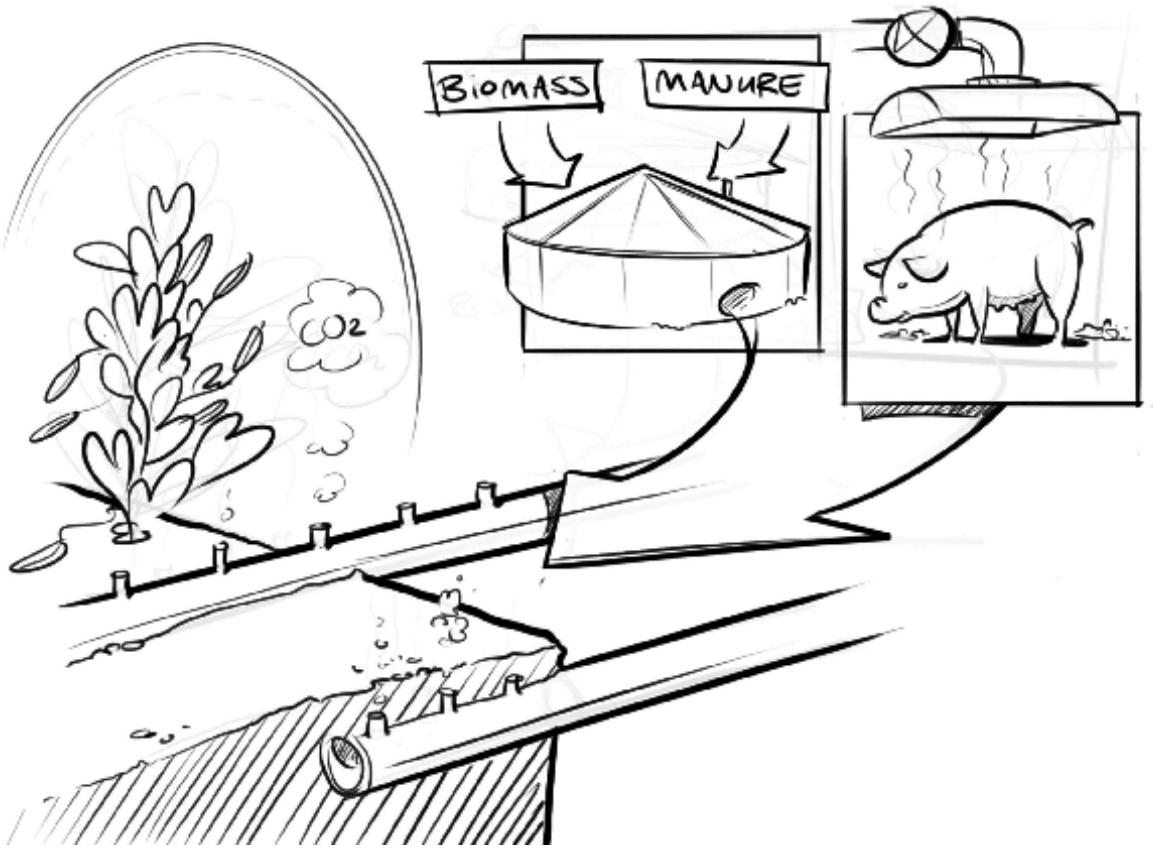
In Europe, some policies have focused on landscape and environment quality. Landscape fragmentation (LF) can be considered as one of the main causes that negatively affect landscape quality, because it triggers habitat loss processes, decline of fauna and flora species, and loss of connectivity. Transport and mobility infrastructures (TMIs) and urban settlement have been acknowledged as key factors in increasing LF processes. Scientific literature describes several metrics able to quantify LF, but methods useful to quantify LF caused by TMIs are poorly described.

In this study, we measure LF in four landscape units (LUs) - two LUs in Wales (the UK) and two in Sardinia (Italy) - to identify areas where defragmentation measures could contribute in reconnecting isolated patches, allowing wildlife movement. We use the Barrier Fragmentation Index (BFI) to quantify the LF due to TMIs and the Urban Fragmentation Index (UFI) for the one due to urbanized areas. The BFI is able to measure LF taking into account how specific target species perceive TMIs. We choose the hedgehog (Erinaceus europaeus) as target species, a quite common species in both the countries. Finally, we apply two additional metrics, namely the effective mesh size (EMS) and the connectivity of natural areas (CNA) in order to verify correlation between the four metrics.

Preliminary results show (i) high values of BFI and UFI in Wales (North East Wales: BFI 299733.70; South East Wales: UFI 7.06) and low values of both indices in Sardinia, and (ii) likely correlation between BFI, UFI and EMS. On the whole, the coastal areas appear as the most fragmented, and measures may be planned to reconnect patches and allow the target species' movement. Furthermore, soil loss in rural and agrarian areas could be avoided by using urban eco-friendly planning measures.


BIOMASS
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CO2

Topic 7: Animal Production Technologies (AP)

Research and application of technology and management of systems to control indoor air quality and thermal comfort in barns, improve welfare and health of animals, reduce emissions and their impacts. Examples include precision livestock farming, CFD and ventilation systems, emissions of particulate matter and gases (e.g. ammonia, greenhouse gases, odour), and control of pest and diseases.

LivAGE – Measuring and Reducing Emissions

Validation Of A Dual Tracer Ratio Method for Comparative Emission Measurements in a Naturally Ventilated Dairy Housing

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This study presents the validation of a dual tracer ratio method for comparative emission measurements in the experimental dairy housing of Agroscope (Tänikon, Switzerland). It consists of two identical, spatially separated experimental sections - each for 20 dairy cows – and a centre section for milking and technical installations. Modular design and flexible floor elements allow the assessment of structural, process-engineering and organisational abatement measures as well as feeding strategies on a practical scale. Thereby, the emission reduction potential of abatement measures can be quantified in relation to a reference.

Mass flow emissions under natural ventilation are determined by continuous areal dosing of two artificial tracers (SF6, SF5CF3) and real-time detection of both tracer and target gases. The diluted tracer gases are dosed continuously via steel tubes systems with critical capillaries into different experimental sections, which enables the independent assessment of both sections. Integrative air samples are collected by multipoint sampling using a grid of critical glass capillaries and directed to the analytics situated in a trailer in the central section. Gas samples from the experimental sections, in-between area and background site are extracted sequentially, using a selector switch and analysed for NH3, CH4 and CO2 by CRDS (Picarro Inc.) and for the tracer gases by GC-ECD (Agilent Technologies).

Systematic validation experiments with different dosing variants demonstrate the suitability for both areal and point emission sources and the equivalence of both tracer gases. The accuracy of the tracer ratio method was demonstrated by CH4 dosing experiments and the uncertainty of the tracer ratio method shown to be in the 3-10 % range, superior to existing alternative approaches. Cross-contamination between the experimental sections of a tracer gas in the respective other section increased with lower wind speeds, but was shown to be low. This should be part of a quality control.

Simulation of Nitrous Oxide Emission from Dairy Manure Stockpile using Dynamic Chamber Technique

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Dairy manure is typically stored within the farm from days to months before land application, for small and middle sized farms in particular, making the dairy stockpiles an important emission source of greenhouse gases (ghgs) in China, including nitrous oxide (N2O), while little information on the emission is available under the management system. Using dynamic chamber technique, experiments were conducted to simulate the N2O emission from dairy manure stockpile in different seasons, and the influence of temperature, surface wind speed and simulated rainfall was explored. The average ambient temperature in spring, summer, and autumn was 21.0°C, 25.2°C and 8.4°C during the trials, and the core temperature (Tcore) of dairy manure was 25.0°C, 25.0°C, and 9.1°C, respectively. Results show that overall daily N2O emissions from manure were 0.24 mg•kg-1, 0.32 mg•kg-1, and 0.03 mg•kg-1 in spring, summer and autumn, respectively, and significant difference was found in seasons. Wind speeds had different influences on N2O than other ghgs, meanwhile the simulated rainfall resulted in a sharp increasing of N2O emission and then the emission decreased to previous level for 6-10 h.

Greenhouse Gas Emissions from Dairy Open Lots in China

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Open lots are popular facilities in dairy housing system to provide free ranging space for dairy cows in China. Due to the deposition of feces and urine, a large amount of greenhouse gases (ghgs) and ammonia (NH3) emit from the open lots, contributing to global warming and causing nitrogen losses. Both field measurements and lab scale experiments were conducted to evaluate gaseous emissions from dairy open lots. In field measurements, ghg emissions (CO2, CH4 and N2O) from the ground level of a typical dairy open lot in Beijing was surveyed by closed chambers in four different seasons. Totally 420 sampling events were conducted, and estimated CO2, CH4 and N2O emissions were 4.9-341.0 kg•hd-1•yr-1,28.8-1306.7 g•hd-1•yr-1, 32.9-331.4 g•hd-1•yr-1, respectively. A scale model of dairy open lots was used to investigate gaseous emissions at varied air temperatures (15-35°C), surface velocities (0.4-1.2 m•s-1) and floor types (unpaved soil floor or brick-paved floor) in controlled laboratory conditions by wind tunnels. CO2, CH4, N2O and NH3 volatilizations were measured in a 24-hour duration after feces and urine deposition. Significantly affected by air temperature and surface air velocity, CO2, CH4, N2O and NH3 emissions were in the ranges of 34.4-202.6mg•kg-1•h-1, 0.3-3.2 mg•kg-1•h-1, 0.05-0.60 mg•kg-1•h-1 and 2.33-13.7 mg•kg-1•h-1, respectively. Compared with unpaved soil floor, higher CO2 and NH3 emitted from the brick-paved floor. Via N2O and NH3volatilization, 1.6%-8.6% of total nitrogen in the manure lost in the latter 12 hours of experimental duration.

Naturally Ventilated Stables: Emission Measurements Combining Open-Path Lasers And Anemometers

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Currently available ammonia emission measuring techniques for naturally ventilated stables rely on assumptions such as homogeneous gas distribution or slow temporal fluctuation. Such assumptions are often difficult to verify under practical conditions

and raise questions concerning measurement uncertainties. Therefore, there is a need for a technique that delivers both spatially detailed and dynamic information on flows and gas concentrations under practice conditions. However, as there is no golden standard, it is essential that this technique is validated in the best way possible.

For this purpose a naturally ventilated dairy cattle stable was equipped with 16 ultrasonic anemometers (2D and 3D) spread across the openings of the building envelope. Each of them was linked to a representative ventilation opening surface area to calculate total in- and outflowrate. Four open-path lasers (OP-TDL) were installed at the major ventilation openings to capture the NH3 concentrations. To gain more insight into the heterogeneity of the NH3 distribution, four automated retractable reflectors were placed in the path of the laser in the ridge, effectively dividing this path into sub-segments. The windscreens at both side vents were manually controlled according to the expert judgement of the farmer.

To justify the reliability of the proposed method, the equivalence between total measured inflow and outflow was assessed. Large differences between both flows were found. Possible causes and solutions will be discussed. The open-path laser set-up in combination with the ultrasonic sensors showed the ridge opening to be a relatively steady environment even under changing meteorological conditions. Therefore a less complex set-up is possible in the ridge. However, measurements at the side vents seem much more susceptible to changes in wind speed and direction and possibly need a more detailed approach. Issues concerning the practical implementation of this set-up are discussed.

Application Of Best Available Technique (BAT) For Emission Reduction Of Livestock Industry In Denmark

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With Integrated Pollution Prevention and Control Directive (IPPC), following by the Industrial Emissions Directive (IED) in 2013, the EU commission has defined the obligations that industrial and agricultural activities with a high pollution potential must comply. Virtually all sectors in Annex 1 to the EU commissions' IED are covered by a BREF document. Of the 28 BREF documents that are currently applicable in Denmark, the BREF for pig and poultry farms is the most widely represented, with around 1,200 farms (The Danish Environmental Protection Agency, 2018). The purpose of the presentation is to provide an overview over the Danish application of Best Available Techniques at livestock production facilities.

In Denmark, the guidelines for BAT have been developed by the Danish EPA. The purpose of these guidelines is to assist the municipalities in setting the BAT requirements and to ensure a uniform practice between the municipalities in defining the BAT requirements for livestock facilities. The BAT-standards conditions include emission limit values for ammonia and phosphorus.

Performance of the techniques within the areas of feeding practice, housing systems, manure storage, and manure application have been analysed and documented in technology sheets. The BAT-assessments for the prevailing combinations of types and sizes of livestock farms have been documented in so called BAT-conclusions that include BAT-emission limit values for ammonia and phosphorous (together with BAT-assessments for nitrate leaching and the consumption of water and energy). The emission limit values apply to the individual livestock production facility, and it is left to the farmer to decide which technologies to apply in order to comply with the emission limit values. The Danish EPA Technology List contains applicable technologies from which a farmer can choose. The presentation will give a thorough description of the technologies listed with focus on technologies that abate ammonia and odour emissions.

Influence Of Wind Direction And Sampling Strategy On The Estimation Of Ammonia Emissions In Naturally Ventilated Barns

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Ammonia and greenhouse gases have a negative impact on our environmental live. The most important agricultural sources of pollutants are cattle housing systems, where dairy cattle housing systems are mainly naturally ventilated. Estimating emissions for naturally ventilated barns (NVB) is challenging due to a great number of influencing factors. Especially the direct coupling of the inside flow regime with the ambient, turbulent weather conditions makes it hard to measure the air exchange rate and the emissions. Often, the measurement setup is designed to cover only the main wind direction. In case of deviating wind directions, the measured values are neglected, which extends the duration of the measurement campaign in order to have a sufficiently large dataset.

To overcome this limitation, we equipped an NVB in northern Germany with an extensive setup, making it measureable for every wind direction. More than 900 m sampling lines in- and outside the barn with critical orifices every 5 -10 m were installed. Gases like ammonia (NH3), methane (CH4) and carbon dioxide (CO2) were measured in parallel with two Fourier-Transformations-Infrared-Spectrometer (FTIR) devices. Hourly emission factors for NH3 over a period of more than 200 days were derived by using the CO2 balance method and two different sampling methods for inside-outside concentrations.

The results show a gain in usable data up to 190% when also taking into account wind conditions that deviate from the main wind direction. The derived emission factors strongly depend on the choice of the sampling line according to the wind direction. A first analysis shows differences of the NH3 emission factors for different wind directions between -2.23 g/h and +0.23 g/h per livestock unit. Further investigation needs to be done to identify the correlation of wind direction, ambient temperature and emission factors.

Legal Requirements on Ammonia and Greenhouse Gas Emission from Animal Production Buildings in European Countries

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Ammonia and greenhouse gas emission from animal production buildings can be reduced by converting to low-emission housing systems, by use of effective abatement technologies, and by changes in the feed composition. These options are usually associated with additional costs, which makes farmers less motivated to make use of them, and therefore additional incentives might be necessary to force a reduction of the emissions. Legislation is a well-known approach to obtain an aim-directed development. Some countries have already substantial experiences with legal requirements on ammonia emission from animal production buildings. One experience is that legislation can be an important driver for development and testing of new abatement technologies. Experiences also show that it is demanding to develop and administrate the requirements, and that there exist large

dissimilarities between specific requirements set by different countries. In addition, it is assessed that mayor advantages may be archived by utilizing experiences from other countries to improve existing legislation, or to develop appropriate legal requirements in countries, which not already have such. Therefore, this work aims to review legal requirements on ammonia and greenhouse gas emissions from animal production buildings in European countries.

The review was conducted though contributions from experts in each of the 27 countries participating in the COST Action "Ammonia and Greenhouse Gas Emissions from Animal Production Buildings (CA16106)", and from an expert in each of the 7 EU-countries which is not jet participating in CA16106.

Sensors Cattle and Sheep

Measuring the Teat Skin Elasticity with the Help of the Suction Method

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The teat of a dairy cow is exposed to a large load during milking because it is the interface between the udder and the liner in the milking process. This results in a fatigue of the teat tissue, especially the teat skin, and can lead to teat damages. The aim of this study was to test the usability of the suction method for teat skin elasticity measurements to get a better understanding of the teat liner interface. The usability of the different measuring parameters was analysed as well. During the present investigation, the Cutometer® dual MPA 580 was used to investigate the teat skin elasticity of the right rear teats from 101 cows. Measurements were carried out in a side-by-side milking parlour before and after milking using the measuring time-strain mode (suction period about 1 second followed by a 1-second suction-off relaxation period; 450 mbar of suction) of the Cutometer® dual MPA 580. The penetration depth of the skin and the gross elasticity were analysed. Descriptive statistics of both traits were calculated. The penetration depth of the skin before and after milking ranged between 0.50 mm and 2.86 mm and 0.50 mm and 2.82 mm, respectively. The gross elasticity before and after milking was around 26%, respectively and ranges between 0.4% and 90.6% before milking and between 20% and 84% after milking. Based on the results of our study we concluded that the Cutometer® dual MPA 580 is generally usable to measure teat skin elasticity. The penetration depth of the skin seems to be an important parameter. In conclusion, a combination of several parameters could be most suitable to evaluate teat skin elasticity. Further studies are needed to validate the method. The influence of anatomical, physiological, and technical factors on teat skin elasticity should be investigated as well.

Visual Scores or Subcutaneous Fat Thickness Measurements, Which is Better for Designing a 3D Vision-Technology Body Condition Assessment Method?

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Assessing body condition (BC) of dairy cows is a way to collect information about their fat reserves, which is essential for effective feeding management. 3D vision-technology might offer the opportunity to automatically and frequently assess BC. Daily monitoring provides a short feedback-loop of changes in fat reserves. Hence, feedings strategies can be optimized which is beneficial from an economic (lower costs), environmental (lower emissions) and animal welfare (lower disease incidences) perspective. This study aimed to determine whether visual scores or subcutaneous fat thickness measurement is better to design a system using 3D vision-technology to predict BC scores.

Cows (n=46) ranging in BC score on a 5-point-scale from 1 (lean) to 5 (fat) were preselected on four farms. For eight body parts, BC scores (1-5) given by two observers independently via visual observation and subcutaneous fat thicknesses (mm) measured by ultrasound were related with corresponding 3D variables. The three methodologies were conducted twice on two consecutive days.

Only two body parts, i.e. sacral ligament and line between spinous process and tips of short ribs could be assessed by all three methodologies (ultrasound was limiting). The inter- and intra-observer agreement (kappa) for visual observation ranged from 0.52 to 0.71 and 0.50 to 0.69 for the two body parts respectively. Correlation coefficients between days for the two body parts were 0.72 and 0.88 for subcutaneous fat thickness and 0.91 and 0.96 for 3D vision variables. Furthermore, 3D vision variables of the two body parts correlated better with visual observations (range 0.79-0.88) than with subcutaneous fat thickness (range 0.55-0.69).

Despite the high precision of the ultrasound device, this method appeared labour intensive and only delivered useful information for two body parts. Instead visual observations were made on all eight body parts and showed better potential for predictive BC models using 3D vision variables.

Comparison of Grazing Behaviour of Sheep on Pasture with Different Sward Surface Heights using an Inertial Measurement Unit Sensor

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Grazing is the most important activity that ruminant livestock undertake daily. A number of studies have used motion sensors to study the grazing behaviour of ruminant livestock. However, few have attempted to validate their approaches against various sward surface heights (SSH). The objectives of our study were to: 1) compare the effects of different SSH on the grazing behavior of sheep by analyzing data collected by a collar mounted IMU sensor; 2) calculate the relative importance of the extracted features on grazing identification and compare the consistency of the selected features across various SSH; 3) validate the robustness by using classifiers trained from the dataset with specific SSH to distinguish the grazing activity on the datasets from different SSH. Experimental results revealed that 1) our approach achieved high classification accuracy on all the epochs regardless of SSH; 2) Mean of accelerometer Z-axis, Entropy of accelerometer Y-axis, Entropy of accelerometer Z-axis, Mean of gyroscope X-axis and Mean of gyroscope Y-axis were the top 5 features that contributed most in classifying the grazing versus non-grazing activities and there were consistent trends in features across the three SSH; 3) there was enough robustness when the trained LDA classifier on a specific SSH was used to classify behavior on different SSH. Overall, our research confirmed that IMU sensors

can be a very effective tool for identifying the grazing behaviour of sheep and there is enough robustness to use a trained LDA classifier on a specific pasture SSH to classify grazing behavior at different SSH pastures.

A Novel Sensor for Respiration Rate Recording in Cattle

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The measurement of the respiration rate (RR) in cattle is an important tool to monitor the health status. Thus, the RR is an indispensable tool for the stress detection, especially heat stress. Heat stress leads to a deviation of the normal RR and results in a decrease of milk production and fertility. Therefore, continuous monitoring of the RR can help to detect heat stress early and thus to initiate timely counteractive measurements to minimize physical stress. The most common method to measure the RR in cattle is to count the flank movement visually. However, this method is time-consuming and labor-intensive. In addition, the continuous measurement of the RR is difficult to implement and can be physically strenuous. Therefore, a device, based on a pressure sensor, which is able to record RR automatically and continuously has been developed to make long-term studies possible. The aim of this study was to validate the data measured by the device with the help of a reference method. The reference method was the counting of the flank movements of a total of six cows (Holstein-Friesian). The rear flank movements of each cow were recorded by a camera and counted independently of the device by an observer. Eight recordings of one minute each were made per cow. The data analysis was divided into three areas of activity: standing, lying and dozing. A total of 48 RR-measurements of the device were compared with the counted frequencies of the video recording. The results were highly correlated during standing (r = 0.99, R^2= 0.99 n=20), lying (r= 0.98, R^2= 0.96, n=15) and dozing (r=0 .92, R^2= 0.85, n=13). The evaluation shows that the device is suitable for automated RR counting. A marketable further development of the device is planned.

LivAGE – Modelling Emissions

Recent Advances of Modelling and Experimental Verification of Ammonia and Greenhouse Gas Emissions from Dairy Housing

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The present study summarizes our recent efforts to design permanent chambers capable of simulating production conditions inside dairy houses so that reliable data pertaining to gas emissions could be collected. We considered replicate chambers, constructed at a selected research facility, in conjunction with an instrumentation system capable of measuring the mass flux of gasses through such chambers. To determine the best locations in which to place sensors and thereby identify best practices intended to reduce the amount of gasses emitted by dairy cows (and also to test mitigation strategies), we developed a computational fluid dynamics model capable of assessing the mixing patterns that gas species would form within the chambers. This work was followed by the creation of a comprehensive computational model of a commercial dairy holding area, a model capable of predicting the biological generation of heat and gas species. The model also considered gas and thermal energy production and was evaluated with experimental data pertaining to air speed and velocity as well as ammonia and methane concentrations. To evaluate the effects of design changes and optimization, the velocity, temperature, and gas concentrations within the animal occupied zone (AOZ) were computationally investigated, and the outcomes derived from modelling cases were compared to the experimental data. The final iterations of the model could be used to improve dairy housing design and provide accurate assessments of ghgs and the volumes of ammonia and methane emitted from a dairy house and, potentially, the related mitigation strategies.

Analysis of Factors Affecting Ammonia and Methane Emissions from Pig Slurries: Slurry Composition and Dietary Factors

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Reducing crude protein is a recommended technique to reduce nitrogen excretion and ammonia emissions. Greenhouse gas emissions from slurry are also affected by nutrient composition. However, it is still needed to evaluate the interactions among nutrients using commercial-like feed compositions. The objective of this study was to evaluate the impacts of different diets on nitrogen (N) and energy balances. A total of 13 diets were evaluated in digestibility trials using 78 animals. Diets were formulated to fulfil commercial standards, although differing in ingredient composition. Nutrient intake, excretion and potential NH3 and CH4 (Biochemical methane potential) emissions from slurry were measured. Animal weight was also monitored. Correlations between emissions and nutrient balance components were done. An analysis of variance was conducted to assess differences in nutrient balance of low, medium and high emitting animals. For the N balance, a two-fold range in faeces to urine N excretion ratio was found throughout the experiments, even considering the low crude protein variations (from 15 to 16%). This was related to the ammonia emissions from slurry ($r = -0.59$, $p<0.001$). In fact, the amount of crude protein ingested to increase 1 kg of metabolic weight was positively correlated with the associated emissions ($r=0.58$, $p<0.001$). The difference between animals associated with high or low NH3 emissions per weight gain was therefore related to urine losses due to excess N intake. The energy balance shows that methane potential from slurry was mainly related to the excretion of indigested feed components, mainly the fibrous fraction (particularly the soluble fibre). When expressed per body weight increase, it was clear that animals emitting high amounts of methane were those with higher dry matter and energy ingestion. The results of this study demonstrate relevant nutrition effects on N and energy balances even at diets formulated according to commercial standards.

Effects of Environmental and Litter Factors on Ammonia Emission from Broiler Houses

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The aim of this study was to gain knowledge in the relationships between feed composition, litter characteristics and ammonia emission from broiler houses. The study consisted of model development on one side and experimental studies on the other side. The study included a total of four complete broiler production rounds in two climate chambers. In these climate chambers temperature, relative humidity and ventilation rate could be accurately controlled. In order to create differences in dry matter and ammonium content of excreted faeces or the excreta, diets with different potassium and protein content were fed. Each climate chamber had 8 pens (area: 1.5 m2) with litter (white wood shavings: 2 kg/m2) for 25 broilers. The length of the production period was 35 days in the first three rounds and 42 days in the last round. Ammonia emission was determined at days 20/21, 27/28, 34/35, and 41/42 (only round 4) of the growing period, with the so-called dynamic box method. The following litter characteristics were determined on these days: pH, temperature, dry matter, total (Ntot) and ammonium nitrogen (NH4-N) content. From the results the following main conclusions were drawn: 1) the following variables had main effects on ammonia emission from the litter: pH, friability of the litter and the dynamic box flow rate ($P < 0.001$). The effects of temperature ($P = 0.032$) and Ntot content ($P = 0.078$) of the litter were less strong. The effect of NH4-N content was not significant ($P = 0.383$); 2) The ammonia emission could not be very well predicted with the current model. Better insight is required into the rate of uric acid conversion and the rate at which the ammonia volatiles from the litter depending on pH and friability of the litter.

Development of a Computational Fluid Dynamics (CFD) Based Ammonia Emission Model for a Ground Channel Ventilated Pig House

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About 70% ammonia emissions emanate from the slurry pit in fully slatted pig houses. Especially in ground channel ventilated (GCV) designs, direct flow of incoming air into the slurry pit can further promote ammonia transport into the pig house. Therefore, a CFD based ammonia emission model of a GCV pig house was developed to better understand the key factors that affect ammonia release and transport from emitting sources depending on the airflow pattern and the ventilation rate. Since CFD provides detailed spatial velocity, temperature and pollutant distribution at minimal costs. Ammonia emission was modelled as a user defined function (UDF) at the first cell zone at the slurry pit and pen floor. The slatted floor was modelled as porous media and pigs at the animal occupied zone as semi-cylinders. The model was validated for airflow pattern (from smoke tests), temperature and ammonia concentration distribution using experimental data at the ground channel inlet, the slurry pit and the exhaust duct. The CFD model predicted similar airflow patterns as observed in the real pig house during a smoke test, including comparable slurry pit headspace ammonia concentration distributions. The CFD model generally under predicted slurry pit headspace temperature in the real pig experiment by 0.6 to 4 °C. The under prediction can probably be explained by the fact that the pen floor in the CFD model was assumed to be adiabatic while in the real pig experiment, pigs laying on the pen floor exchange heat to the pen floors and the slurry pit headspace. Further simulations with the validated model could provide information on ammonia transport behaviour to building designers in order to optimise GCV buildings.

Effect of Sidewall Openings on Flow Pattern and Gas Emissions of a Naturally Ventilated Dairy Barn – A Wind Tunnel Study

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To provide good indoor air quality for livestock, and quantify emission of ammonia and greenhouse gases, it is essential to understand indoor air characteristics with respect to ventilation openings in naturally ventilated livestock buildings. The objectives of this study were to investigate the influence of the sidewall opening size and location on indoor airflow patterns and airflow characteristics within the animal occupied zone (AOZ), above the floor and the effects on gas emission and dispersion properties. This study was carried out in a large boundary layer wind tunnel and with a scaled dairy barn model. Eight cases with different opening ratios and opening locations were designed and tested under cross-ventilation conditions. Air velocities inside the scaled model were measured with a 2D Laser Doppler Anemometer. The results showed that when the openings were positioned at the top and the opening ratio was no greater than 62.7%, a 'ceiling-attaching' airflow pattern was observed. The incoming air went across the AOZ without circulating with the surrounding air when the sidewall heights were below the AOZ height. This airflow pattern was better for removing gaseous emissions from the AOZ but might increase total ammonia release rate and thus give negative effects on gas removal efficiency when applying a partial pit air exhaust. Besides, it was found that the concentration of the air contaminant behind the building was affected by the opening size and unaffected by the opening location, and the plume width was not influenced by the sidewall openings.

Challenges of Predicting Ammonia Mass Transfer Coefficient in Pig Houses

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To abate ammonia emissions from livestock production processes has been a prevailing topic for researchers and policy makers. To quantify the effects of the best available technologies for ammonia emission abatement, feeding and management, it is imperative to predict the ammonia emissions appropriately since online monitoring is almost impossible for commercial farms. A dynamic model was developed by Dr. Aarnink for ammonia emissions predictions in Netherland. During the modeling processes, the mass transfer coefficient of ammonia should be given, which was borrowed from a literature in 1920s. This paper is to use the Computational Fluid Dynamics (CFD) to re-determine the mass transfer coefficient model. First, we would like to identify if there is a big difference between the one used in the dynamic prediction model and the one developed from CFD simulations. If the difference is obvious, then how it could affect the results of ammonia emission predictions. Some simulations have been conducted and challenges have been found in CFD modelling, which includes the determination of the boundary conditions,

unsteady phenomena etc. We would like to share the experience with the other researchers and also would like to discuss this important issue and learn from the others.

Microclimate Characterisation And Ammonia Emissions Of Typical Greek Livestock Buildings

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The present economic situation in Greece (but also in the EU level) livestock production forces producers to focus on improving efficiency in order to increase their competitiveness. Among the important factors in achieving improved efficiency is the provision of an optimal building environment with low Greenhouse Gases (ghgs) emissions. In Greece we have very few data concerning the internal environment and the emission of intensive livestock buildings. On this aspect we have successfully finished the implementation of three national projects dealing with the characterisation of internal microclimate and emissions of livestock buildings in for pigs, poultry and sheep livestock facilities. The main focus of our project was to assess the environmental footprint of livestock facilities through a sustainable reduction of released air pollutants and ghgs along with a decrease in energy consumption. This will be achieved through an integrated approach aimed at the optimisation of the end-use energy demand, and control of atmospheric pollution through the optimum management of internal microclimate, design of livestock's buildings facilities construction and electromechanical (E/M) systems for building automation. Results (numerical with CFD and from experimental measurements) on the distribution of climate variables and ammonia on these livestock facilities will be presented and analysed. Present results are further analysed in order to be used by relevant stakeholder (farmers, industry) for the optimisation of the management and construction of livestock facilities in relation to the specific climate conditions of Greece.

Sensors Pigs and Poultry

Predictors for Disease Severity in Growing Pigs

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Reducing the impact of diseases in growing pigs can be achieved if susceptible pigs are timely identified before infections are present. Effective interventions can then be implemented, thus reducing the damage of infections. It is not yet clear which predictors are most informative with respect to the damage of infection in pigs.

To identify pigs that are more susceptible to develop severe disease symptoms, different host-related indicators were tested to predict disease severity after an experimental co-infection. A data set was used of 14 pigs that were infected with PRRSv and one week later with Actinobacillus pleuropneumoniae. Average, variance and level changes after specific events (weaning, PRRSv-infection) were calculated for different repetitive physiologic measurements (rectal temperature, growth, blood cell/serum examinations) acquired prior to and between both infections. The pigs were also subjected individually to a backtest, to assess their coping strategy. A standardized patho-histological assessment of the lungs was performed to quantify the impact of the co-infection. Regression analysis was performed with the severity of disease as dependent variable and each physiologic indicator (i.e average, variance of rectal temperature) considered as explanatory variable.

Lower average levels of white blood cell count ($p<0.05$), lymphocytes ($p<0.001$), NK cells ($p<0.01$), naive T cells($p<0.05$) and memory cells ($p<0.001$) prior to both infection, showed significant higher patho-histological score after A. pleuropneumoniae infection. A higher PRRS virus clearance in the blood was predictive for a lower patho-histological score after A. pleuropneumoniae infection ($p<0.05$). Furthermore, a low-resistor coping strategy was associated with a higher clinical impact of disease ($p<0.05$). Temperature and growth features prior to infections were not predictive.

These results are a first step to identify predictors for the impact of disease in growing pigs. With reliable predictors of disease susceptibility, timely interventions can result in higher health and welfare, as well as optimal productivity.

Broiler Health Monitoring Through Automatic Camera-based Technologies

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Precision Livestock Farming is an emerging technology that allows the real-time monitoring of livestock animals through sound analysis, image analysis and sensor technology. The goal of this research is to show the potential of a camera-based monitoring system as an early warning tool to identify management issues in a broiler house.

In a PLF demonstration project in Belgium, five commercial broilers farms were equipped with a camera-based monitoring system. The monitoring system consisted of four cameras per house that were installed in top-down perspective at the ceiling. The build-in image analysis software analyzes automatically the flock behaviour by calculating the activity, the occupation density and the distribution of the broilers in the house. Flock behaviour was sampled at one sample per minute. The trial started in Sep-Oct 2017, and will continue until June 2019. In a four month period, we have discovered several cases in which a deviation in flock behaviour identified a management issue in the broiler house related to climate control settings, defects in equipment and broiler health issues.

The number of identified cases in this short time frame shows the potential of this technology in commercial flocks. An improved, faster and continuous observation of flock behaviour allows the farmer to solve management issues in his house as quickly as possible, which will impact the technical and economical key production indices on his farm.

Future research will focus on the identification of more cases and the translation of the acquired data into useful information for the farmer, because appropriate data visualization is key to the success of PLF-technology.

This research is funded by the European Agricultural Fund for Rural Development (PDPO) and by the Flemish Government, department of Agriculture and Fisheries, section Education, target group policies and plant quality.

Automatic Detection of Sneezing Sounds in Broiler Chickens

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Broiler chickens are today housed in large groups making it difficult for the farmer to monitor all animals in a precise way. This work is a preliminary study with the aim to identify sneezing sounds in an automatic manner. Sneezing sounds occur when chickens have respiratory issues due to for example certain diseases or sub optimal climate in the farm. A group of 51 Ross 308 broiler chickens were housed in two different plastic cages (1 m x 3 m: 36 animals and 1 m x 1 m: 15 animals) in the same room (5 m x 4 m). At 27 days old the chicks were vaccinated by a conventional Newcastle vaccine with the knowledge that respiratory disturbances occur common using this vaccine. Monophonic sound was monitored continuously in the room during the full experiment. To develop the algorithm 85 minutes of data were labelled exhaustively. Of this 85 minutes 65 were used for training the algorithm (78 sneezes) and 20 minutes were used for validating the algorithm (75 sneezes). A basic algorithm first identified possible sneezing events by selecting the moments where the energy of the sound signal between 9 000 – 12 000 Hz exceeded an adaptive threshold. Second the algorithm calculated different time and frequency domain features for every event that was identified. Lastly, classification was performed by manually adjusting the threshold on the different features. The event detection step yielded 1994 events and after classification 9.3% of the sneezes were detected. No false positives were detected, 90.6% of the sneezes were falsely classified as not a sneeze. The algorithm yields a high precision (100%), however, the recall (9.3%) is low due to the many sneezing events falsely classified. Looking at the results it is possible to detect sneezing of broiler chickens in an automated way.

Evaluating Pig Ear Skin Temperature: Intercontinental Transport vs Housing conditions

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Variations in the skin temperature are often used as indicators of stress in animals. With advances in technology, it is now feasible to record high frequency livestock temperatures continuously for extended periods. In this study the objective was to analyze the response of pigs to different environmental conditions. The ear skin temperature of two batches of animal in intercontinental transport and housing was registered and characterized by the use of phase space diagram methodology.

Eleven pigs were monitored during transport from a farm located in Reston (Canada), until their arrival at a farm in Montiel (Spain) during the month of May 2016. After the itinerary by airplane and trucks separated with rest housing, pigs arrived to the farm after 94 hours. Fourteen finishers were monitored in one pen on a breeding farm in Villatobas (Spain) during one week in June 2017.

To measure ear skin pig temperature, one logger with sensor of temperature (iButton DS1923) was glued to the RFID tag of each pig and placed on the inside half of the left ear. The areas and centroids of the phase space diagrams of ear skin temperatures were used to quantify the variability of the time temperature series. It was considered analysis of full times series and time series by periods (transport modality, transport transfers and day and night). The time series pattern for each individual was analyzed independently in order to identify differences between animals of the same batch.

The thermal variability between animals of the same batch was higher during transport than those identified in housed animals. The maximum area for an animal during transport was more than twice the maximum area for housed animals; however, the values of minimum areas were similar in both conditions, indicating more exposure to thermal stress during transport management.

Side and Belly Lying Posture Detection in Group Pig Based on Binary Images and SVM Classifier

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Animal behaviour provides information about their health, welfare and environmental situations. In different climate conditions pigs adopt different lying postures, i.e., in higher temperatures pigs tend to lie on the side with their limbs extended while, in lower temperatures they will adopt a sternal or belly lying posture. Image processing, as a cheap, non-contact and non-stressful technique, along with data classifiers has been widely used in recent years to monitor individual and group pig behaviours. So, the aim of this study was to determine whether two-dimensional image can be used for side and belly lying posture detection in group pigs under commercial farm conditions. An image processing algorithm with SVM classifier were applied in this work. Pigs were monitored by top view RGB cameras and animals were extracted from their background using background subtracting method. Based on the binary image properties, boundaries and convex hull of each animal were found. In order to find their lying posture, area and perimeter of each mentioned features were calculated as inputs for SVM classifier. By means of the image features and the classification technique it was possible to automatically find the side and belly lying posture in group pigs under commercial farm conditions with high accuracy using two-dimensional images.

Gender Distinction of Broiler Breeders by Camera

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The weights of broiler breeders are important parameters for the productivity of the animals. However, the existing poultry weighing system can't add gender tag to data. The objective of this study was to investigate and validate an automated image processing method for online gender distinction of broiler breeders as a possible improvement for an automatic weighing system. For this experiment, 17 broiler breeders, 15 hens and 2 roosters, were kept under controlled conditions with ad-lib access to feed and water. The birds were 61 weeks old at the start of the experiment and measurement were taken during the following 16 weeks. Top-view images, including colour and depth information, were captured using a Kinect camera (version 2). Images were

captured every week for 2 hours at a frequency around 30 FPS. A series of image analysis algorithms were developed to localise and track individual animals and to extract features that could be used for gender distinction. These features included foot pad size, comb area, body area, body length, body width, body ratio (length/width), and body height. This study explored the potential suitability of these features to detect hens and roosters. The result of this study shows that the gender can be determined using all investigated features except foot pad size and body ratio (length/width). The results in this paper could improve the automatic weighing system by monitoring the gender of the birds.

Ammonia, Greenhouse Gas and Other Emissions

Ammonia Emissions from Dairy Barns in Finland

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Ammonia emissions from dairy barns depend on several variable factors, most importantly on indoor temperature, ventilation, manure composition (type, nitrogen content and pH), manure handling method used, and the quality and quantity of litter. National Finnish emission model for nitrogen compounds, however, has been developed on the basis of international guidelines. In order to check and improve the reliability of these calculations, a sufficient number of domestic emission measurements is needed.

In this study, ammonia emissions were measured in six different dairy barns in four seasons. Continuous measuring data loggers were used and the measurements were done during one-week measuring periods. The measured results were compared to those of the national emission model.

The ammonia emissions measured varied considerably both between seasons and barns, being mainly less than 5 g / cow / day in loose housing. In stationary barns, ammonia emissions were on average less than 3.5 g / cow / day.

The share of volatile ammonium nitrogen calculated from the ammonium content of manure varied between 1% and 17%. The mean value for free stall barns was 5.5%. This is significantly lower than the 17.6% calculated with the emission model. The mean value for stationary barns, 9.3%, was, in turn, higher than the <6% calculated by the model.

The measured ammonia concentrations were lower than those previously measured in comparable circumstances. In Finland, relatively few ammonia emission measurements have previously been made on animal housing and none during all seasons. The results obtained also give new information on the seasonal variations in emissions.

Still, the results represent only few measurements and locations and their use is limited. In addition, a new kind of measurement method has been used and it should be further assessed and developed.

Effect Of Grazing On Ammonia Emission From Dairy Housing With Slatted Floor

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In Dutch emission regulation grazing of dairy cows is rewarded with an ammonia emission reduction of 5%. This reduction is based on Monteny et al. 2001. They estimated the ammonia emission reduction from housing at 2.4% per hour grazing. However, recent measurements to proof validity of current ammonia emission effect of grazing from modern dairy housing are lacking.

The reduction of ammonia emission from housing during grazing is based on the assumption that after the cows leaves the barn, the floor emission will decrease to a stable level within a few hours, representing the contribution of the slurry pit to the total ammonia emission. Upon return of the cows the emission will increase again to the emission level prior to the grazing period. Both decrease and increase can be described with an exponential function.

Goal of the research was to investigate the decrease and increase patterns of ammonia emission from dairy housing due to grazing and to establish to pit contribution to the total ammonia emission.

Research was done in four identical measurement units of Dairy Campus in Leeuwarden, The Netherlands. These units housed 15 lactating dairy cows each and were mechanically ventilated. Grazing was simulated by removing the cows from a unit for one week. All other circumstances were kept equal. In two rounds each unit received two times the treatment grazing. In each unit ammonia concentrations of incoming and outgoing air and were measured using a Teledyne T200 NOx analyser.

Analyses of daily emission results showed that ammonia emission started to reach a stable level from the third day after cows removal. Reduction of ammonia emission was around 1% per hour grazing resulting in an emission reduction per year of 2.6%. Further analyses of emission results on hourly basis will improve estimates of ammonia emission reduction.

Elevated Feeding Stalls To Reduce Soiled Area In Dairy Housing: First Results From Comparable Ammonia Emission Measurements

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In the case of a raised standing surface with partitions - so-called feeding stalls - the cows are guided at the feeding place in such a way that very little excrement accumulates on the platform. Further, feeding animals are not disturbed by the scraper when dung removal occurs at more frequent intervals. Therefore, the heavily soiled area is reduced, which should lead to lower ammonia emissions. Aim of this study was to quantify ammonia emissions of a dairy housing system with feeding stalls in comparison to a reference.

The investigations were carried out in the experimental dairy housing for emission measurements in Tänikon (Switzerland). The housing consists of two experimental compartments – each for 20 dairy cows. The two spatial separated housing compart¬ments enable comparable measurement conditions (e.g. climatic conditions) on a practical scale. In one compartment, the feeding area was constructed with elevated feeding stalls with partitions at every second place, whilst the reference compartment was equipped without feeding stalls. To determine emissions under natural ventilation, a tracer-ratio method with two tracer gases was used (Mohn et al. 2018). To describe each measurement situation and further aspects of the investigated system, relevant

accompanying parameters were recorded (e.g. climate, milk urea and urine urea content, feed data, soiling of aisles and feeding stalls, feeding behavior). Measurements over three seasons covered climatic variations in the course of the year.

First ammonia emission calculations for the sub-variant with twelve dung removal events per day and outdoor exercise area show clear seasonal effects: emissions in summer were higher than in the transition period and in winter. The ammonia emission reduction effect of feeding stalls was highest in the transition period with 19% and in winter with 16% but distinctly lower in summer with 8% (means over four days).

A Novel Method with Improved Accuracy to Determine The Reduction Potential for AmmoniaoOf Innovative Dairy Cow House Floor Systems

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A private initiative, Meet-ID (www.meetid.nl), was developed to assess the reduction potential for ammonia emissions of innovative abatement solutions for dairy cow barns. This method consists of a case/control set-up under laboratory conditions, where all emission influencing factors, except the innovation, are controlled and kept constant on practical average values.

Two separate compartments of 3.0 * 3.7 m each were constructed, representing an approximately 10 m2 section of a dairy cow house. Each compartment consists of a slurry pit (0.8 m depth). A pre-fouled traditional slatted floor is placed on top of the first compartment ('control'), whereas an pre-fouled innovative floor system ('case') is put on top of the second. Prior to the emission measurements, both floors are treated with fresh dairy cow faeces (10 kg) and fresh dairy urine (10 L), to mimic cow's urination and defeacation behaviour. Slurry, feaces, and urine are sampled before each measurement, and analyzed. Mechanically ventilated (0.15 m/s) Lindvall-boxes are lowered directly after, and ammonia concentrations are continuously measured using a photo-acoustic monitor (QCL) over a period of 24 hours. Each treatment is repeated 4 times.

Outcomes are the cumulative ammonia emission during 14 hours, being the average urine pool residence time on the floor in a modern dairy cow barn. The cumulative emission of the 'case' relative to the 'control' represents the emission reduction potential. Additionally, the contribution of the slurry pit (constant emission after 24 hours), and floor are calculated, as well as the 'urine pool thickness' on the floor, using the floor emission over 24 hours, and the urinary-N content as parameters.

In the paper, results of measurements for various floors are presented. The outcomes are compared with results from ammonia emission measurements on practical farms with the same floors. Additionally, a discussion is presented on the representativeness of this case/control method.

Low Emission Slat Design for Swine Buildings

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In 2015, agriculture accounted for more than 90% (455 kt) of all NH3 emissions in Canada. Livestock production was the largest contributor; emitting around 66% (300 kt) of the agricultural emissions. NH3 is mainly produced by the degradation of the urea in urine. The contact between air and excreta plays a key role in ammonia emissions from livestock buildings. Consequently, the emission rate is closely related to the soiled floor surface. The objective of this study was to reduce ammonia emissions from swine buildings using a modified slat design profile. The new profile has a notch along the side of the slat so that the manure will drip directly in the pit without sliding down the side in order to minimize the soiled area. Two control and two treatment slat sections were placed in two pig rooms (16 pigs each) for 8 weeks. The four soiled sections were then removed from the pig rooms and put in four individual desorption chambers made of galvanized steel where NH3 emissions were measured individually. Additionally, emissions from an empty chamber were measured to determine background levels. Airflow, NH3 concentration and temperature from each chamber were monitored on a regular basis. Emissions were first monitored for seven days. The slats samples were then exposed to a washing process with pressurized water and reintroduced in the emission chambers to measure the NH3 emissions for an additional seven days with the aim to evaluate the persistence of the emission reduction effect after a cleaning process. The tests are currently in progress. Results will be introduced and discussed in the final paper.

Survey Of Air Scrubber Performance At Pig Farms In Practice: Odour And Ammonia Removal Still A Challenge

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In countries such as the Netherlands, Germany, Denmark, and Belgium, air scrubber technology is used at large scale to reduce emissions of ammonia, odour, and particulate matter. The main types are single-stage acid scrubbers, biotrickling filters, and multi-stage scrubbers (or combi-scrubbers) that combine a water spray section with either an acid or, in most cases, a biotrickling step. A survey was carried out in the Netherlands with the objective to evaluate odour and ammonia removal performance level of scrubbers in practice. In total 48 farm locations were visited, without prior notice. Odour removal (30 min. sampling, olfactometric) and ammonia removal (gas detection tubes) and pH and electrical conductivity (EC) levels of the washing water were determined. The results show that odour an ammonia removal for acid scrubbers (n=16) and biotrickling filters (n=3) were close to assigned removal values in regulations. For combi-scrubbers (n=29), however, an average reduction was found of 40% for odour and 59% for ammonia, whereas assigned regulatory levels amounted 70-85% for odour removal and 85% for ammonia removal. The low odour removal of combi-scrubbers might partly be caused by systematic differences between the odour laboratories in this survey and laboratories that were involved in tests on which the assigned removal capacities were based. Earlier research demonstrated strong differences in removal capacity between laboratories evaluating the same air scrubbers, despite all of them using EN13725. Another factor could be better operation conditions of air scrubbers during test programs (which regulatory levels are based on) than during normal farm practice. For ammonia, low removal efficiencies are expected to be caused by operational parameters, although pH and EC levels were mostly within normal range. It is concluded that the performance level of combi-scrubbers in practice are not meeting expectations, and that test procedures with regards to odour removal need improvement.

Performance of a New Two-step Chemical Air Cleaner for Livestock Pit Ventilation Air

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A two-step chemical air cleaner with an acid step and an alkaline step was developed by Agrifarm as a part of their farm concept with naturally ventilation and partial pit ventilation. The air cleaner is designed to treat pit ventilation air with high concentrations of ammonia and odorants from facilities with pigs. The air cleaner is cylindrical, 2.8 m wide and 11 m high, and with a capacity of ca. 20,000 m3·h-1.

The first step is a packed bed acid scrubber unit with recirculated diluted sulfuric acid kept at a pH of 2.2 that removes ammonia, other alkaline and water soluble gases. The second step is a packed bed alkaline scrubber unit with recirculated diluted sodium hydroxide with a pH of 9.8 that removes hydrogen sulfide and other acidic gases.

The air cleaner was tested at a pig house for growing-finishing with partial pit ventilation at 16 m3·h1·pig-place-1. The air cleaner was tested over one year according to the VERA protocol for test of air cleaners. Ammonia and carbon dioxide were measured by infrared photo-acoustic spectrosco-py, odour by dynamic olfactometry, and odorants by proton-transfer-reaction mass spectrometry. The following odorants were measured: hydrogen sulfide, dimethyl sulfide, methanethiol, carboxylic acids, phenols and indoles.

The ammonia and odour removal rates were measured in an 8-weeks summer period and an 8-weeks winter period. The average ammonia removal was 90 percent, and 98 percent without down-time. The average odour removal measured by olfactometry was 72 percent. Mass spectrometry showed that methanethiol and dimethyl sulfide were not removed, whereas the removal rates for carboxylic acids, phenols and indoles were 95 percent. Calculated as the sum of odour activity values, the removal was around 80 percent.

In conclusion, an effective chemical air cleaner has been developed that can treat pit ventilation air from pig houses.

Emission of Nitrous Acid (HNO2) and Other Nitrogen (N) Compounds from Biotrickling Filters Treating Exhaust Air of Pig Houses

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Air scrubbers are used for removal of ammonia (NH3) and other compounds from exhaust air of mechanically ventilated animal houses. In single-stage biotrickling filters, and multi-stage scrubbers (combining a water spray section with biotrickling), ammonia is converted to nitrite (NO2-) and nitrate (NO3-), and discharged with the waste water. In some cases an additional denitrification step is used. Such systems normally operate at near-neutral pH (6.5-7.5). A field survey was carried out to investigate effects of pH on emissions of a range of nitrogen compounds. Samples of inlet and outlet air of biotrickling filters were taken at 15 farm locations and analysed for NH3 (gas detection tubes), nitrous oxide (N2O) (gas chromotography) and nitrogen oxides or NOy (chemiluminescence NOx analyser). Results show that systems running at normal pH (n=3) had an average NH3 removal of 65% and low production of N2O and NOy. Systems with added denitrification (n=4) had relatively high N2O emissions, equalling 14% of all NH3-N removed. Systems operating at low pH (< 6.5) (n=6) showed very high NOy emissions, equalling 61% of all NH3-N removed. This appears to be caused by evaporation of nitrous acid (HNO2), which is a volatile compound. This reduced the apparent N-removal of the scrubber system from 100% (as based on NH3 only), to a net N-removal of 36%, if all N compounds are taken into account. Systems with high pH (> 7.5) (n=2) showed low NH3 removal (22%) and relatively high N2O production (71% of all NH3-N removed), but the net N-removal was only slightly lower (19%). As scrubber performance (N-removal) is commonly estimated based on NH3 measurements only, the emission of other nitrogen compounds might often remain unnoticed. It is concluded that it is important to prevent low pH conditions in biotrickling filters, as the net N-removal can be drastically affected.

Ammonia Emission From a Fattening Pig House With Partly Slatted Floor During Warm Thermal Conditions

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One of the most important factors controlling ammonia emission from livestock buildings is area of floor surface covered with urine and faeces. Due to reduced slurry pit area and increased clean pen floor area, partly slatted floor pens for fattening pigs have shown lower levels of NH_3 release compared to fully slatted floor pens. However, studies with partially slatted floors have also shown very high ammonia release due to fouling in the pen. At warm thermal conditions, pigs spend more time in the cooler places of the pen, which are usually the dunging areas. They also use the lying area for excretion, which results in increased fouling of the pen and impaired animal hygiene. The objective of the project is to test technical solutions for improving pen hygiene in growing-finishing houses by cooling the pigs during warm thermal conditions reducing the pen fouling. Two technical solutions are investigated; showering the pigs with low-pressure water sprinklers above the slatted floor, and convective cooling of the pigs with higher air velocity on the lying area. The research is carried out on a commercial pig farm with 480 sows and 3 600 growing-finishing places. The pig house where the studies are performed consists of 10 identical compartments with 16 pens per compartment (160 pigs per compartment). During 10 batches for two years, whith two compartments filled simultaneously, ammonia emission, pen hygiene and pig behaviour will be measured and analysed. NH3 and CO2 concentration are measured using a photo-acoustic multi-gas analyser 1412 and a multiplexer 1309 (Lumasense Technologies S/A, Denmark). Ventilation rate is determined with indirect CO2 tracer gas method calculated according to CIGR. Preliminary data will be presented from the measurements started in January 2017. The project is part of the ERA-NET SusAn project PigSys.

Environmental Footprint Of Fattening Pigs: Do Including Agro-industrial By-products In Feed Mitigate Emissions?

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The potential of nutritional strategies to mitigate environmental impacts from pig production has been demonstrated. Previous digestibility tests using olive cake and citrus pulp have shown potential emission reductions from slurry degradation. In this work, we explored the gaseous emissions associated with fattening pigs production following a LCA approach. Two agro-industry by-products (citrus pulp and olive cake) were used for feed formulation by replacing traditional ingredients such as barley and sunflower meal. Diets were formulated following nutritional and commercial constraints achieving inclusion levels up to 12% for olive cake and 24% for citrus pulp. The study on olive cake was concluded, whereas the citrus pulp assay is ongoing and its results will be presented at the conference. A complete nutrient balance was performed and potential emissions of NH3 and ghg from resulting slurries were determined during two months. Carbon footprint from feed ingredients were obtained from Ecoinvent 3.01 Database. Introducing olive cake in diets did not affect productive parameters either potential NH3 emissions. Potential CH4 emissions were slightly reduced (by 13% expressed as potential emissions per animal) when introducing olive cake in diets. Contrastingly, carbon footprint of feeds increased when by-products were included as ingredients as expressed per kg of dry matter (12% for citrus pulp and 5% for olive cake diets respectively). This effect was stronger for citrus pulp, since the drying process enhances this by-product carbon footprint to similar levels than cereals. Moreover, since it presents lower energetic density than barley, the need to include palm oil in the diet raised its carbon footprint as expressed per kg of dry matter. In the case of olive cake feed, despite this by-product was assigned with no carbon footprint, the feed to introduce a higher proportion of protein-rich ingredients (soybean meal), increased the feed carbon footprint.

Potential for Predicting Ammonia Emissions from Naturally Ventilated Dairy Houses based on Indirect Parameters

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Measuring ammonia emissions from naturally ventilated dairy houses is costly and time consuming. Hence, there is an interest in investigating alternatives to full-scale absolute emission measurements.

In this study, ammonia emissions were predicted using partial least squares (PLS) models based on emission data, barn parameters, meteorological data and analysis of manure and feed samples. In addition to predicting emissions, the models can also be used for identifying factors of importance for the emissions. The models were generated based on ammonia emissions from eight naturally ventilated cubicle dairy barns in Denmark for which emission data was determined during six measuring campaigns distributed over a one-year period. Four barns with slatted floor and four barns with solid drained floor were included. The concentration of NH3 and CO2 was determined in three perforated sample lines spanning 20 meters of the center of the barn and two background-measuring points were placed on each side of the barn. NH3 was measured using cavity ring-down spectroscopy (CRDS) and CO2 was measured using photoacoustic spectroscopy (PAS) and nondispersive infrared spectroscopy (NDIR).

The prediction model based on measured parameters was able to explain ~80% of the variation in ammonia emission for barns with solid drained floors (R2=0.75). For barns with slatted floors this was only ~60% (R2=0.36), indicating that the measured parameters are not adequate to describe this type of barn. The most significant parameters for predicting emissions were pH, floor surface area and temperature. The variation in the reference measurement data affects the precision of the model and is therefore included in the discussion. Generally, less than 10-15% variation was observed.

An alternative approach is to use the ratio of N-to-K in manure combined with an animal excretion model to predict ammonia emissions. Quality criteria and key uncertainties in relation to this approach are presented and discussed.

Ammonia Emission Assessment After Buffalo Manure And Digestate Application

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Quite recently, considerable attention has been paid to the effect of anaerobic digestion on ammonia emissions from digestate spreading in the field, due to the growing interest in NH3 emission monitoring. Unfortunately, there are still some different studies finding about the effect of anaerobic digestion on ammonia emissions. Thus, more research into this topic is still necessary before obtaining a definitive answer to the increment or not in emission. For this purpose, this paper proposes comparison study between ammonia emissions from buffalo raw (Farmyard) manure and digestate on bare soil under Mediterranean climate, using the wind tunnel equipped with acid traps, to assess the ammonia emission fluxes. The sampling campaign, in three replicates, lasted each time, for 6 days to ensure that most of the ammonia has been emitted before the end of each campaign. The results obtained indicate that a diurnal correlation between emission and external temperature occurs, especially during the first days. Specifically for both fertilizers, ammonia volatilization increased with air temperature raising. Overall, the total digestate cumulative NH3 emission is 54% higher than raw manure emission. This is certainly due to the Total NH4+-N rate, which was 55,8kg ha-1 for the raw manure and 107 kg ha-1 for the digestate, around 1,9 times higher for the digestate TAN content. Finding suggests the need for adjusting digestate application rate based on TAN content, in order to reduce the impact on the environment.

A Simple Model to Predict Ammonia Emission from Livestock Pens

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Emissions of ammonia from surfaces of solid floor, slatted floor or slurry pits are controlled by two different production and transport patterns. Ammonia originates from urea in urine and its degassing depends on urea and ammonia concentrations, pH, temperatures and surface areas. Degassing is often estimated by an emission factor assuming that a specific proportion of the urea and ammonia content is degassed, or it is estimated by assuming a specific emission per area unit. Both methods have limitations.

Assuming that a certain fraction of the ammoniacal nitrogen is degassed from the urine puddles on the floor using an emission factor, whereas the emission from the slurry pits is primarily controlled by the surface area, a simple model can be constructed with good explanatory power. Emission data from conventional finishing pig production in Denmark with different solid and slatted floor ratios as well as slurry pit areas were used to calibrate the model, and then the model was used to predict emissions from

organic pig production with larger indoor and outdoor areas. Environmental technologies reducing the emission from the slurry surface in the slurry pits were incorporated in the model by using specific emission reduction factors.

The model predicts that the ammonia emission from the solid floor is an important source, and actions that will ensure a high proportion of urine is excreted on the slatted floor is of great importance for the emission reduction potential. The potential of technologies that limit the emission from the slurry pits, e.g. slurry acidification or slurry cooling, is likewise very dependent on the proportion of urine added directly on the slatted floors above the slurry pits. The prediction quality of the model will be improved in future by using emission data from urine puddles, slatted floors and slurry pits measured by flux chambers.

Farm Technology

Test of UHF Ear Tags for Piglets and Growing-Finishing Pigs on an Optimized Test Bench.

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Ultra-high frequency (UHF-) RFID systems (865-868 MHz) could provide advanced applications of electronic animal identification such as automated activity measurement and real-time localization of animals. However, in UHF systems strong influence of reflections and absorption leads to signal attenuation, which poses major challenges. Especially ear tissue causes strong absorption of the electromagnetic waves, changes in the resonance frequency of UHF transponders and, thus, impairs reading performance. In a current research project, UHF ear tags, readers and antennas for pig farming are being developed further. The objective of this study is to test a series of small UHF ear tags, which were designed especially for use in piglets and growing-finishing pigs, on a test bench and later on for behavior monitoring of pigs.

An automated test bench was developed to test UHF ear tags, readers and antennas in a standardized manner within a short time and in a measuring field of 3.5 x 3.5 m. The measured parameters are the received signal strength indicator (RSSI), the read range and the detection area of different types of transponders. In order to minimize the influence of reflections and to lower the measurement bias, the test bench was partially equipped with electromagnetic (EM) absorbers. Six different types of new UHF transponder ear tags for piglets and growing-finishing pigs were tested on the test bench with and without real pig ears. These ear tags were optimized in terms of directional characteristic, resonance frequency and bandwidth to lower the influence of ear tissue. A randomized complete block design was used as test design and the data is currently being analyzed using mixed models for RSSI and read range. First results show a read range up to 1.75 m with a reader output power of 1 W. The final results will be presented at the conference.

Measuring the Walking Distance of Growing-Finishing Pigs with UHF-RFID

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Activity data can provide valuable information on behaviour, health and reproduction status of animals. Systems for activity measurement and especially for real-time localisation of animals are often complex and expensive. The objective of this paper is to present a simple approach for measurement of the walking distance of growing-finishing pigs with an ultra-high frequency radio frequency identification system (UHF-RFID) by applying cell-of-origin localisation. Ten UHF patch antennas were placed horizontally above a pen for 25 growing-finishing pigs, each covering a sector of 1.6 x 1.6 m. The walking distance of four pigs tagged with UHF-RFID ear tags was observed by video on three days with different combinations of antenna output power and height. The video data was compared to calculated walking distances based on the RFID registrations and sector visits created from the RFID registrations. Each change of a pig between antenna sectors added the Euclidian distance between the two sector centres to the calculated walking distance. The smallest difference and highest correlation between observed and calculated distances was achieved with the highest output power (30.8 dBm), an antenna height of 2 m and sector visits with a minimum duration of 1 s and a bout criterion of 100 s. The calculated distances were 78 ± 22 % (mean ± SD) of the observed distances with an R^2 of the linear regression of 0.77. These results show the potential of this technology for activity monitoring in pigs. Further research should be conducted with increased distances of the UHF antennas to prevent overlap of the sectors and to decrease system costs.

The Use Of Electronic Identification in Fattening Pigs Combined with Slaughterhouse Data to Improve Farm Management

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Assessment data on fattening pigs become available in the slaughterhouse. These data include weight, backfat and loin depth, and abnormalities found. They are used for the pricing of the carcasses and meat processing. The assessment data are also presented to the farmer, but in standard practical situations, can difficultly be interpreted by the farmer, as they are usually not combinable with the individual pig data collected on farm. Resulting in the situation that for example the age of the pigs is not known.

Data can be recorded from birth to slaughter by using radio frequency identification (RFID). The RFID tags are applied at birth and remain in the ears until read out at slaughter. The age at slaughtering can be calculated from the data recorded in combination with the RFID number. RFID can be used on the farms to record treatments of animals, and so the meat of animals that, throughout their life, have not received any treatment can be certified as antibiotics-free meat. Combining slaughterhouse data with birthdate can give insight into the effect of age on animal characteristics. RFID is being introduced by a Dutch slaughterhouse on associated farms. The RFID's are now being scanned at slaughter allowing the possibility of combining slaughter data with farm management data.

The relation between slaughterhouse data with farm management data has been explored, relating the growth rate of individual animals with recorded abnormalities and treatments. First results will be presented. These combined data have also been used for benchmarking when comparing farm-specific data with the average of all farms. This can give clues on the potential of improving the management on individual fattening pigs farms.

Experimental Study on Feeding Accuracy of The Projection Type of Quantitative Feeding Machine in RAS

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In recent years, China's aquaculture has developed rapidly, it is a necessary trend that the use of feeding machine replaces the artificial feeding. The use of feeding machine in China has a variety of types, and can be roughly divided into the type of pneumatic pipeline, track, vibration, rotate throwing and projection.

In order to find out the factors that affect the accuracy of the feeding machine and thier influence degree, this paper takes the QC-TR-15 feeding machine which is the type of projection as the experimental object, as its cost-price is high, has representation in China's feeding model.

Then, the single factor pre-test was carried out, and the test factors and their levels were determined by pre-test. After that, 29 sets of test tests were designed by using the response surface design method of Box-Behnken Design (BBD), and in accordance with the order of experimental numbers to start the test., the effects of wind speed, feeding interval, feeding amount and feeder loading on feeding accuracy were studied, then used the Design Expert software for data analysis, obtained a quadratic regression model for the feeding accuracy.

The variance analysis was performed on the regression model, the results show that the model is extremely significant($p<0.0001$), mismatch is not significant($p=0.635>0.05$), indicating that the model is appropriate. and the results also show the wind speed has a extremely significant effect on the accuracy of feeding ($p <0.001$) in the four factors, and other factors have no significant effect on them. Then the single factor analysis and interaction analysis were carried out, and we can get the influence degree of each factor on the accuracy of feeding: wind speed> feed amount> feeding interval> cylinder volume. The results of this study can be used as a reference for optimization and application of the feeding machine.

The Effect of Liner Type on the Teat Load Caused by a Collapsing Liner Using a Pressure-Indicating Film

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During milking the teat of a dairy cow is exposed to a high load. The teat cup liner is the interface between the teat and the milking system, so it should be very well adapted. The most commonly used method to detect the impact of liner type is to visually evaluate teat condition based on teat color, swelling, ring formation at the teat base, and teat-end hyperkeratosis. In addition, sensor-based determination of the influence of liner type on the teat load caused by liner collapse can be performed with several measuring devices, such as ultrasonography, infrared thermography, and pressure-sensitive sensors. As the methods commonly used to detect the effect of liner type on the bovine teat are very subjective and because the tested sensor-based methods are very complex to use or have shown limited usability, the aim of this study was to determine the effect of liner type on the directly measured teat load caused by a collapsing liner with a pressure-indicating film. The Extreme Low pressure-indicating film was used to detect the effect of six different liners on teat load at artificial teats. For each liner, six positions in the teat cup were specified, and six repetitions were performed for each position with a new film piece each time. Analysis of variance was performed to detect differences between the six liners, the positions within a liner, and the measuring areas. The pressure applied to the teat by a liner depends on the technical characteristics of the liner, especially the barrel shape. A square and a concave liner applied the highest teat load at the teat base, while a round silicone liner and a round rubber liner applied the highest load at the teat end. For all tested liners, a higher teat load was found at the teat end.

Evaluation of a Robotic Manure Scraper in Dairy Production by Means of Ethological and Technical Parameters

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The application of robotic manure scrapers in housing for dairy cows is increasing. Beside the time saving for cleaning the floor the robot should also provide a cleaner environment, thereby improving claw health and reducing ammonia emissions. However, there is a lack of recommendations how to operate such machines. Up to now, farms cannot fully exploit the potential. The aim of this study was to evaluate the cleaning quality of the LELY Discovery 90 SW (Maassluis NL) and to investigate effects on the animals.

The investigations were carried out in the experimental dairy housing for emission measurements in Tänikon (Switzerland). The experimental compartment for 20 cows was equipped with slatted and solid floors which were covered with rubber mats. Four variants with different frequency of cleaning (no, rare, frequent, optimized) lasted four days each, with a preceding acclimatization period. The cleanliness of the floors was scored once a day. The behaviour of the cows was observed in two blocks each day. This included the avoiding behaviour related to the robot, the feeding behaviour and the events of slipping.

Cleaning the floor more often leads to lower soil levels, lower percentages of straw on the floor, lower amounts of smear layer and less slipping events of the cows. The use of the robot's water sprayer improved the cleaning results. The amount of smear layer was higher in the situation without water. The robotic cleaning process in the feeding aisle interrupted the cow's feeding periods, but they continued eating right away. In addition, the cows became accustomed to the robot very quickly. The investigations showed that an optimized cleaning interval combined with the use of water is recommendable.

Development of a Test Stand for the Testing of Alternative Manure Removal Methods in Slurry Channels

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Animal welfare is becoming more important in animal husbandry which leads to an increased use of organic enrichment material to e.g. counteract tail-biting. However liquid manure systems are not designed for the increased dry matter and fiber contents. The results are dense, thick and sticky floating layers concentrated under mangers and feeders which results in labor intensive stirring, rinsing and shoveling to remove the remains of solid matter.

The research aim is to develop new technical solutions for liquid manure channels to remedy these problems. As first step a test stand is being constructed at the University of Hohenheim. Made of transparent acrylic glass and PVC, the test stand allows the simulation of the complete manure removal process and gives an insight into possible bottlenecks, blockage points and residue deposits. A stainless steel frame allows the secure attachment of various newly developed and retrofitted stirring, pulling, chopping, scraping and rinsing modules. Together with variants of basin designs, lock compartments, flushing nozzle positions and flow rates, a large number of combinations can be tested.

In order to ensure the comparability of the test runs despite the heterogeneity of pig manure a substitute fluid will be developed to simulate the rheological properties of a fibrous pseudo plastic suspension. Organic fiber material, roughage pellets, sand and water mixed with natural and synthetic thickening agents serve as the basis for the test medium.

Preliminary tests will be conducted to explore the limitations of the system and the substitute fluid in terms of the DM contents, fiber lengths and viscosity. Purging intervals and different mixing ratios will be validated to obtain a baseline for the start of the main test series of mechanical manure removal solutions. First results are expected by the end of May.

Evaluation of Novel Farrowing Systems with Possibility for the Sow to Move – Effects on Working Time Requirement

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According to the amendment of Austrian animal husbandry regulation all farrowing pens on Austrian farms must provide at least 5.5 m². Moreover, it is allowed to crate the sows to protect their piglets only until the end of the critical phase of life of the piglets (max. 6 days after birth). The farrowing crates must be adjustable in width and length in accordance to the individual size of the sows. During a trial of three years, three new developed Austrian farrowing pens and two from the European market were tested on animal welfare, economic efficiency and occupational safety. This paper reports about the effects on working time requirement compared to the conventional pen.

Time studies were carried out on three research farms, which used new farrowing pens as well as the conventional pens. For data collection all operations were divided into parts of an operation and work elements. For collecting labour input data of the individual work elements, the digital time measurement system Ortim a3 and video analysis were used. Statistical evaluations of the data were done by means of ORTIMzeit Professional and SPSS 19.0. Basing on determined standard times for the work elements model calculations were done for farms with 140 sows.

In comparison to conventional farrowing pens, the additional working time requirement in the examined novel pen types ranged from 0.18 (+4 %) to 3.47 (+ 85 %) man-hours per sow and year. The main causes were:

• poorer visibility into the pens, • greater freedom of movement for the sows, • poorer accessibility of the pens, • larger area of the pens. In addition to the overall increase in working time requirement in the novel pens, labour peaks were aggravated during introduction to farrowing pens, birth monitoring, catching of piglets, removing piglets from the farrowing pen and the cleaning the pen.

Continuous Electronic Behaviour Monitoring of Growing-Finishing Pigs with UHF-RFID

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Systems for automatic recording of activity and behaviour can provide detailed information about the influence of a housing system on the behaviour of the animals. This information is valuable for assessment and comparison of different housing systems in terms of animal welfare and performance. The objective of this contribution is to describe the feeding, drinking and playing behaviour of growing-finishing pigs in a conventional housing system with fully slatted floor and a liquid feeding system with a sensor-controlled short trough.

The behaviour of 300 growing-finishing pigs in three fattening periods (four groups of 25 pigs per period) was recorded using an ultra-high frequency radio frequency identification system (UHF-RFID). The system consisted of UHF ear tags, antennas, readers, and a monitoring software. The accuracy of the detection of the animals was validated with video observations and was between 97 and 99% depending on the location. Occurring RFID registrations at the trough, the drinkers and a playing device with straw were recorded constantly for every individual pig during the fattening periods. In addition, the pigs were weighed every four weeks.

The average weight gain and the behaviour of the animals were similar between the fattening periods. On average, the pigs spent about 60 ± 30 minutes (mean ± sd) per day at the trough, 10 ± 9 minutes at the drinkers and about 37 ± 27 minutes at the playing device. The results show a high inter- and intra-animal-variability of the behavioural data. The analysis also reveals typical periods of activity during the day at the hotspots, especially the playing device, with a higher duration of stay in the afternoons. Furthermore, a strong influence of the feeding system on the behaviour can be seen in the short time spent at the drinkers and a high level of competition at the trough.

On Farm On-Line Somatic Cell Count Measurements

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Early detection of mastitis is important to keep cows healthy and to have good quality milk. The somatic cell count (SCC) is an important mastitis indictor. The company Mastiline has developed LUCI. With this instrument the SCC in the milk can be determined by ATP value determination during the milking of a cow. ATP method is scientifically proven to have good correlation with the flow cytometry results which currently remains the gold standard in somatic cell counting. The instrument consist of a sampling module in which a milk sample is collected and is brought into contact with a reagent. The ATP value is then determined by comparing the measured sample with an internal standard. The instrument is initially developed for application in a milking robot, but may eventually also be applicable in conventional milking stalls. The relationship between the LUCI analysis and the standard SCC analysis has been investigated.

In 7 weeks' time, spring 2018, during 4 periods of 3 consecutive days 50 milk samples have been taken in a robotic milking system at a test farm in the north of The Netherlands. The, in total 600, samples were randomly taken of cows milked, by the

standard installed ICAR certified milk meter. After milk sampling, the sample was split into two samples, one sample was directly analysed with LUCI and the duplicate was stored and sent to a certified laboratory to compare with the flow cytometry results .

First results show a high correlation between LUCI analyses and the flow cytometry SCC analyses, final results will be presented.

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Climate Control

Monitoring Environmental Quality on Commercial Pig Farms in Europe

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A number of production related parameters, such as air temperature, relative humidity, carbon dioxide, ventilation rates were monitored in a number of commercial piggery buildings in Spain and Hungary over a 12 months period. Selected results from these long term monitoring events will be used in this article to highlight the beneficial effects of routine monitoring of these important production related parameters in commercial livestock buildings. The authors will argue that such information might be used eventually to evaluate the 'quality' of management procedures used on specific farms. The statistical analysis (using general linear models) identified that improved ventilation and thermal control conditions as key factors contributing to improved production efficiency. Thus, it was concluded that monitoring and better controlling these production parameters in piggery buildings could result in improved profitability of commercial livestock farms.

Long Term Investigations to Compare Different Renewable Energy Sources for Heating and Cooling Pig Houses

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Three different renewable energy sources were compared in practice under long term conditions for heating and cooling in pig houses. The investigations were done in Germany under summer and winter conditions in different pig houses with typical insulation and forced ventilation systems. During the periods, the temperature of outdoor, fresh, supply and section air were recorded continuously, along with the relevant air flow volume, electricity and gas consumption. The tested systems were:

1) Geothermal heat exchanger (GHE), 2) Ground water heat pump. 3) Air-to-air heat exchanger. The coefficient of performance (COP) of each system was calculated by the equation:

$$COP = \frac{\text{thermal energy output for heating or cooling [kWh]}}{\text{electricity input [kWh]}}$$

The modular housing concept was a barn system with an integrated GHE area where fresh air is led through a space between slurry pit and soil to condition the supply air. This modular housing system was investigated for the first time over a one-year experimental period in in western Germany (Krommweh et al. 2014).

The second pig farm used three heat pumps (each 40 kW electric performance) supplied with deep ground water. The heated water was used for floor heating systems in piglet rearing compartments.

In the third measuring period in two pig houses air-to-air heat exchanger were evaluated in different positions. One position was directly in the exhaust air without outlet air purification (Rösmann & Büscher 2010). In the other barn the air-to-air exchanger was integrated in the bioscrubber for air cleaning. In that case, the exchange area was drained and cleaned by the recirculation water. That effects the COP positive. Under strong summer conditions we observed first time that the incoming air was cooled down by the cleaning water (Krommweh & Büscher 2017). That leads to the interesting conclusion that bioscrubbers have a usable heating and cooling potential!

Optimal Ambient Temperature with Regard to Feed Efficiency and Daily Gain of Finisher Pigs

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Optimal thermal conditions for farm animals are crucial preconditions for development of improved climate control methods. Temperatures outside finisher pigs' thermal comfort zone are known to comprise both daily gain and feed efficiency. Literature disagrees on at which temperatures the productivity begins decreasing and at which temperatures the reduction in daily gain and feed efficiency is critical. The aim of this work was to decide the optimal ambient temperature for finisher pigs with regard to daily gain and feed efficiency.

Literature assessing daily gain and feed efficiency at different ambient temperatures was gathered using Cab Abstract and Google Scholar. The results were transformed to relative values with 100% being the temperature at which the highest productivity, in that particular study, was found. The slope corresponding to each degree Celsius was calculated within the investigated range of that particular study. The mean slope values for all studies were calculated and the average response was illustrated in a graph.

Results showed that the two productivity parameters did not peak at same ambient temperature. The daily gain peaked at 15.5°C and was within its maximum 95% between 9.5 and 21°C. Feed efficiency peaked at 22.5°C and was within its maximum 95% between 17 and 29°C.

The optimal ambient temperature for finisher pigs was found in the range between 15.5°C and 22.5°C. For the individual farmer, the economic optimal temperature is dependent on feed costs, energy costs, and on whether additional pigs are available to utilize the housing capacity gained by increased grow rate. In the latter case, the optimal temperature will be lower than if the faster growth causes a reduced utilization of the housing system.

Animal Welfare Indicators in Growing and Fattening Pigs with Different Environmental Conditions

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The application of different technological innovations in the intensive systems of pig production has generated some problems related to health and animal welfare in modern facilities. To measure animal welfare is necessary to use a set of indicators (behavioural, physiological, productive and sanitary) capable of expressing the animals' adaptability to the environment. Temperature is one of the main components of the environment, since it influences the physiology, behaviour and productivity of the pigs. The aim of this study is to verify the adaptive evolution to different environmental conditions (winter, thermoneutrality and summer) in growing and fattening pigs through physiological, behavioural and productive indicators. Seven females with initial weight of 45kg. The animals were housed in a room equipped with an environmental control system. The area per animal was 1,5 m2. The environmental data collected were temperature, relative humidity and wind speed. The physiological parameters measured were body surface temperature, rectal temperature and salivary α-amylase. The feed intake was monitored through an individual feed machine equipped with animal weight scale. In order to monitor the behaviour of animals, video cameras and microphones were installed.

The final weight of the animals was about 95 kg. The daily food intake and mean daily gain of live weight were 2,70 kg.day -1 and 0,611 kg.kg -1; 2,51 Kg.day -1 and 0,947 kg.kg -1 and 2,17 kg.day -1 and 0,526 kg.kg -1, respectively in winter, thermoneutrality and summer. The corresponding values of body surface temperature were 25,4 ºC; 29,1 ºC and 34,1 ºC and the concentration of salivary α-amylase were 1,09 U/ml; 0,35 U/ml and 0,24 U/ml, respectively in winter, thermoneutrality and summer.

Climate Conditions – a Status Quo at Dairy Farms in North - East Germany

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The issue of animal welfare is in the focus of politics and customers. This poses enormous challenges for the future viability of modern animal husbandry. The most deficits are the technical design in dairy barns. The energy-efficient ventilation and air-conditioning systems could improve the welfare and efficiency of dairy cows and are used in the barn, the living area and the milking parlour. In a research project were collected 202 parameters in each barn of 34 dairy farms. The measurements to evaluate the climate in different barns were implemented with the thermo-hygrometer (temperature and humidity) and the anemometer (air velocity). The data collection occurred three hours after feeding at five different places: at the feeding table, at the cubicles, at the feed alley and at the cubicle alley also once in the milking parlour. Every barn has a climate system, like eave ridge ventilation, vertical transverse flow system with curtains and jalousie and ventilators, but no barn has pipe aeration. Only the use of ventilation systems which result of the barn construction are in over 80% of the analyzed farms not sufficiently. 29 of the analyzed farms have old DDR barns. Especially with this type, a technical assistance system like a ventilator is essential, but only 16 of them have ventilators installed. The temperature values are on average 20,21 °C in the barn and 18,47 °C at a outside temperature on average of 22,5 °C. The humidity is on average over 75% and except of three barns, no barn has a continuous air circulation. The most air circulation (on average 1,2 m/s) was at the feeding table. No air circulation occurred in the milking parlour. The same deficits show the 19 new built barns either. The farmers don´t know how to handle it and are often wrong advice.

Effects Of The Accumulation Of Heat Load Duration On The Activity Behavior Of Lactating Dairy Cows

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In the course of the predicted climate change, the problem of welfare and heat load of dairy cows has become increasingly important even under moderate climate conditions. The objective of the present study was to analyze the effects of the daily duration of different heat load levels (HLL) on the activity behavior of lactating dairy cows. Additionally, the adaptation effects of the cows regarding the accumulation of heat load duration (HLD) on all three days preceding the activity measurement day was investigated.

The study was conducted from June 2015 to May 2017 in a naturally ventilated dairy barn. The barn climate was measured at high temporal and spatial resolution, and the average temperature-humidity index (THI) was calculated every ten minutes (n = 842,112). The THI was used to define the heat load the cows were exposed to. HLL were determined by defined THI thresholds. The activity behavior of the dairy cows (n = 176) was measured using IceTag3DTM pedometers and described with several behavioral traits per cow and day. The analysis models included autocorrelations in time series as well as effects of individual cows.

The results showed significant behavioral adaptations ($P < 0.01$) regarding the increasing HLD within each HLL at the day of measurement. There was a decrease in lying time, number of lying bouts, average lying bout duration, and number of standing bouts per day. The average number of standing bouts and the number of steps per day increased with increasing HLD at the measurement day. The accumulation of HLD on all three days preceding the measurement day lead to less behavioral adaptations at the day of measurement ($P < 0.01$). This indicates that the cows could not further increase their adaptation beyond some limit, they reacted weakened and had to follow the need for more lying time.

"Influence of Evaporative Cooling on Respiration Rate of Lactating Cows Under Hot Climate Conditions"

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The present study aims to investigate the influence of cooling on the respiration rate (RR) of lactating dairy cows at two different cooling frequencies per day, considering cow-related factors (standing and lying posture). Respiration rate was hourly measured

by visually counting flank movements in a total of 21 Israeli Holstein dairy cows (2nd to 7th lactation), housed in a naturally ventilated barn in Rishon LetZiyon, Israel. The cows were randomly divided in two groups among cooling frequencies: with three times (control) and eight times per day (experimental). Each cooling phase took place during 45 minutes with side fans and sprinklers. During 25 days measurements between July and August 2017, the experiment was divided in three different day times (early morning, afternoon and night). Data were analyzed for differences between factor levels with a repeated measurements linear mixed model at an overall significance level of 0.05. During the experimental period the temperature-humidity index (THI) inside the barn was recorded as 79.5 ± 3.16 (mean ± SD). RR of cows differed between groups ($P < 0.001$). The average RR of the control group was 7 breaths per minute (BPM) higher than experimental group. During the cooling, BPM of cows in the control group and in the experimental group decreased by 31 and 20 BPM in comparison to the barn, respectively ($P < 0.001$). Standing cows (69 and 56 BPM) inside the barn showed higher RR than lying cows (62 and 53 BPM) in the control and experimental group, respectively ($P < 0.001$). The results showed that in hot climate zones, evaporative cooling helps to relieve heat stress in dairy cows. An increase of evaporative cooling frequency per day reduces RR and improves heat abatement in lactating dairy cows regardless of cow body posture.

Integrated Analysis of Data Acquired by Automation Devices for Precision Dairy Farming

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Information and Communication Technology devices applied to livestock farming produce ever increasing amounts of data. They are used for real time analysis of the conditions of productivity, oestrus, animal welfare, and to record the main historical values referred to each animal. With particular reference to dairy cattle farming, Automatic Milking Systems (AMS) and the related devices and control software represent a highly informative source of cow-specific data. At the same time, indoor climatic conditions in terms of temperature and humidity within dairy livestock barns can be easily monitored, recorded and processed, also in real-time. It is well known that they represent a crucial issues in farm building design and farm management, since these parameters can remarkably influence cows behaviour, milk yield and animal welfare. Nevertheless, the huge potential of PLF and environmental records is still mainly unexploited.

The research aims to develop and test innovative procedures for the comprehensive analysis of AMS-generated multi-variable time-series, with focus on herd segmentation and the effects of heat stress conditions on animal welfare and production. The research has been performed with reference to study cases of commercial dairy cattle farms in the Po valley, Italy. In particular, a methodological approach has been formulated to detect numerical specific pattern for individual animals, able to best characterize each cow and identify clusters which can support an optimized management of the herd. Moreover, meteorological parameters and internal climatic data of the barn have been studied to understand the temporal trend of the influence of high values of the temperature-humidity index on milk production. The model under study is meant also to have a forecasting function for what concern the responses of the heard and individual cows to expected environmental conditions.

Odour and Fine Dust (Particulate Matter)

Effects of Feed and Litter Management on Odour Emission from Broilers: An Exploratory Study to Develop Mitigation Measures

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A first exploratory study was carried out to develop odour mitigation measures for broiler barns. In a factorial experiment effects of feed composition and litter management on odour emission were investigated. Two feeds were compared that differed in composition to create a difference in the dry matter content of the manure, with the hypothesis that drier manure leads to less odour. In addition conventional litter management was compared with treatments applying an extra layer of litter (at 17 and / or 23 days of age) once or twice, or replacing all litter with new one (at 23 days of age). The research was carried out in a mechanically ventilated section with a total of 16 pens of 2.7 m2. Each pen housed 40 male birds (Ross 308). They were given unlimited feed and water during the entire 37-day growth period. During the growth period in each pen the litter was regularly sampled to determine dry matter. A dynamic flux chamber was used for the determination of odour and ammonia emission rates from each individual pen. Odour concentration in samples were determined by olfactometry (EN 13725). The results showed a third lower odour emission for the low odour feed composition, but only at the end of the growing period. This was accompanied by a higher DM contents in the litter at the last measurement day. In contrast the ammonia emission was more than a factor 3 higher for the low odour feed throughout the growing cycle. The litter management treatments had no effect on odour and ammonia emission. The results demonstrate the possibility to reduce the odour emission by feed that stimulates dry manure. In contrast, the ammonia emission of the low odour feed was considerably higher. This negative coupling requires attention in the eventual further development of low odor emission feed for broiler chickens.

Reduction of PM from Aviary Houses for Laying Hens through Alternative Foraging Methods

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Aviary houses for laying hens emit high amounts of particulate matter (PM) and contribute substantially to increased background concentration in the neighbourhood. The foraging and dust bathing behaviour of hens on a floor with litter (i.e., manure and feather particles) contributes to the aerosolization of small particles which are subsequently emitted with the ventilation air. Air quality regulations require current sources to reduce their PM emission.

We investigated two alternative methods for foraging, called SUNtastic and bLokken, in comparison to foraging on standard litter. SUNtastic consisted of artificial grass onto which grain was spread; bLokken consisted of movable transparent blocks (38*38*34 mm) with two holes filled with feed on a concrete floor (# blocks per m2). These methods were tested during three weeks in three identical, completely separated, units with 20 laying hens. An additional room to each unit was equipped with one of the three substrates and the substrates were switched between the units. During 3 weeks, 5 days a week, and 3 times per day, laying hens entered the additional room with the foraging methods, attracted by the supply of wheat.

The PM10 concentration in the foraging room was measured with a DustTrak (TSI, model 8520) during 15 minutes and the behaviour of the laying hens was monitored. Mean PM10 concentrations were 48.6 mg/m3 for the reference unit, 4.4 mg/m3 for SUNtastic (91% reduction), and 3.6 mg/m3 for bLokken (94% reduction; all differences $p<0.05$). The absence of a litter source on the floor was attributed as the main cause for the reductions. The behavioural observations showed a slight reduction of the foraging behaviour for SUNtastic. We conclude that alternative foraging methods can reduce PM10 concentrations with more than 90%, and offer promising perspectives for future PM10 emission reduction from aviary laying hen houses.

Effect of Odour Laboratory in the Evaluation of Odour Removal Performance of Air Scrubbers

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Earlier research in evaluating odour performance of air scrubbers demonstrated considerable differences between laboratories with different panel procedures and equipment that are allowed within the European standard for odour concentration (EN13725). In the Netherlands odour regulations for livestock facilities include odour removal percentages that are based on measurements by different laboratories. An exploratory study was carried out with the aim to investigate whether systematic differences exist between laboratory types when evaluating odour removal performance of combined air scrubbers (combi-scrubbers). The odour sampling and measurements were carried out both by a laboratory using the so-called forced choice method (lab A) and a laboratory using the yes/no-method (lab B). Also the olfactometric equipment differed between lab A and B with regard to stabilisation time. Measurements were carried out at two types of combi-scrubbers on four farm locations, two farms per type. At each farm 6 odour removal measurements were done simultaneously by the two laboratories in the summer of 2016.

Systematic differences in reported odour concentrations existed between both laboratories. Concentrations measured by lab A were on average 4.5 times as high as the values of lab B. The correlation between the odour concentrations of identical samples taken simultaneously by both labs was weak ($r = 0.24$), which together with the large systematic difference, indicates a low level of reproducibility. The study showed that both combi-scrubbers achieved much lower odour removal efficiencies than their assigned values of 85% and 70% in odour regulations, mean farm removal efficiencies varying between -1 and 35%. Odour removal performances did not significantly differ between both laboratories at these low removal efficiencies. It is concluded that the observed low reproducibility between the two laboratories raise doubts to the effectiveness of the current method for determining odour emission factors and odour removal efficiencies in odour regulations.

Current State of Ionization Technique in Mitigation of Particulate Matter (PM) Emission from Animal Barns

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Nowadays, there are some significant challenges about designing of animal barns and the most important one is finding effective ways to reduce the rate of Particulate Matter (PM) emission from them. Reducing the amount of dust in the indoor air of animal barns such as poultry houses not only reduces the overall emission of airborne bacteria, ammonia, and odor emission into the environment but also has the potential side benefit of improved animal productivity.

Common ways to reduce PM emission are using the wet scrubbers, dry/biofilters, oil spraying systems, and ionization technique. In this study, the ionization technique is broadly investigated and reviewed. After that, different methods for modelling ionization including experimental, analytical, and numerical methods will be briefly reviewed. At the end, the numerical techniques which have been conducted to model ionization will be determined to evaluate the pros and cons of those numerical methods in modelling the ionization.

In this study, the various numerical methods are reviewed to determine their reliability and accuracy in the modelling of ionization. It is seen that the Computational Fluid Dynamics (CFD) technique is a suitable method for simulating the ionization phenomenon. Additionally, coupling this technique with the particle tracking methods such as Discrete Element Method (DEM) could significantly increase the accuracy of results. In addition, the lack of sufficient study regarding the relation between the electric filed and its impact on the charging particle is observed.

Reviewing the Current State of Particulate Matter (PM) Liberation Modelling Techniques in Poultry Houses

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Livestock housing, especially in the poultry and pig sectors, is a major source of Particulate Matter (PM) emission into the environment. According to a report in 2015, the Dutch agricultural sector makes up approximately 25% of the total primary PM10 emission and almost 70% of this amount comes from poultry houses. In other words, about 17% of total PM10 in the Netherlands is caused by poultry houses which worries citizens and Dutch governments, and thus have to be reduced.

Factors such as manure property, poultry activities, and microclimate condition of poultry house that influence the rate of dust liberation from poultry litter are not sufficiently studied yet. Numerical modelling techniques are known as cost effective and reliable methods for studying the effect of those factors on the dust liberation. In this study, micro scale numerical models with application in this field of study that are suitable for analysing systems of approximately 1 m2 in size and about a minute in time will be reviewed.

The review showed that Computational Fluid Dynamics (CFD) coupled with Discrete Element Method (DEM) can be used as a reliable and accurate technique for modelling fine dust liberation from poultry litter. Considering the fact that the dilute regime of PM10 has not any influence on the airflow pattern, it was concluded that the Lagrangian particle tracking method along with one-way coupling scheme should be used in CFD-DEM model to simulate fine dust liberation from a simplified poultry bedding.

Slurry Curtains for Improved Effect of Point Extraction System in a Finishing Pig House

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Point extraction systems have shown that they can collect the main part of odour and ammonia emissions in a small amount of air that subsequently can be cleaned, and thereby be a cost-effective solution in finishing pig houses. Due to the air flow pattern, the highest concentrations of ammonia and odour are found in the slurry channel underneath the lying area, which is where the suction points of the point extraction system are placed. The aim of this study was to investigate if slurry curtains improved the effect of a point extraction system in a finishing pig house. The pig house had diffuse air inlet and a ventilation capacity of 100 m3/h/pig. Of the total ventilation capacity, the first 10 m3/h/pig were ventilated through the point extraction system. The remaining 10-100% were ventilated through a ceiling exhaust. In group 1, the experimental unit had only point extraction system and group 2 had point extraction system and two slurry curtains placed in the slurry channel. The first slurry curtain was placed 2.2 m from the back end of each pen with a gap of 0.14 m underneath the slats. The second curtain was placed 2.0 m from the other curtain and 1.5 m from the front of the pen with a gap of 0.103 m. The results showed that 66%, 56% and 62% of the total ammonia, odour and hydrogen sulphide emissions were collected in the exhaust air by the point extraction system in group 1. In group 2, 68%, 55% and 66% of the total ammonia, odour and hydrogen sulphide emissions were collected by the point extraction system. The study confirmed that the point extraction system could collect a significant amount of the total emissions. However, slurry curtains did not improve the collection of emissions significantly.

Climate and Light Control

Differences in Light Concepts of Animal Welfare at Dairy Farms in North - East Germany

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Cow comfort is the basic requirement for the health and animal welfare of dairy cows. Farmers underestimate many factors, especially the installation of extra equipment becomes neglected. In a research project was analyzed this claim and were collected 202 parameters in each barn of 34 dairy farms. The farms are assorted to the number of milking cows (group 1: up to 300 milking cows, group 2: 301 to 599 milking cows, group 3: 600 to 900 milking cows, group 4: over 900 milking cows). For this study we only looked at the housing conditions, especially at the light types and light conditions in the barns and milking parlours. The light conditions were measured with lux meters. The data collection occurred three hours after feeding at three different places in the barn: the feeding table, at the cubicles and in the milking parlour at the milker pit and the cow area. Each measurement was carried out with light turned on and off. On the feeding table the light conditions were in average 878 lx (light turned off), so it was more than the theoretical optimum value of 200 lx. In the cow area, the light conditions were very bad in each barn: on average 64 lx (light turned off) and 96 lx (light turned on). The same issue presented in the milking parlour. The broadest grievance is the choice and the intensity of the lamp types. Only one barn has LED lamps. The other 33 farms have light pipes in their barns and 5 of them have also metal halide lamps. These types show that the light intensity cannot be well because light pipes have no big illuminance. This inventory and unawareness of the farmers show the biggest deficits in regards to light systems in new and old barns.

Influence of Increased Light Intensity on the Lying and Excretory Behavior of Fattening Pigs

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Due to the increased demands on animal welfare in pig farming, animal welfare labels have been introduced and set requirements for the size, design and enrichment of the different functional areas in pig husbandry. In this project lasting from 2018 till 2020, different options will be tested to rebuild conventional fully slatted housing system for fattening pigs. One main aim is to design a comfortable lying area that is used as such throughout the year.

On a research farm in two compartments with six pens à 18 pigs, the influence of different pen structures and management tools are under investigation. In the two further compartments with four pens à 28 pigs, the influence of a floor cooling or heating will be tested. In this paper, the first results of the effect of an increased light intensity on the lying and excretory behavior of fattening pigs are shown. This was tested in four pens with identical pen design, with eighteen pigs in each, over two fattening periods. In two of the four pens the light intensity over the slatted floor (0,5 m² per pig) was increased by means of two spotlights positioned above the slatted area. The lying area was 0,6 m² per pig and the total area was 1,1 m² per pig. With two lux meters, the light intensity was measured over the lying and the excretory area. Weekly scores were used to monitor the fouling of the pen and the animals. Using video analysis, the lying behavior was monitored three times a day, three days a week. First results show a decreased fouling of the lying area and animals in the pens with increased light intensity and that more animals use the lying area for resting compared to the pens without increased light intensity.

Sensitivity Analysis of Animal Modelling Approach on Airflow Pattern in a Pig House by Numerical Study

Hao Li, Li Rong, Guoqiang Zhang

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Knowledge of the airflow pattern in the animal housing is essential for ventilation system design and animal welfare. Computational fluid dynamics (CFD) modelling has been increasingly adopted in studies of airflow distribution within the animal house. However, due to the limitation of the computational power, simplified animal modelling approaches, e.g., rectangular prism, cylinder, and porous media, are commonly used in the full-scale simulation study. To identify the uncertainty of the modelling approaches, numerical studies were conducted first on single pen scale to compare the simplified approaches with the approach with complex pig model. Additionally, two porous treatment methods were also investigated for airflow pattern. The first one is full porous treatment in which defines the resistance coefficients of the pig pen as a whole part. The second one is separated porous treatment which separates the pig pen into parts based on pigs location and defines the resistance coefficients of each part separately. Full-scale simulations using both porous media and complex animal geometric model were furtherly conducted to investigate the influence of using porous media on large-scale simulations. The complex animal models were placed at three locations in different cases, i.e., at the first pen close to the inlet, at the pen in the middle of the pig barn, and at the pen that is close to the outlet. Results show that simplifications of animal models do influence the airflow pattern, although those approaches can reduce the computational requirement on both modeling process and iteration time.

Smart Complex Ventilation for Thermal Environmental Control of Livestock Housing

Guoqiang Zhang

Aarhus University, Denmark

A sustainable livestock production requires smart ventilation system design and control to ensure (1) optimal thermal environment and (2) desired air quality in house; (3) minimum environmental impact to the atmosphere and (4) consuming minimum energy for the operation. Such a system is very much region (local climate) dependent. In a climate complex region, a smart complex system should be considered for an optimal result. This paper provide a few examples of varied design and control of such a complex system.

Combination of tunnel ventilation with wet cooling pad in summer hot weather and mixing ventilation mode in other period is one of the complex systems. Using this method, the heat stress of animals can be mitigated via high ventilation air speed in room and cooled supply air during the hot summer; and the operation and control of mixing ventilation instead of tunnel ventilation in other period can maintain the desired thermal condition in rest of year and to avoid draft in cold winter weather.

Combination of diffusion ceiling air supply and ceiling (wall) jet supply can ensure very low airspeed in animal occupant zone (AOZ) in winter by using diffusion ceiling air intake to avoid draft issue; and switch to jet air supply when outdoor air temperature above a defined level, to increase airflow speed in AOZ to avoid possible heat stress in summer.

Hybrid air exhaust design is another approach to remove the most pollutant air via the pit exhaust and send it to an air purification unit for cleaning. Such a design and control can greatly improve the indoor air quality and effective cleaning the exhaust air for reducing the negative environmental impact of livestock production. The hybrid air exhaust can not only applied to a mainly mechanically ventilated housing but also a mainly naturally ventilated housing.

Modelling of Environmental Time Series in Livestock Facilities by Hybrid Model of ARIMA with Wavelet Transform

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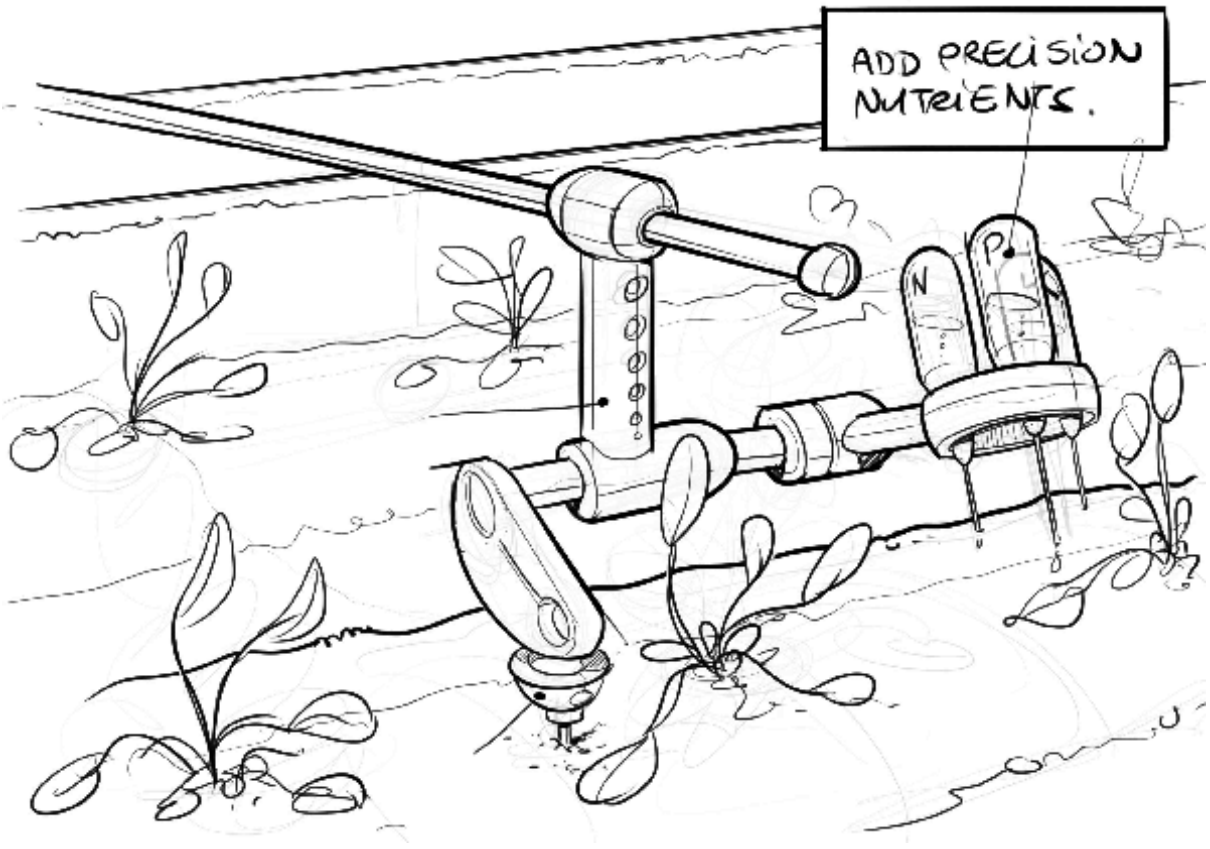
University of Santiago de Compostela, Spain

Environmental control in livestock buildings is a key element to ensure optimal animal welfare and to reduce the environmental impact of animal activity. Although environmental control has been performed mainly by establishing a temperature setpoint, the development of Big Data and smart farming have brought to light new methodologies –such as those based on predictive control– that allow for the incorporation of different environmental variables. The statistical modelling of such variables allows for the use of predictive control algorithms that are more precise than traditional algorithms. Wavelet transform is a recent technique for modelling time series that allows for multi-resolution analysis of the series, which helps improve the performance of the generated models. This paper compares the performance of hybrid models combining a Discrete Wavelet Transform (DWT) and an ARIMA model. For the purposes of comparison, we modelled a relative humidity series from a weaned piglet building in northwest Spain using an ARIMA model and a hybrid Wavelet-ARIMA model, and implemented on-line and off-line predictions of the hybrid model.

With the off-line hybrid model, prefiltering the time series considerably reduced prediction errors as compared to conventional ARIMA modelling (Mean Absolute Relative Error, MARE: 0.4% vs. 1.5%), which provided a more precise modelling. The prediction errors for real-time modelling using the hybrid model (MARE: 1.5%) were very similar to those obtained with the conventional model and therefore greater than the errors of the off-line hybrid model. Such a decrease in the efficiency of the hybrid model was caused by the influence of the border distortion on the wavelet transform technique.

In conclusion, statistical DWT-based hybrid models significantly improve the performance of traditional models. Yet, such an improvent was not verified for on-line predictions. Consequently, our research must continue on the search of the optimal design for these models.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Topic 8: Plant Production Technologies (PP)

Technology and management systems to control weeds, diseases and pest in crops, and equipment for seeding, maintenance and harvest. Contributions may include automation and autonomous systems, precision farming / agriculture, integrated pest management, precision spraying, geo-information systems, and related applications of drones.

Planting

Design and Development of Machinery to Plant Daffodil Bulbs in Upland Pasture and Harvest the Above Ground Biomass.

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The number of people suffering from dementia is considerable and growing at a significant rate. Alzheimer's Disease accounts for between 50 and 75% of these cases. Galantamine is a pharmaceutical compound that has been an approved treatment for Alzheimer's Disease since 1998. Galantamine can be synthesised chemically but it is a difficult and expensive process. Producing galantamine from the alkaloid galanthamine extracted from daffodils is more cost effective, but supplies are limited.

Research has suggested that the environmental challenges associated with upland areas trigger a higher yield of galanthamine in daffodils compared to daffodils grown under lowland conditions. A 4.5 year UK Agri-Tech Catalyst Industrial Research project is investigating daffodil-derived galanthamine production by integrating daffodil growing into permanent upland sheep pasture. The aim is to increase the economic sustainability of hill farming by providing farmers with a high value supplementary daffodil crop while maintaining a traditional farming system.

Machinery is readily available for lowland daffodil production for the cut flower market and for the production of bulbs. Soils are typically deep, fertile and free draining. However, the UK uplands are characterised by low temperatures; exposure to wind; high rainfall; winter snow and frosts; thin impoverished stony soils; a shortage of major nutrients and steep slopes. As part of the research project Harper Adams University agricultural engineers have developed machines for planting daffodil bulbs and harvesting the above ground daffodil biomass in these arduous upland grassland pastures. The planter uses belts to meter and deliver bulbs from the storage hopper to two drop chutes positioned above the purpose built ground opening winged tines spaced so as to produce rows 850 mm apart. The harvester flails, removes and collects the above ground biomass which is then transferred to sealed containers before being processed.

Evaluation of an Automated Seed Drill Depth Control System for Precision Seeding in Heterogeneous Fields

Søren Kirkegaard-Nielsen[1,2], Lars Juhl Munkholm[2], Frederik Foldager[1,3], Alevtina Evgrafova[1], Kathrine Hauge Madsen[4], Eskild Hohlmann Bennetzen[4], Jens Erik Jensen[4], Ole Green[1,2]

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An accurate and uniform seeding depth is crucial for homogeneous crop development, as the depth affects the length of the crop, emergence period, and the germination rate. A homogenous crop establishment supports a robust crop development, which in most cases has a positive effect on the yield. Considerable seeding depth variations can be observed under practical conditions for low-cost as well as high-end modern seed drills. These variations can be correlated to variable soil resistance affecting the drill coulters depths. The spatial field variability is caused by variations in the soil mechanical properties, e.g. variations in texture, water content or tillage treatment. The results of these factors are unwanted low-frequent coulter depth vibrations and, consequently non-uniform and incorrect seeding depths.

The aim of the study was to develop a seed drill with coulter depth sensing and an automatic coulter pressure control system to maintaining a consistent depth. Furthermore, the focus was to evaluate system performance in a field experiment together with an estimation of areas with poorly established crop.

A survey study among Danish crop production advisors indicates that suboptimal winter wheat establishment may account for considerable yield loss (average of 8 pct. poorly established crop area). A range of causes are assessed to have significance, e.g. hill top, field depressions, poorly drainage, structural damage, suboptimal tillage strategy, etc. However, between 75-94 pct. of the farmers established their desired seedbed, seeded at the best estimated time and in their desired depth.

The experimental evaluation of the developed depth control system included a randomised split-plot field experiment and an analysis of the data, by monitoring the seed drill and quantifying the agronomic effect.

The research showed that soil variation in the experimental field considerably impacted the coulter depths, however, the magnitude was reduced after activating the automatic coulter depth control system.

Managing Weeds in Wheat and Pulses by Optimising Plant Spatial Arrangement and Sowing Time

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Weed competition is a major constrain in both organic and non-organic cropping systems. In Mediterranean environments, it can represent a major drawback of pulses, since breeding have scarcely taken into account the competitive ability against weeds. Such limits are particularly important in organic cropping systems, where legumes are needed to increase crop biodiversity and provide or spare N through biological N fixation or N sparing. Previous reports on wheat showed that the crop competitive ability against weeds can strongly be improved by a proper management of the plant spatial arrangement. We also have seen that such

management consists, at one time, in an increase of the ability of nutrient uptake irrespective of the presence of weeds, and such results is likely mediated by a stimulation of the growth rate during the early phases of the crop growth.

The objective of this work was to evaluate the effects of sowing time and spatial arrangement of chickpea, lentil and durum wheat on weed biomass and yield using an unmanned aerial vehicle (UAV) remote sensing platform equipped with visible, thermal, and multispectral sensors for precision agriculture applications.

Durum wheat and pulses were sown in two contrasting spatial arrangements (5-cm and 17-cm rows) with constant seed rate per species. Legumes were sown both at the end of autumn (December) and in the middle of winter (February), in a Vertisol located in a semi-arid Mediterranean area in Italy.

Preliminary results showed a significant effect of sowing time and spatial arrangement on traits evaluated. In particular, the percentage of soil coverage and weed biomass, estimated using RGB (visible), multispectral (NDVI) and thermal images captured during the growing season, showed a better performance of treatments in which the plants were sown with a reduced inter-row distance (i.e. 5 cm). The discrimination results will be presented and discussed.

Tillage and Controlled Traffic Farming

In-field Traffic Management: Logistics Optimisation Tool as a Soil Compaction Mitigation Strategy

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The necessity of reducing production costs in a demand growing food market has lead the agricultural manufacturers to produce larger and accordingly heavier machinery. This development can indirectly cause adverse effects on crop development and yield in many fields due to the deterioration of the soil physical properties caused by intense heavy traffic.

Reducing traffic intensity by optimised route planning is one of many strategies that have been profusely described in literature to mitigate soil compaction problems. A fleet logistics optimisation tool has been used to simulate optimised harvesting operations, in order to compare the traffic intensity of simulated and recorded operations over a set of fields. The tool optimises the harvest time by planning the route for all the vehicles involved in the operation, reducing idle times in the field and inefficient driving by guiding the operators in the right directions at the right times.

The traffic intensity has been calculated by dividing the field into a grid and for each cell counting the number of vehicle passes, the total vehicle weight, and maximum weight at one time. Even though the logistics optimisation tool used in the analysis is not designed to reduce traffic intensity in the field, the results show reduced traffic in the field, principally in the main field area where the crop is most productive, as it confines most of the non-working traffic to the headlands.

The benefits of such system are not only a higher efficiency of the fleet operations, but the reduced impact on the soil also contributes to a more sustainable land management, which translates into sustainable intensification in practise.

Controlled Traffic Farming “light”- A way to Improve Soil Structure?

Annett Latsch, Thomas Anken

Agroscope, Switzerland

Traffic induced soil compaction and the associated negative effects on soil structure and soil functions have been shown to be significantly reduced by the use of permanent traffic lanes for all field vehicles – known as Controlled Traffic Farming (CTF). With regard to a sustainable management of agricultural soils CTF is also an interesting approach for Switzerland, but with permanent lanes only for heavy machines (contact pressure >0.8 bar) used for crop protection, fertilisation and harvesting. Three-year trials (2015-2017) on 17 fields located in the Swiss Central Plateau were used to investigate the practicability of such a “CTF-light”-system with standard machinery and to examine the effects of permanent lanes in combination with minimum tillage (depth max. 10 cm) on soil physical properties and yields. Soil and yield surveys were carried out in four replications within and between harvest lanes. Penetration, infiltration and yield data were collected once a year. In addition, soil samples from three selected sites were taken in spring 2017 to determine macropore volume and bulk density.

Harmonization of machine working widths was challenging and required intense planning, but “CTF-light” could be realized on all sites. After three years of controlled trafficking an incipient differentiation of soil properties could be observed. In untrafficked areas there was a tendency to decreased penetration resistance and bulk density as well as increased infiltration rate and macropore volume. This had a significant positive effect on maize yield, which is known to be very sensitive to soil compaction. For other field crops no consistent yield differences could yet be determined. Considering that soil regeneration is a very slow process, results indicate that soil structure and soil functions can be improved by “CTF-light”. However, the technical and organizational effort to realize permanent traffic lanes for heavy standard machines is not to be underestimated.

Optimization of the Main-Headland Zone using Mouldboard Plough Section Control to Improve the Conditions for Crop Establishment

Søren Kirkegaard-Nielsen[1,2], Lars Juhl Munkholm[2], Frederik Foldager[1,3], Alevtina Evgrafova[1], Michael Hviid Aarestrup[1], Martin Hviid Kristensen[1], Hans Christian Carstensen[1,2], Michael Nørremark[3], Jesper Rasmussen[4], Ole Green[1,2]

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In conventional tillage, a homogenous seedbed is crucial for successful crop establishments. A successful crop establishment ensures the desired germination and crop development, which may increase the yield. Inversion tillage using mouldboard ploughing may be required – depending on climate, soil type and cropping system. If so, an adequate ploughing operation covering the entire field is highly preferred in order to achieve a homogenous seedbed.

Special attention should be given to the intersection zone between headlands and the main working area of the field. Overlapping with multiple inversions causes uncontrolled mixing of the topsoil, rather than the desired soil inversion. Thereby, it may lead to

insufficient weed treatment and undesired incorporation of surface residue, which may impair crop establishment and increase weed infestation. This issue is relevant in organic farming as well as conventional.

The research aim was to study and develop a full-scale mouldboard plough with individual section control and to evaluate the agronomic effects as the result of the section control. The concept of individual section control was verified using modelling and the controllable mouldboard plough was evaluated in a randomised plot experiment on a temperate sandy loam soil in Denmark.

The research showed that the plough was functional for individual section control, which significantly reduced the overlapped area, hereby improving the conditions for crop establishment. In additional, the functional system was developed with hydraulic stone release and individually activation and deactivation of the sections. By deactivating one section, a new traction force reduction control system was integrated, usable when operating in hilly areas, as more traction force is needed uphill, than downhill. Furthermore, on-the-go deactivation of the individually sections can also be used to improve wedge operations, when finalizing the main working area of the field.

Yield Response and Crop Damage Induced by Multipath vs. Multidrive Transport Trailers

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The development of agricultural machinery using innovative concepts is a priority task in order to sustainably maintain agricultural soil quality and soil functions, which directly affect yields and the quality of plant production. Thus, the research goal was to evaluate a newly developed multipath transport trailer for in-field biomass transportation, designed to reduce soil compaction and crop damage during traffic in the field.

A field experiment was conducted in the western part of Jutland, Denmark (56°3'34.09"N, 8°22'6.99"E) on loamy sand soils in order to estimate the effects on yields and changes in fresh biomass (t/ha) induced by the three trailers by comparing with a control (no driving). Precisely, the effects of a multipath trailer equipped with an offset steering system (i.e. lower load per width, kg/cm) and two commonly used multidrive standard transport trailers were compared.

This study reported that the yield harvested using the four different treatments were not significantly different, thus, not affected by higher total load per wheel-soil contact as it was hypothesized. Additionally, a trend toward a yield decrease was observed from the Standard trailer > Concept trailer with an offset steering system inactive > No drive ≥ Concept trailer with an offset steering system active. Furthermore, the study showed the advantage of including the spatial distribution and variability of such parameters as soil clay content, the maximum or accumulated wheel loads during the field traffic into the analysis.

TRACLAS: a Project to Improve under Canopy Tractor Safety in Case of Overturning

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Tractor overturning is the first cause of serious (often fatal) accidents in agriculture; in Italy annually determines about 120-140 victims. The ROPS (Rolling Over Protective Structure), in combination with a seat belt regularly fastened, retain and protect the driver from being hit and crushed by the tractor in case of overturning.

Various types of ROPS are available, from simple two post roll-bar to cabs. For narrow-track tractors, used particularly in specialized crops (fruit, grapevine, vegetable and nursery gardening, greenhouse, etc.), two post roll-bar, fitted in front of the tractor and that could be tilted to allow the travelling under canopy without damaging foliage and fruits, were introduced for a long time. These roll-bars were designed to stay in vertical position (protection on), or be lowered when the vehicle has to pass in the rows or under the trees. Unfortunately, very often this type of roll-bar after being tilted, is not longer repositioned vertically, neutralizing its protective function.

For eliminating this problem, INAIL (National Insurance Institute for Occupational Accidents) has funded a research project, named TRACLAS, for the designing and manufacturing of a compact tractor, that could be complementary and competitive, in terms of performance, to what is now available on the market, but that has to be equipped with a fixed ROPS.

This research involves the Universities of Milan, Bari, Palermo, Tuscia and CREA-ING of Treviglio (BG), which are working together to develop this prototype and test it in different Italian realities and cultural practices (vineyard, olive, almond and hazelnut tree, etc.).

The tractor design is in progress and the prototype has still to be built. After it will be tested and compared with tractors that are currently used in those realities. Evaluation of ergonomic and safety conditions, stability measurements and field performance measurements will be carried out.

Spraying

Multiple Row Orchard Spraying Improves Spray Deposition and Reduces Spray Drift

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To improve the current practice of spray application in fruit crops a research programme is setup assessing spray deposition and distribution in orchard trees of nowadays often used orchard sprayers. Potential pathways of improvement are air amount, air distribution, nozzle type and therefore liquid distribution as the spray is transported by the moving air into the tree canopy. Comparative measurements of a reference spray technique and multiple-row spraying techniques are performed for liquid

distribution, air distribution and spray deposition in apple trees. The objective is to find the optimum combination of application parameters for different stages of canopy development to improve spray deposition (following ISO-22522) in tree canopies and minimise emission to the environment. In the experiments multiple-row orchard sprayers were compared to a conventional cross-flow fan sprayer. First results of the Munckhof multiple-row sprayer are described for spray deposition in the fruit trees showing that spray deposition can be increased by 25%. Spray drift measurements (following ISO22866) with the Munckhof multiple-row sprayer incorporating adjusted nozzle and air settings in the outside tree rows of the orchard show that spray drift reduction can be classified in the Drift Reduction Technology (DRT) classes DRT95, DRT97.5 and DRT99 (following ISO22369). When spraying with multiple row sprayers, the tree rows are sprayed from both sides at the same time, in contrast to standard orchard sprayers that spray the tree row only from one side at a time. Results show that spray deposition is improved with multiple row sprayers and dose can therefore be reduced accordingly, without reducing biological efficacy. Spray drift of these multiple row spraying systems is also reduced. The emission of plant protection products to the environment can therefore be further decreased because of the required lower input of plant protection products with these systems.

Laser-guided Variable-rate Pesticide Spray Technology for Specialty Crop Production

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Advancing conventional sprayer technology with precision variable-rate capability is an economically feasible method to solve current challenges associated with imprecise application and extensive waste of foliar-applied pesticides and other products. A versatile laser-guided spray control system was recently developed as a retrofit for most orchard air-blast sprayers currently used in ornamental nurseries, fruit and nut orchards, small fruit plantings, vineyards and other specialty crops. The control system enabled existing sprayers to have the capability to detect tree canopy presence, map the canopy structure, estimate the foliage density, measure the travel speed, calculate the sectional canopy volume and spray volume designated to individual nozzles, and manage variable numbers of nozzles to discharge variable spray outputs to match tree architectures. Field tests of the new spray system retrofitted on four conventional sprayers owned by growers and on six concept-proven sprayers started in 2017. Evaluations included effectiveness of insect pest and disease control and new spray system reliability under commercial nurseries, apple orchards, peach orchards, blueberry and raspberry production, and vineyards in five different states of different climates. On-farm field tests demonstrated the pest control efficacies of the spray systems with and without the laser-guided spray control function were comparable, while the sprayers activated with the control function could reduce pesticide use by more than 60% with significant annual chemical savings. This new spray control system will significantly advance conventional spray technologies and offer an environmentally responsible and sustainable approach to controlling insects and diseases and applying other foliar products for specialty crop production.

Adapting the PPP Spraying Machinery to the European Environmental Guidelines: Field Testing of Newly-Developed Air-assisted Sprayers for Traditional Olive Canopies

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The European guidelines in pesticide application lead to a responsible use of pesticides. The sprayers acting in traditional olive canopies need specific adaptation to be efficient. An air-assisted sprayer specially adapted to traditional olive canopies was developed and tested in real field conditions. This work aimed to assess the main spray quality parameters of this sprayer, its drift losses and also its work capacity in comparison with a conventional sprayer.

A total of 30 ha were sprayed with both sprayers — with Tartrazine as tracer — in a commercial olive farm with traditional cultivation pattern (quincunx disposition, 12 x 10 m). The two machines were monitored with pressure and flow sensors and a GPS modem to record data every second to track them. The theoretical applied volume was 900 L ha-1, with a forward speed of 4 km h-1. A total of 2 trees per ha, selected at random, were monitored to compare the coverage levels of both treatments by using water sensitive paper (WSP). 5 more trees were completely monitored with WSP and filter paper to assess the spray coverage and deposition, respectively, in the whole tree crown. 150-mm Petri dishes were placed on the ground to assess the spray drift losses.

The results showed that the spray deposition and coverage were higher and more homogeneous in the case of the prototype (25% and 85%, respectively), especially in height, having the prototype much higher deposit in the top of the crown. This fact was also supported by the random coverage sampling. In the case of the field work performance, it was similar in both cases, with effective work ratio of 67%. The drift was reduced by the prototype in about 53%. These results confirm that adapting the spraying machinery is a necessary step to match the European guidelines.

Sprayer Boom Optimization for Bed-Grown Crops

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For full-field grown arable crops, the application of evenly distributed sprays can be managed by selecting proper nozzles, nozzle spacings and sprayer boom height. For bed-grown crops, ideally the spray is applied evenly to the bed only, while no spray should be applied onto the paths in between the beds. This is a complicating factor that usually cannot be fulfilled easily.

A model has been developed to help design the adequate set-ups of nozzles on a sprayer boom optimized for bed-grown crops. For this purpose, the spray distribution patterns of various single nozzles at different boom heights have been measured on a patternator. The model combines these spray patterns while varying nozzle types, nozzle spacings and the position and tilting of end nozzles. The model searches for set-ups that fulfil the requirements as defined by the user.

Currently, the model focussed on the use of Lechler Varioselect fourfold nozzle bodies to find optimal solutions for beds with widths between 1.1 and 1.5 m and boom heights of 0.2 to 0.6 m above the crop, while being able to apply different dose rates depending on crop canopy height. Hundreds of thousands potential set-ups were simulated, but only relatively few meet the requirements. In the ideal set-up the application rate would be manageable by merely opening or closing the nozzles while assuring an even spray distribution on top of the bed. The model can be modified easily to use different nozzle types and boom

set-ups, provided that the necessary spray patterns are available. Different user requirements can be implemented as well, for instance for band spraying or other user-definable spray distributions.

Canopy Characterization of 65 French Orchards by Using a Terrestrial Lidar: a Data Review

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The optimization of spray application in French orchards is currently studied in the PulvArbo Program as part of the National Action Plan for the reduction of pesticide use in France. Two complementary objectives are i) a better knowledge of the canopy structure via 2D terrestrial Lidar measurements and ii) the adjustment of spraying conditions including a proper dosage and application volume. This paper introduces the implementation of a set of measurements in representative orchards including pome fruits, stone fruits and nuts by using a commercial Lidar (SICK LMS100) 905 nm, 270° with resolution of 0.5°, 50Hz, 5km/h, connected to a RTK GPS and a datalogger. Altogether 65 fields were scanned in 2017 at 4 different periods starting from the dormant situation (March) to full vegetation stages (July). The spatial resolution of a single echo is about 4 cm² that is less than the surface area of an apple leaf. Specific vegetation indicators derived from Leaf Wall Area(LWA) and Tree Row Volume (TRV) were calculated and compared with the manual measurements of tree dimensions (height and depth). Results show that manual measurements of LWA are consistent with the Lidar results considering the 95th percentile of the tree height; manual TRV appears relatively consistent with the Lidar data considering the 95th percentile of the tree depth especially for pome fruits. Compared to manual measurements, the Lidar offers the possibility to calculate 2D or 3D porosity indexes. These indexes are calculated along the season offering possible strategies for the airflow adjustment (reduction) to mitigate drift effects. The specific canopy structure in gobelet shape for stone fruits is discussed as well as the very dense and recovering vegetation of nut trees.

Hyperspectral Remote Sensing Applications in Raspberry Plantation

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In Hungary one of the biggest challenge of raspberry production is the reduction of sunburn related damages (slowing plant growth, yield loss, heat stress, reducing leaf area). Breeding of resilient species is a long period, it can take several years, while the direct physical intervention can be a quick and effective solution. In our experimental area two types of shading nets were applied, in which cases the differences between phenology, morphology and spectral features of plants were investigated by portable hyperspectral remote sensing instruments as snapshot imaging spectroscopy (Cubert Camera) and as non-imaging spectroscopy (ASD FieldSpec Max3). Based on the reflectance curves different vegetation indexes were calculated. Additionally, the chemical features of the leaves were analysed. Preliminary results show significant differences between covered and uncovered plantations where the different species react differently. The first results show close correlation between the cover materials and raspberry yields. Basically more and healthier raspberry yield were occurred in case of covered plantations. During the research the hyperspectral remote sensing proved to be a simple and reliable tool to detect differences between each plantations and species generated by various exposures to sunshine. In the same time further measurements and analysis are necessary to identify the best cover material and production practice.

Measuring Apple Blossom, Fruit and Tree Development for Improved Plant Protection and Orchard Management

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In fruit production reliable and accurate information is needed for optimal orchard management. Due to an increase in farm size and high labour input, a grower gets less information feedback from what is going on in the orchard. Besides that, more detailed information about the fruit production is needed later in the chain to meet consumer demands and regulation requirements. Therefore the goal in the Fruit 4.0 project is to get a better insight in apple production by gathering more data and improving data management.

In order to improve current practices we aim to quantify the most important parameters used in decision making during the growth season: number of blossom clusters, fruit number and size (> 10 mm), shoot length, leaf vitality, leaf quantity and fruit colour. Throughout the growing season it is also a goal to measure tree parameters such as canopy volume, height and vitality. Sensors used for these purposes are a 2d-lidar system, a chlorophyll sensor and a RGB-d camera.

Apple trees produce variable numbers of flowers per year, but in general high numbers, with a high variability. To get to an optimal number, chemical, mechanical or manual thinning is applied by the grower. To automate this process we are using RGB-d images taken throughout the flowering period and at fruitlet stage combined with different classification techniques to estimate the number of blossoms and fruitlets per tree, to apply tree-specific thinning in the future.

At later stages of the growing season the number and size of fruits are determined to optimise yield estimations and the harvest time, so labour requirements can be better estimated and planned. The demonstrated multi-sensor setup gives better insight into the growing conditions of the trees in order to optimise crop protection application and management practices tree specifically.

Analysis of Different Mechanical Pruning Strategies on the Production of Clemenules Mandarin and its Costs

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Spain is the sixth citrus producer in the world and the first exporter for fresh consumption. However, the profitability of citriculture is going down due to the increasing production costs and the low prices perceived by farmers.

Between farming operations, pruning is done manually, which represent around 15.3% of the total production costs. The objective of this study was to analyse the effect of different mechanical pruning strategies on the production of mandarins variety 'Clemenules' comparing them with manual pruning, and to determine their costs.

A trial with a random blocks experimental design with 5 repetitions was carried out in a commercial Clemenules orchard located in Calicanto (Valencia). During season 2017, eight pruning strategies were assessed: C (control, no pruning); M (manual pruning, with hand saw and pruning shears); and six mechanical pruning with disc pruner: TEW (Topping, Hedging both sides, East and West), TR (Topping, Manual follow-up), TER (Topping, Hedging Est side, Manual follow-up), TE (Topping, Hedging Est side), EW (Hedging both sides) and E (Hedging Est side). The results of trials showed differences in production and costs between the pruning strategies. C was significantly the most productive with 157 kg/tree; the following more productive were M, EW and E ranging between 128 and 132 kg/tree with no differences between them; and in a third level were all treatments where Topping was carried out (TEW, TE, TER and TR) that oscillate between 72 and 85 kg/tree without significant differences between them.

Cost were higher for treatments with manual pruning. Cost for M was 441 €/ha and for the treatments with manual follow-up pruning they oscillated between 459 and 293 €/ha. However, the cost for mechanical pruning ranged between 25 to 110 €/ha depending on the number of machine passes. To get more consistent conclusions, more seasons must be performed.

'Clemenrubi' Mandarin Size Development after Manual and Mechanical Thinning

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Fruit thinning is the operation of removing fruits on the tree in order to increase final fruit size. Citrus fruit thinning is usually done by hand, selecting the adequate fruits to remove. Mechanical thinning has been tested to reduce costs. In this research work, fruit growth from trees with different thinning treatments (intensities and dates of manual and mechanical thinning) were tested in order to asses fruit size increase with a non-selective mechanical thinning compared to the selective manual thinning. Early severe thinning treatments had fruits with higher diameter close to harvesting time. Mechanical thinning treatments needed more than 30 days to have fruits with higher diameter values than the fruits from the non-thinned trees. However, when the thinning treatment is done close to the harvesting date, the fruits left on the tree do not have enough time to increase fruit size.

Mechanical Pruning of Lemon Trees

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Manual pruning of lemons in the Southeast of Spain entails approximately 39% of the total labour costs of the crop. Mechanical pruning can be integrated into a management strategy to reduce pruning costs. However, this technique is not widely accepted by farmers for many reasons, such as a lack of rigorous studies with varieties and farm management justifying its potential benefits.

This research evaluates mechanical pruning combined with manual pruning in 'Fino 95' lemons over four years. Five pruning treatments have been carried out with different intensities of mechanisation: hand pruning (Mcontrol) and four types of mechanical pruning: FTDR/FTIR (mechanical skirting, topping and hedging of one face of the orchard plus manual pruning of the opposite face to the one hedged), FTR (mechanical skirting and topping plus manual pruning of all the tree), FTDI (mechanical skirting, topping and both faces hedging).

Moreover, each year different types of pruning have been applied to each tree. In this work the results of the two first years of experiments are shown, that include the following combinations (year 1 + year 2): FTDR + FTIR, Mcontrol + Mcontrol, FTR + FTR, FTDI + hand, FTD + FTI.

Yield, fruit size, fruit quality, pruned biomass and pruning cost have been analysed.

The accumulated production was significantly higher in the treatment of mechanical pruning with alternate faces hedging during the two years and without manual intervention (FTD + FTI). On the other hand, the least productive treatment was the one where trees were pruned mechanically with a subsequent hand pruning. The treatment with the highest yield was the one with the lowest biomass cut. Additionally, fruit size was inversely proportional to yield.

Phenotyping Weeds and Crops

Automated Weed Intensity Mapping

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Weeds do not appear uniformly across agricultural fields, and not all fields do not contain the same weed pressure. Therefore, there is a potential to apply pesticides in a non-uniform manner across a single field based on a weed intensity map, and also a new strategic option to choose which fields to spray when the opportunity/the optional weather conditions is present. Many external factors can limit the time window for applying pesticides and plant protection efficiently, such as rain and heavy winds. In this limited time window, it is advisable to attend to the most problematic fields first.

In this paper, we present an automated and low-cost method for measuring and mapping weed intensities in row crop fields. An automated weed intensity mapping, may produce insight to the position of weed patches, allowing for graduated spraying, and average weed pressure across fields, to serve as an operational planning tool for prioritizing treatments. The method is not limited to chemical weed treatment, as mechanical weeding also suffers from limited time windows due to weather. In mechanical weeding, the knowledge of the position of weed patches can also serve as a tool for in field prioritization.

We present weed intensity data from multiple agricultural fields, and show how automated weed intensity mapping can serve as a tool to save time and pesticides in weed treatment operations.

Field Performance Evaluation Method for a Machine Vision Based Intra Row Hoeing Machine

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Wageningen University & Research developed a machine vision based intra row hoeing machine in collaboration with Steketee, a manufacturer of agricultural machinery. Although the machine is used in agricultural practice for several years already there is still a lack of an experimental method to evaluate the field performance of such a device. Reliable, quantitative information about the performance of the machine in the field is therefore not known and the effect of variations in field conditions and machine settings on the performance were not previously researched. The relative number of crop plants damaged by the machine and the relative amount of soil around the crop plants not hoed were used as criteria to assess the field performance. The performance was measured both manually on the field and with the help of sensors by logging the actuation response of the hoeing elements. In th e field trial four treatments were combined: 1) the relative number of lettuce plants, 2) the weed density on the field, 3) the driving speed during hoeing, and 4) the moment of hoeing. Each combination was repeated three times. It was concluded that the developed method was suitable to determine statistically significant differences in the hoeing results for the applied treatments. The performance of the machine showed to be quite sensitive for the settings of the user such as e.g. the value for the plant segmentation threshold and the not to be hoed safety zones. No difference in the machine performance was found for different numbers of missing crop plants in a plant row. The machine performance decreased in terms of the relative number of damaged crop plants in case of high weed density treatments and decreased in terms of the relative number of not hoed intra row spaces in case of high speed treatments.

Classification of Herbicide Resistant Papaver rhoeas L. and Stellaria media L. Using Spectral Data

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Sensor technologies are of increasing importance for agricultural applications, providing information about plant and crop characteristics. Different sensors exist at the market today, which are usable for plant status measurements. For implementing a successful sort- and long- term herbicide management strategy it is of vital importance to identify herbicide-resistant populations. In the current study, we examined the classification of herbicide sensitive and resistant plants with a spectrometer. A herbicide sensitive and a resistant population of Papaver rhoeas L. and Stellaria media L. were sprayed with three different acetolactate-synthase (ALS) inhibitors, namely tribenuron-methyl, metsulfuron-methyl, and florasulam. Water spraying was used for the untreated control plants. The spectrometer had a spectral range of 360-1000 nm with a resolution of 10 nm. For each measurement, information for both the plant reflectance and the current illumination was gathered. Four-leaf stage plants were sprayed with the aforementioned herbicides and transplanted into two different fields in southwest Germany. The trial was set up as a Latin square split-plot design with the herbicide treatment as the Latin square factor, and the populations as the plot subfactor. Three plants of each population were transplanted into each plot. Five measurements per plant were performed daily for the first seven days after the herbicide application and on the 14th day after application. Data were preprocessed, normalizing for the illumination, removing non-plant measurements and then averaged per treatment, plant and measurement day. Spectral features, that could relate to biological parameters, and separate between herbicide sensitive and resistant plants were examined. For S. media, the separation between sensitive and resistant plants was done from the third day after the application. A normalized index using 760 and 530 nm was able to differentiate the sprayed sensitive plants from the rest. For P. rhoeas the result was inconclusive until the 7th day after treatment.

Semantic Segmentation of Clover-Grass Images using Images from Commercially Available Drones

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Automated estimation of the clover-grass ratio can serve as a tool for optimizing fertilization of clover-grass fields. A higher clover-grass ratio gives a higher performance of the cows, when the harvested material is used for fodder, and thereby this has a direct impact on the dairy industry. The clover is able to fix nitrogen (N) from the air, but if there is enough N in the ground, the grass will outperform the clover. It is thus possible to change the clover-grass ratio by adding more or less N to the fertilizer.

It has been shown that it is possible to use CNN to perform a semantic segmentation for distinguish between the clover and grass in the images with shadows removed and of high resolution. Hereby getting pixelwise classification in the different classes: grass, clover, soil and weed. These high-quality images are not always available due to their high cost in camera technology.

In this paper, we present an algorithm for semantic segmentation on lower quality images. The lower quality images are captured from an unmanned aerial vehicle (DJI Phantom 4). We compare segmentation results from the high-quality images with results from the drone based images.

The results show that the algorithm on the lower quality images performs almost to the same level as the result from the high-quality images, allowing for low cost mapping of clover-grass ratio in clover-grass fields.

Development and Assessment of a True Colour Sensor Array for Real Time Differentiation between Crop- and Weed Plants.

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Extensive application of synthetic herbicides still is the dominant practice in modern agriculture even though its risks and negative environmental effects are known. Thus the selective application of herbicides is one of the main focusses in precision farming development.

A selective application requires concepts that can differentiate between crop- and weed plants. Current systems are able to detect weed on fallow land or field of stubble. However, systems that differentiate between crop- and weed plants during growth period do not yet perform as required for arable farming practice.

True colour sensors are cost-effective and can precisely differentiate between colour nuances in real-time on the basis of reflection measurements.

The integration of a true colour sensor array into the boom of a sprayer offers the opportunity to selectively apply herbicides during growth period, based on the detection of colour differences. Environmental effects, that might change colour shades, are eliminated by a sensor-internal light source.

Our studies show that the sensors reliably differentiate backgrounds and green shades. Field use demonstrated that artificial and real plants are detected on vegetation-free and vegetation-covered backgrounds.

The basis for field operation e.g. integration into a sprayer boom or even control of mechanical weeding tools is the presence of a reflection database of backgrounds, crops and weed plants at all growth stages. The development of this database is the main focus of further work and of the presentation. Field use of the implemented system is planned for row crops (e.g. sugar beet) to focus on selective spraying within the intra row area, where mechanical weed control is restricted.

Phenotyping Pests and Crops

In-field Potato Diseases Detection

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Plant diseases result in serious reductions in quality and quantity of agricultural products. They are threats to food security but also to farmer's revenues. Diseases cause yield loss and need for chemicals to prevent or cure diseases are expensive. Therefore, an early detection and diagnosis of these diseases are needed. Our research concerns potato plant diseases with distinct visual symptoms, which can be used to identify and classify them correctly. An early disease detection system can improve crop management and can further prevent the spread of diseases. Manual visual analysis for potato disease detection in the field is a time-consuming task, while automated inspection may be more efficient and cost-effective. This paper describes a potato plant diseases detection method that utilizes a convolutional neural network architecture to distinguish between healthy and sick potato plants based on images captured in the field. The potatoes used in this research have been manually infected, and images of the potatoes have been captured frequently, during their growth. In this preliminary work, we are able to detect three different diseases: Virus Y, Late Blight and Leaf Roll in four different potato varieties.

Automatic Monitoring of Insects in Oil Seed Crops

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Insect attacks often cause serious damage to oilseed rape crops. Chemical pest control is often prophylactic, leading to an unnecessary use of insecticides. To prevent this and support Integrated Pest Management (IPM), it is important to be able to determine the presence and number of pest insects, the timing of attack and its economic effect.

An automated system for insect monitoring (the BugIT-system) was constructed and tested. It consists of five electric detectors, connected with a microprocessor and a radio frequency module for remote reading powered by solar panels and a battery. It was used to monitor migration and presence of insects such as pollen beetle (Meligethes aeneus) in spring oilseed rape fields. The insects were attracted to the traps by a yellow-coloured disc impregnated with an odorant lure consisting of allyl-isothiocyanate and methyl-ethylisothiocyanate in equal proportions. The detector recorded all insects that short-circuited the sensor. The automatic estimate obtained was compared with the number of pollen beetle counted in the traditional way close to the monitor. The BugIT device allowed the development of an insect population to be monitored in detail under field conditions and to observe the effect of spraying with insecticides on the level of insect activity. The detectable level of infestation was 0.5-1 pollen beetles/plant. This level of detection is like the one used in guidelines for decision of treatment with insecticide. Our result indicates that the device could play an important role in the development of improved Integrated Pest Management in oil seed rape.

Effects of Drone Based Spatial and Temporal Distribution of Fertiliser in Grassland: Experiment Grass4Farming

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The objective of the Grass4Farming experiment is to see if spatial information of soil and grass can be used in two different variable rate fertiliser application strategies to influence grass growth. In an experiment a parcel was divided in three strategies. The SE-compensating strategy tried to influence grass canopy so that variation within the field is reduced. It should result in a uniform product for conservation. The SO- anticipating strategy has its focus on maximising fertiliser efficiency. Soil-Plant places that produce efficient receive more fertiliser than the inefficient places. The Dairy Campus strategy was used as reference and had no spatial difference in the fertiliser application. Soil characteristics were measured once with a Veris scan. Grass production was measured using an eBee Drones, a pasture reader and a Haldrup. For every grass cut the average amount of fertiliser was based on the Dairy Campus year plan. The spatial WVDI information from the drone delivered the grass information, that together with the strategy was used to determine the task chart. Originally it was the idea to take also the Cation Exchange Capacity and the Organic Content of the soil into account. The Fertiliser was applied using a Kverneland fertiliser spreader. Harvest data for grass cut 1 to 4 and spatial grass information from the Pasture reader showed that it was possible to influence the growth of the grass. The intended strategies could be realized, and the idea was that the WVDI signal could be used in the strategies. The temporal effect of grass cuts were bigger than the observed spatial effects. It could be concluded that the whole chain of data

collection till variable rate based spreading of the fertiliser worked. This first experiment focused on the proof of concept. Basic elements worked, and in 2018 the experiment will be continued.

Towards a More Sustainable Way of Nitrogen Management in Potatoes

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Farmers are facing more and more challenges with their nutrient management, as the government introduces tighter restrictions in the 6th Dutch program to reduce nitrate-leaching. Precision agriculture has the potential to cope with these challenges, however is not widely adopted by farmers because of the complexity, time-consumption and uncertainty of the costs-benefit. Therefore, we developed an user-friendly online app which translates multispectral sensor readings to nitrogen sidedress advices during the season. The total N application is split up in a (flat) base application of nitrogen at planting and a sidedress application around the end of June using the NBS-app. Contractors provide services to make biomass maps with drones, planes and satellites. These biomass maps can be uploaded in the NBS-app on www.akkerweb.eu. Based on research, the application calculates nitrogen uptake maps of the potato. Using an growth model and decision rules, the app then gives an place specific N advice for the sidedress application. Dependent on the weather, average nitrogen savings are in order of 40 kg N/ha. Under wet conditions risk on leaching is minimized. The farmer can also respond to years with above-average mineralization. All combined, the farmer manages his nitrogen management more efficiently, thereby reducing the impact on the environment. The basics of the app will be explained and results of on-farm research will be presented.

Automatic Monitoring of Slugs in Winter Crops

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Slugs caused major problems in field drops. Today there is no evaluated and established method for assessing the risk of field slug infestation in winter crops in Sweden. The aim of the project was to develop an automatic slug detector that enables remote reading of slug infestation in crops. Today traps consist of a wooden disc (25 cm x 25 cm) with an attractant placed under the disc. The reading is performed manually including three readings before harvest of the preceding crop and five readings after drilling of the following winter oil seed rape.In 2014 a demonstrator was launched and tested under field conditions based on a light beam being interrupted by slugs entering the trap. In 2017 field slugs were estimated using android phones, battery packs and the AtHome Camera app from the iChano Inc. (www.ichano.com). Nine cameras (eg prepaid phones) were tested. The trap consists of a bucket (dia. 30 cm). The camera lens and lamp of the mobile were centered over a hole in the reversed bucket and a second bucket is used as cover and protection against moisture and shades of light. The bait was a mix of müsli, dried fruit, light beer and water. Near the bucket reference traps were placed, eg 25x25 plywood boards. Validation of the bucket traps was made by comparison between camera count and manual reading under the plywood. The conclusion is that it works quit well to detect slugs with mobile cameras, but technical improvements are needed. The advantage of automatic monitoring and 3/4G enables simplified remote monitoring of slug populations.In future automatic monitor units could be included in both local and regional IPM-forecasting and warning systems for pests.

Preliminary Data of the Associated Crop in the Growth of Ulmus Pumila with Different Plant Coverings.

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The present work has for general objective the development of a system of sustainable management system of short rotation coppice (SRC) suitable for rain-fed conditions of central Spain, with a view to the diversification of rural economy, the conservation of the environment, the mitigation of the climate change and the security of biomass supply for solid biofuels, in line with the Spanish Bioeconomy Strategy.

Ulmus pumila L. is a woody perennial species used as a short rotation energy crop. These crops are relatively new so there is not much information about them. The trial was conducted at IMIDRA (Madrid, Spain). The plant material most used, so far, for the establishment of energy crops of Elm, has been the seedling produced by seed. Due to this, a very heterogeneous crop is started.

Specifically, the research is focused on the sustainable management of *Ulmus pumila* L. (Siberian elm) in SRC (SRC-Elm) in rain-fed conditions, unlike other SRC studies in Spain, that are conducted in irrigated lands. The proposal benefits from the availability of already-established plantations hold by the partners, and significantly, from the availability of a long-term SRC-Elm plantation, that is considered as a reference in Spain.

The objective of this activity is the multilocal study of the SRC-Elm system in the first productive stage -from establishment to first shift of cutting-, in order to optimize it. On the one hand, the use of intercropping between plantation lines in newly established plantations, vetch and broom has been studied. Control treatment has been used in monoculture (without legumes), the legume being the variable. Different parameters were measured such as height, chlorophyll, longest spread, diameter. From the analysis of these parameters, it can be observed that there are significant differences between the different treatments. Observing that each treatment has a different behaviours.

Control Effect of Drone in Rice Sheath Blight Disease

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This experiment was performed to evaluate control effect of a drone in rice sheath blight disease. The developing control system of drones in rice cultivation can take advantage of labor saving and lower costs.

Rice sheath blight occurs throughout temperate and tropical production areas. Initial symptoms are usually lesions on sheaths of lower leaves when plants are in the late tillering or early internode elongation stage of growth. More than 50% yield losses would be occurred if all the leaf sheaths and leaf blades are infected.

Unmanned helicopter control has not only a similar effect of controlling the rice diseases with conventional control, but also the advantage of taking of costs down and labor savings. However, it has disadvantages in optimum timing to control because of controlling local area at a time.

In this experiment, we compared with 4 types of control methods in paddy field, which were drones, unmanned helicopters, conventional control and untreated. When the drone flew at flight level of 3 meters for spraying pesticides, it has a downward wind of 2.6m/s, which was about 50%of unmanned helicopters.

The drone showed similar results with unmanned helicopters in terms of standard of grading pesticide deposit. It was 82.4% in Control value of drone, 82.1% in Control value of unmanned helicopters and 84.7% in Control value of conventional control in rice sheath blight.

Phenotyping Orchard Crops

Management of Chemical Residual Volume Relative to Use of Stationary Spraying System: Case of Moroccan Greenhouse Crop Production

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This study aims to solve problem of residual volume of chemical applied in greenhouse using a stationary spraying system with lance. A direct injection method is proposed to avoid chemical mixing as a potential source of residual volume. The work is based on a survey to estimate effective residual chemical volume per square meter. Furthermore, an experiment was done for testing possibility of using direct injection system as alternative for clean chemical spraying. A low cost technology based on a venturi injector system using calibrated orifices to optimally setting and controlling applied chemical injection rates according to a large range of active ingredient rates of plant protection products used in greenhouse vegetal crop productions. The injection system performance was tested in laboratory using fluorescing tracer as injected chemical.

Results showed that is possible to design an affordable (less than 100€ per unit) venturi metering system to overcome problem of the residual chemical volume estimated at 80 liter per hectare per spraying application.

Effect of Nozzle Type, Pressure and Height on Spray Distribution Pattern and Droplet Characteristic

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Various plant protection measures are followed throughout India, among which chemical method is most widely used. The uniformity of spray and droplet size are important parameters for effective disease control. Therefore, selection of nozzles for agricultural sprayers is very important. The nozzles were tested in the laboratory using Patternator to find volumetric distribution, swath and spray angle at operating pressures of 1.5(147.1 kPa), 2(196.13 kPa), 2.5(245.16 kPa), 3(294.2 kPa) and 3.5 kg/cm2 (343.23 kPa) and nozzle heights 200, 300, 400, 500, 545 and 600 mm. The droplet size determination tests were conducted at operating pressure of 1.5, 2, 2.5, 3 and 3.5 kg/cm2 and fixed nozzle height of 450 mm. The droplet size was measured using Spraytec laser diffraction technique and the Number Median Diameter (NMD) and Volume Median Diameter (VMD) of the droplets were measured. The NMDs and VMDs of the hollow cone nozzle varied between 34 to 23 and 200 to 114 µ, respectively while for flat fan nozzle it was 108 to 23 and 199 to 129 µ , respectively in pressure range from 1.5 to 3.5 kg/cm2. The flat fan nozzle gave most uniform volumetric distribution at pressure of 2.5 kg/cm2 and 300 mm nozzle height while for the hollow cone nozzle it was observed at pressure of 2 kg/cm2 and 400 mm nozzle height. The swath and angle of spray of the nozzles were determined and it was found that with increase in pressure and height the swath increased while the spray angle increased with pressure. The hollow cone nozzle produced droplets ranging from extremely fine to extremely coarse droplets, while the flat fan produced droplets in the range of extremely fine to very coarse for the pressures between 1.5 kg/cm2 pressure to 3.5 kg/cm2.

Prognosis of Leaf Chlorosis in Catherina Peaches Based on RGB Images and on the Mineral Composition of Flowers

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The peach tree is one of the fruit species with the highest production and area cultivated in Spain, which rootstock show a marked influence on the mineral content of leaves and consequently on chlorosis. The nutritional diagnosis of the peach tree, based on the mineral analysis of leaves, is often late for in-season amendments, while leaf diagnosis based either on photosynthetic activity (non-destructive) or on iron chlorosis is always late and in many cases imprecise. Previous work from Aula Dei (CSIC) has established the possibility and efficiency of making a mineral prognosis of leafs based on the mineral composition of flowers not only in peaches but in pear and cherry trees. This current work aims to go further in non-destructive prognosis by selecting key features from RGB images and validating them in a set of 300 photographs. The test was carried out in a plot located in the Experimental Station of Aula Dei (CSIC), the soil of the plot being heavy and calcareous. Six plumxpeach trees have been used determining the foliar and floral mineral concentration on flower at full blossom (FB), and corresponding leaf samples at 120 days aFB. The ions in flowers and leaves were determined by plasma-mass spectroscopy, while the measurement of the photosynthetic activity of the leaves and their mineral composition was carried out 120 days after full flowering using a SPAD meter. The SPAD used as a reference for the identification of chlorosis in peach leaf appears correlated with several leaf minerals: Ca, S, Fe, Cu and Sr, restricted to Ca and Sr when compared with the mineral composition in flowers. The mineral composition of the flowers allows anticipating extreme cases of chlorosis based on Sr and Ca levels, while the methodology developed based on RGB images shows promising results and is still ongoing.

Implementation of a Step Reducing Logarithmic Sprayer

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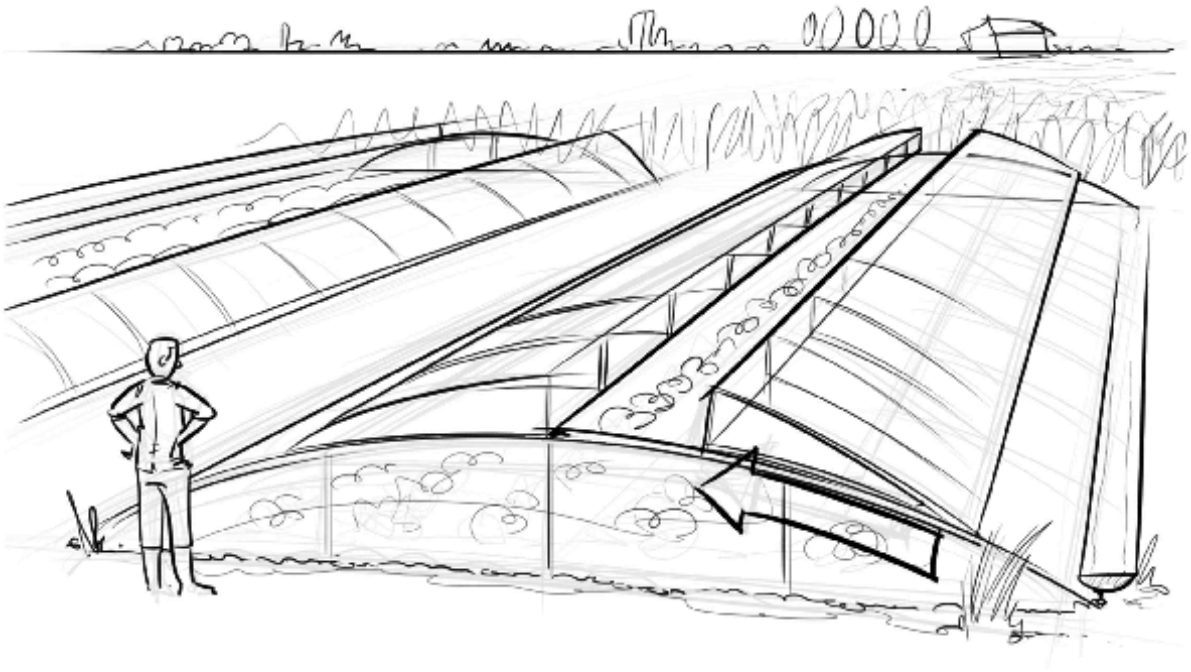
Logarithmic sprayers are commonly used for dose response studies for a wide range of pesticides. A typical logarithmic sprayer consists of a mixture tank and a pressurized water input. Water is continuously transfered into the mixture tank, steadily diluting the applied dosage. Therefore, the actual concentration applied in the field, can be influenced by various factors like the fluctuation of the water pressure, the quality of the pipelines, the nozzles, the application speed and the current type and formulation of the pesticide. One of the major drawbacks of the typical logarithmic sprayers is that the pesticide dose decreases continuously. The objective of this study was to develop and test a logarithmic sprayer with a stepwise dose reduction. In such a system, the pesticide dose, delivered to the spraying boom from the sprayer in a certain area is known and uniform for each plot.

The principle of the proposed system is to separate the current sprayed mixture in two distinct parts. One part is for performing the current pesticide application. The second part will be transferred in a second spray bottle and refilled with water. By controlling the volume of the mixture and water inserted in the second bottle a specific new mixture can be realized. When the current spraying dose has been applied in the field and the new mixture created, the system is ready to apply a second dose of the same volume, yet, with a predefined dilution ratio. The proposed system has been realized and tested in a field, using glyphosate as a general purpose herbicide. The outcome showed an increase in the weed population with the dose reduction, as expected from the dose response curve of glyphosate. The system can be proposed as an improvement to the current logarithmic sprayers, enabling logarithmic applications in various agricultural scenarios.



'ARENA' - ROOF.

Topic 9: Greenhouse Production Technologies (GP)

Technology and management systems for greenhouse production systems. Contributions may include greenhouse structures, covering materials, climate and energy systems, design of ventilation and CFD applications, automation and decision support systems for greenhouse climate, crop, water and nutrient management, as well as pest and disease detection and control.

Co-production and Implementations of Technology in Food Production Systems

An Inventory of Smart Farming Technologies

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We define Smart Farming Technologies (SFT) as any measuring or actuation technology used in precision agriculture, including robotics and software for farm management and decision making. Farmers can use SFTs to increase input use efficiency and a reduced impact on the environment ("more with less") but sometimes lack knowledge about which SFTs are available. Therefore the goal of our work was to create an inventory of SFTs for farmers and farm advisers. Our inventory lists commercially available SFTs as well as SFTs that are being investigated in applied research projects and SFTs described in the scientific literature. The inventory is available at www.smart-akis.com and can also be accessed via the www.ask-valerie.eu semantic search engine. Analysis of the data indicates that commercially available SFTs tend to lead to higher productivity and profitability; reduction of emissions (nutrients, pesticides, ghg) is sometimes a side-effect. There are few SFTs that directly increase indicators of sustainability (e.g. biodiversity, soil compaction). Scientific research on SFTs often focuses on sensing technologies. There seems to be a knowledge gap between measuring the status of crop and soils on the one hand, and using that information to make practical decisions in farming on the other hand.

Management System of Small Farm Machinery Hiring Business for Rice Farming Operations in Kampar Region, Indonesia

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Development of using farm machines for agricultural operations has created business opportunities for smallholder farmers in rural areas. Custom hire offering machinery services for farmers is one of business models at the farm level which has been adopted widely in many developing countries with different management system and economic benefit depending farming practices. This paper attempts to examine the management system of small farm machinery hire businesses for rice farming operations in Kampar Region. We have surveyed and purposively selected as 20 groups of hire service providers of small farm machinery in the region. Group managers and machine operators were personally interviewed using questionnaires to collect primary data during September – October 2017. The results showed that the small farm machinery hire services were small businesses managed by farmer groups and operated within village area. They managed 2 - 4 kind of farm machines and offered hiring services for their group members according to machine owned with a lower charge rate. The businesses became sources of increasing and diversifying family incomes for smallholder farmers in the region. Moreover, the availability of the farm machinery hire businesses was helpful stallholder farmers to access farm machinery for being mechanized their rice farming operations.

An Innovation System Supporting the Adoption of Precision Agriculture in Sweden: The Case of Yara N-Sensor

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In Sweden, nutrient leaching and fertilisation strategies have been prioritised for approximately 30 years. The public project 'Focus on soils' that started in 2000, focusing on fertilisation strategies considering fields as homogenous entities. In parallel, the development of precision agriculture (PA) enabled the farmers to treat fields heterogeneously. To succeed with PA, farmers need credible and usable agricultural decision support systems (AgriDSS). However, uptake and acceptance of complex AgriDSS has generally been slow. The Yara N-sensor (YNS) was introduced on the Swedish market in 2000. In 2016 a Yara representative claimed that 'the plug has gone out'; considering YNS use and selling, meaning that finally farmers seem to accept, believe in and use the YNS. This paper aims to investigate and analyse the YNS adoption process in Sweden from 2000 to 2017 by answering the following research questions: 1) How can the innovation system concerning YNS be described? 2) What are the main implications for the regime shift from considering a field as a homogenous entity to a heterogeneous ditto?

A qualitative inquiry was conducted in 2017, in which interviews with different actors within the Swedish AKIS were performed. The collected data were analysed, using thematic analysis based on theories from the field of innovation systems. The findings revealed a complex innovation system, driven by a company with long-sightedness and a group of interested farmers, closely cooperating with one Yara representative. Additionally, important actors have been a regionally funded PA network. The general technology development in society has supported the adoption of the YNS. Three identified success factors are: 1) Cooperation between companies, organisations and universities concerning PA development, research and field trials. 2) Established trust among different actors within the Swedish AKIS and; 3) The weather conditions during 2015 which seem to have validated the function of YNS.

Skills Needs for a Sustainable Farmer in the Framework of the Sagri Project

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In the EU almost 50% of the territory is covered by farmland (both arable and permanent grassland), which means that agriculture plays a key role in land management and has a huge responsibility in the preservation of natural resources. In order to practice a sustainable agriculture, farmers responsible for the management of farmland must adopt correct and environmental friendly practices, using appropriate technology and complying with EU regulations for a sustainable agriculture. Recent developments in science and technology, that could be an added value for farmers' crop and land management, are still unutilized in many situations because farmers have not been introduced to them or have not been trained to use them. The SAGRI project (http://www.sagriproject.eu/) is an ERASMUS+ Project which main goal is to advance the skills of European farmers and agricultural extension staff through the development of new curricula and teaching programmes that integrate in a practical way the latest developments in agricultural applied research. The purpose is to provide farmers and agricultural stakeholders with knowledge, skills and competencies in the field of agro-environmental technology for a sustainable agriculture. There were identified six major areas, where significant technological developments occurred and that can help farmers for a more sustainable agriculture: 1) Precision agriculture; 2) Integrated pest management; 3) Agricultural reuse of organic residuals; 4) Drip irrigation and water-conserving technologies; 5) Renewable energy; and 6) Bioenergy and energy crops. For each of these topics there were identified job-specific skills with a highlight in the awareness for all agricultural sustainability aspects and in the introduction to major technological developments in the specific areas. These skills will be the basis for the developing of new innovative curricula integrating the latest advancements of the "agri-tech" sector, and training courses for agricultural workers according to the EQF/ECVET framework.

SPARKLE Project: e-Learning Solutions to Create New Digital Agronomist Profiles on European Students

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New technologies applied to agriculture are creating a gap in the employability of agronomy students. In the short term, future-oriented farmers, motivated by the increasing market competitiveness, will demand the existence of small and medium-sized enterprises (SMEs) capable of applying innovative solutions to agriculture. These new companies should have business models capable of providing a "digital accompaniment" to these farmers, also involving research institutions. Nowadays, at European level, students are well prepared in agronomic terms but lack knowledge about generating new business models based on the effective application of new technologies for Sustainable Precision Agriculture (SPA).

The aim of the project is to disseminate knowledge and innovation, linking universities, farmers and students by providing a learning opportunity to students, but also by enabling universities to validate real solutions to specific problems in applying SPA in field conditions with the help of the farmer's experience.

The SPARKLE project will contribute to build a methodological a theoretical framework for future-oriented agripreneurs, coupled with the development of e-learning based educational solutions, in order to facilitate achieving a new awareness and maturity levels among SME, students and educators on technologies, business and innovation in agriculture.

The expected outputs of the project will be to acquire knowledge and skills for universities by training more students in SPA technologies and business. With this in mind, it will be possible for students to have the opportunity to manage a real experience with companies specializing in SPA. Therefore, companies are given the opportunity to get directly involved in training and the opportunity to interact with students and future technicians.

In the long term, the expected results will be to create impact through growing synergies between the educational offer of the University and the companies, extending the higher education offer through the crossing between new technologies in agriculture and new business models.

Long-Term Tracking and Automated Analysis of Tractor Behaviour with JDLINK

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JDLINK is an application for farm management under a precision agriculture strategy (variable rate application of inputs with geolocated data and maintenance alerts among others. It allows accessing to isolated or groups of machines, with the possibility of downloading CAN BUS data in periods established by use (engine hours) or by date. JDLINK can be considered a SCADA (System Control - SC- and Data Acquisition -DA-) where the visualization of data is indispensable to the manager of the fleet of machines. Our approach in this research is clear: What practical recommendations in terms of energy efficiency, work performance and improvement of use (maintenance) can be made based on the automate analysis of the information contained in JDLINK? For this prospective study, two tractors were used: one of 380 HP (1000 hours) belonging to a cooperative in Navarra, and another one 7R 230HP belonging to a private farmer in Ciudad Real (500 hours of use); we chose 42 variables: 17 motor, 10 on maintenance and 17 derived from the tasks performed. Then we programmed and tested an automated multivariate analysis for the recognition of agricultural activity patterns which consists of a Principal Component Analysis (PCA), an unsupervised cluster (Cluster) and a multiple analysis of variance or MANOVA. The use of the automated procedure has led to the isolation of several patterns as identifiable tasks while six different patterns have been found for the 7230 tractor. As a consequence, a multivariate pattern became available and thus the identification of machine performance and fuel consumption pattern (l/ha). Moreover, clear conclusions were derived upon the misuse of counterweights, low level and excessive variability of slippage (below 4% on average basis. At present this procedure is available for dealers to provide highly valuable agricultural consultancy for farmers.

Greenhouse Production: Various Topics

Wind Pressures on Arched Roof Greenhouses

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Greenhouses are light-weight low-rise structures made mainly of steel. They are designed for several combinations of actions, including snow and wind according to Eurocodes and EN 13031-1-2001. Strong winds are a frequent cause of structural failures in greenhouses. The present research work focuses on a greenhouse type widely used in the Mediterranean region, namely the plastic-covered arched-roof greenhouse with sidewalls. Only a few published research results concern wind loads on arched roof greenhouses, in contrast to duo-pitch structures, such as the Venlo type, and tunnels.

Design Codes and Standards define the procedures for determining the design wind loads for different greenhouse types depending on their geometrical characteristics, duration of life, wind climatic data etc. Recent research works have revealed several discrepancies and the lack of detailed information regarding the provisions of the Eurocodes and EN 13031-1 for the wind loads on arched roof structures with sidewalls. For this reason, there is a strong need for updating the current versions of the Design Codes with new research results.

A numerical investigation of the wind pressures developed on a typical arched roof greenhouse as a function of its geometric characteristics is presented. The numerical method is validated against recently published experimental data (Kim, R., et al., 2017. Biosystems Engineering, 164: 235-256). The effects of different geometrical characteristics of arched-roof greenhouses, such as height/span ratio, roof height/span ratio and curvature radius of the roof, are studied through computational simulations. The obtained results indicate that the wind pressures are sensitive to key design parameters. The present work is expected to contribute to updating or refining the relevant provisions of EN 13031-1-2001, currently under revision.

Rule-based Versus Model-based Control of the Greenhouse Environment

Ido Seginer[1], Peter Van Beveren[2], Gerrit Van Straten[3]

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Problem: Current greenhouse environmental control is mostly rule-based, utilizing rules such as “if it is daytime and the greenhouse temperature is above T, open the windows”. These rules are based on experimental results and on grower’s experience and are meant to insure an optimal environment for the crop. The rules are adjusted to the type and state of the crop and they respond to the changing weather.

Growers are reluctant to replace this approach by the model-based control developed over the years by the academic community, despite its theoretical superiority. Apparently because they do not trust the crop models imbedded in these systems.

Objective: We attempt to show that a relatively simple model-based optimal control algorithm can produce an environment which is at least as good as the currently produced environment; probably better.

Method: An actual year-long data-set, measured in a commercial tomato greenhouse, is mimicked by our simulation-optimization algorithm. The modelled system includes a water tank for day-to-night heat storage, which is helpful mainly in summer-time CO2 enrichment. The simplified greenhouse model has no explicit crop and cover temperatures and no explicit long wave radiation flux. Evaporation rate is taken from standard practice.

Results: The temperature and humidity levels specified by the algorithm fit the measured levels mostly rather well, while the achievable CO2 concentration, particularly in summer when it is most useful, is considerably higher than in the actual greenhouse. On-line adaptation of the algorithm should be possible both in the short-term (evapotranspiration) and in the long term (growth).

Conclusions: The results to date suggest that the model-based system is safe enough to be considered practical. In particular, it has safe constraints on the greenhouse temperature and humidity. The optimization inherent in the control algorithm assures that the achievable environment is economically the best.

Analysis of Greenhouse Cover Properties for Optimal Net Financial Result

Yuexiang Chen, Bert van 't Ooster, Eldert van Henten

Wageningen University, Farm Technology Group, Netherlands, The

Greenhouse cover parameters affect indoor light intensity and solar heat load, which in turn influences temperature, plant growth, and economic profit. Cover parameters are normally material related and considered constant over time. It is however not known what parameter values result in highest Net Financial Result (NFR). Also, it is expected that varying the cover parameters dynamically in time might contribute to improving NFR. Therefore, the objective was to identify the effects of optimizing constant parameters and of optimized time-variant cover parameters on the NFR. This research used the genetic algorithm to obtain the optimal values of constant and time-variant cover parameters for maximizing NFR. Respecting time-invariant cover parameters, sensitivity analysis revealed that NFR sensitivity was highest for the transmission coefficient of PAR (photosynthetically active radiation), NIR (near infrared radiation), and the emission coefficient for FIR (far infrared radiation). The optimal values of cover parameters for Dutch climate maximizing NFR via time-invariant cover parameters showed high τ_PAR (PAR transmission coefficient) and ϵ_FIR (FIR emission coefficient), and a low value of τ_NIR (NIR transmission coefficient); Theoretically best values for τ_PAR, ϵ_FIR, and τ_NIR were 0.999, 0.999, and 0.001 respectively, where nominal values were 0.85, 0.85 and 0.82 respectively. NFR increased from 16.14 € m-2 y-1 at nominal values to 18.98 € m-2 y-1 for optimized parameter values. These optimum values were obtained from simulations with a validated model but the optimization outcome could not be validated explicitly. For the time-variant cover parameters, NFR was hourly optimized using the genetic algorithm. Due to the high demand for computing power, this optimization was executed for a time period of 50 hours only. It showed that optimization for time-variate cover parameter enhanced NFR with 57% compared to the simulation of the same period with nominal cover parameter values.

Disease Detection and Rate of Spread in Solanum Lycopersicum Leaves under Variable Bioevironmental Conditions using Image Processing Technique

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Cultivating crops using greenhouse technology is an advancement in food production. One major challenge of this methodology is the detection and spread rate of diseases that occur through variations in environmental conditions of the greenhouse such as temperature, humidity, light intensity etc. Detecting diseases in plants accurately and timely can help mitigate much losses in food production in greenhouses. For the past decades, many researchers have been working on innovative technologies that helps in timely detection and classification of diseases in plants. The aim of this research was to develop an algorithm to detect diseases in tomatoes, classify and determine the rate of spread of the diseases with time using image processing techniques. This disease occurred naturally due to fluctuations in the bioenvironmental conditions. The plants under research were subjected to temperature and humidity range of (-2C - 14) ˚C and (30 - 55)%rH respectively. RGB visual light cameras were used to capture images of the tomato plants (leaves) for diseases detection over thirty two days period. Algorithms for image processing such as thresholding, color masking, segmentation et al using MATLAB R2017b were developed to detect diseased areas as well as to determine the rate of spread of this disease in the tomato leaves. The algorithm developed was able to detect the diseases, classify and quantify them by finding the area of the spread region. The percentage rate of spread was analyzed from the results given. It was concluded that the rate of spread increased with increasing variations of temperature and humidity over time. The spread was at its peak from the 12th to 26th day due to imbalances in temperature and other environmental conditions.

The Role of Crop Properties in Energy Efficient Greenhouse Design

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The design of a greenhouse crop production system incorporates knowledge and technology from various different fields including structure design, crop selection, and climate management. Given an existing system, it is often unclear which attributes should be changed in order to improve performance. In this case study, we consider the problem of minimizing greenhouse heating costs while maintaining high yields. We investigate a model of a winter lettuce crop under optimal climate management by applying a sensitivity analysis and examine the roles of various properties of the system on energy consumption. The results show that crop properties such as resistance to low temperatures and high humidity are crucial for reducing greenhouse energy consumption, and highlight the economic and environmental benefits of selecting for energy efficient greenhouse crops.

Effect of Bench Heating on Growing Medium Temperature and Heat Loss From a Greenhouse in Wintertime

Massimo Brambilla[1], Elio Romano[1], Maurizio Cutini[1], Marco Fedrizzi[2], Mauro Pagano[2], Gianluca Burchi[3], Sonia Cacini[3], Daniele Massa[3], Chiara Terrosi[4], Carlo Bisaglia[1]

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The dynamic behaviour of greenhouse microclimate is a combination of physical processes involving energy transfer (solar radiation and heat transfer) and mass balance (water vapour and CO2 fluxes) at varying of outside environmental conditions. In Italy, 52.3% of greenhouse production sites are placed in the North and in the Centre of the Country and exposed to a variety of climate conditions: greenhouse microclimate control plays a key role in the management of such production systems, in particular when automated. In the research activities under the project AGROENER (http://agroener.crea.gov.it/), funded by the Italian Ministry of Agriculture (MiPAAF), with this work, we present a preliminary study aimed to assess the energy losses occurring in a greenhouse while providing bench heating to a growth substrate (50% peat and 50% perlite). In wintertime, inside a greenhouse with double polyethylene cover, benches of growth substrate were heated circulating warm water (37.3± 0.06°C) in plastic pipes placed at three different depths (on the top, in the middle and at the bottom). The temperatures of the substrate, as well as the microclimatic parameters inside and outside the greenhouse, were collected. The heat loss (kW) from the structure was assessed in accordance with the ASAE EP406.4 standard net of the heat occurring from solar radiation. Data processing by GLM (using the position of the pipe as factor and the temperature and the solar radiation as covariates) pointed out that pipe position significantly affected the temperature of the medium and the heat loss: as a matter of fact, pipes placed inside the substrate provide the highest temperature of the growth medium (16.3 ± 0.02 °C) and for the lowest heat loss from the greenhouse (1.34 ± 0.05 kWh) on hourly basis that is 34.7% lower than that related to the heating pipes placed on the top of the growing substrate.

Effect of Dimethyl Ether (DME) Combustion on Lettuce and Chinese Cabbage Growth in Greenhouse

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The problems of agriculture in recent years are seriously increased, especially in greenhouse farms where large operating systems for energy are very costly. Therefore, the purpose of this study was to determine whether the thermal energy and carbon dioxide produced by the combustion of DME (dimethyl ether) can be beneficial to the greenhouse plants. DME is a colorless gas and form of natural gas, it is non-toxic and biodegradable synthetic fuel and known as clean fuel. In this study, we investigated the effect of DME combustion on the growth of lettuce and Chinese cabbage in three experimental greenhouses (width 3 m, length 4 m, height 2.5 m) at Gyeongsang National University. Three tests were performed to compare and analyze the growth of lettuce and Chinese cabbage, chlorophyll content, CO2 and temperature in greenhouses at different flow quantity of DME. DME supply time was 0.5hr/day, 1hr/day, 1:30hrs/day and 2hrs/day on week 1, 2, 3 and 4 respectively. The average DME flow quantity in duct was 17.4 m3/min and 10.2 m3/min to Greenhouse 1 and Greenhouse 2 and no DME gas was supplied to Greenhouse 3 which was left as control. As a result, DME combustion significantly affect growth of lettuce and Chinese cabbage in two greenhouses. At end of experiment, the highest fresh weight and dry weight of lettuce and Chinese cabbage were measured in

Greenhouse 1 and followed by greenhouse 2. Similarly chlorophyll content of Greenhouse 1 were 15% higher than greenhouse 3. CO2 were significantly increased at the time of DME supply to greenhouses. In conclusion, DME gas can be used for rapid growth of lettuce and Chinese cabbage in common greenhouses

Estimation the Strength of Biodegradable Organic Pots During Process of Growing Plants in Control Greenhouse

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In the process of transplanting biodegradable pots can be damaged and there is high risk of damaging plant's root. The objective of our study was to estimate the strength of biodegradable organic pots in the process of growing plants in control greenhouse. Total 120 biodegradable organic trays were used in control greenhouse of Gyeongsang national university. All trays were filled up with commercial compost and pepper seeds were planted in total of 60 biodegradable organic trays while other 60 trays were remained with no seeds. Water spray were supplied 5 min/day and temperature were maintained between "20-30" degrees C inside greenhouse which is recommended for growing pepper seeds. We did analysis on weekly basis by taking 9 pots samples from each tray (with seeds and non-seeds) and checked the strength of biodegradable pots after removing the compost and plant. EZ 20 material testing machine were used for tension and compression test of individual pots and also for sides of each pots by cutting it in (3x2 mm) rectangular shape. Also we checked the moisture content of individual pots of biodegradable pots by using dry oven. The initial average maximum tension load of pots were 71.083 N in 3.08 sec and average maximum compression load of pots were 78.6 N in 14.06 sec. For sides of pots the initial average maximum tension load were 198.6 N in 4.38 sec and average maximum compression load were 59.7 N in 3.0 sec. The results showed that water content and long roots of pepper can have significantly effect on biodegradable pots. Although there were no significant difference observed before roots reached to sides of pots. In conclusion, water content and roots elongation have significant effect on biodegradable organic pots so there is need to improve materials of biodegradable pots while using in transplanting machine.

Sensitivity Analysis of a Modified Equation for Greenhouse Energy Demand Assessment.

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Within the framework provided by the Italian Ministry of Agriculture with AGROENER project (*http://agroener.crea.gov.it/*), a modified equation for the assessment of greenhouse energy demand was developed. As a matter of fact, in Italy, almost 30.000 heated greenhouse production sites undergo variety of climate conditions. With particular reference to the Northern part of the Country (Po and Adige valleys) and to the Central one (low inland) humid subtropical climate can result in moderately cold wintertime.

Starting from the recommendations of ASAE EP406.4/08 [B1] standard, the overall heat loss from the greenhouse (Qt) has been assessed as function of the heat losses by radiation, conduction and convection (Qrc), by infiltration (Qi) and the heat occurring from solar radiation (Qs).

Qt = Qrc+Qi-Qs [kW]

All the accessory variables needed for heat loss assessment were assessed in accordance with ASAE D271.2/99 and ASAE EP 460/01. To understand the relationships between information flowing in and out of the model, a sensitivity analysis was carried out by means of Monte Carlo analysis. Multiple evaluations with randomly selected model input were performed to determine both uncertainties in equation predictions and evaluating the importance of each individual input variable with reference to the uncertainty of the output by means of standardized coefficients: 22900 runs were performed.

The expected mean value and variance for Qt resulted to be 3.45 kW and 32.0 kW. A preliminary investigation of variable importance using the Pearson correlation coefficient (r) pointed out that the overall heat transfer coefficient (U-value, W m^{-2} $°C^{-1}$), the area of the cover (Ac, m^2) and the temperatures (°C) inside and outside the greenhouses were the variables whose variations were mostly influencing the equation output. The standardized regression coefficients resulting from linear regression proved the temperatures are the most important variables followed by U-value and the area of the cover.

Fuzzy Logic Based Simulation For Balancing Environment Variables in Greenhouses

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The greenhouses as a controlled environment provide an important opportunity to combine optimal temperature, light and humidity conditions with proper watering, fertilization and management to produce top quality plants. Some crops are grown only in greenhouses during the year. For this reason, environmental management in the greenhouses is becoming increasingly important for the food supply. The most important environmental parameters that need to be controlled for optimal greenhouse climate are temperature, relative humidity and light intensity. Temperature has a significant role in plant growth and development thus, temperature control is the most important parameter in greenhouses. The optimal temperature depends on the plant species grown and desired level of photosynthetic activity. Optimum indoor temperatures for plants growing in the greenhouses vary 10 to 28°C and moisture value for normal plant growth is between 50 to 80%. On the otherhand, light is an important source of energy (Photosynthetically Active Radiation, PAR) for photosynthesis, and there is an optimum light level for each plant species. The average light levels for flower and vegetable varieties range from 150 to 750 $mmol.m^{-2}.s^{-1}$. The amount of light may need to be increased or decreased to keep the light at the optimum level. The light level can be increased by artificial lighting sources (such as LED, high and low intensity discharge lights) or reduced by using shading screens.

This paper describes a fuzzy logic based lighting intensity, ventilation and irrigation algorithms, which can calculate different temperature, relative humidity, outdoor and indoor light intensity and soil moisture under pre-defined boundary conditions in a greenhouse environment. In the paper, a novel model has been developed based on a Mamedani's fuzzy logic method. The study contains the simulation of the design in a MATLAB software environment using Fuzzy Inference System.

Effects of Infrared Radiation on Growth Parameters and Physiological Characteristics of Eggplant Cultivation

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The advantages of Infra-Red (IR) heating is verified and demonstrated in an experimental greenhouse with eggplant cultivation. Infrared radiation heating systems possess the advantage of high directional control and focused compensation of energy losses, appropriate for creating local temperature conditions in open or thermally unprotected spaces resulting in an overall reduction of heat losses and consequently heating energy needs up to 50%. IR heating systems can efficiently maintain favourable environmental conditions at the plant canopy. The objective of this research is to investigate the effect of infrared radiation on growth parameters and physiological characteristics of eggplant. Extensive experimental results are presented from a full cultivation period inside two identical, small scale experimental greenhouses, with IR and forced air heating system, correspondingly. Eggplant (Solanum melongena L.) is used as the test crop for a three months period. The produced data include solar radiation, relative humidity, greenhouse air and cover temperature and plant growing are presented. Results are compared to conventional cultivation. In parallel with plant growing parameters' evaluation, the antioxidant and metabolic profile of eggplant from the experimental greenhouse was evaluated in comparison to conventional cultivation.

Selecting Significant Wavelengths To Predict Chlorophyll Content For Paprika Seedlings Leaves

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Chlorophyll content related to the quality of vegetable seedlings is greatly affected by the concentration of nutrient solution as well as aerial environment in nurseries. Four levels (0.5, 1.5, 2.5, and 3.5 mS cm^{-1}) of EC concentration were provided to investigate the chlorophyll content of paprika (*Capsicum annuum L.* cv. Nagano) seedlings nursed under LED with photosynthetic photon flux of 200 μmol m^{-2} s^{-1} and photoperiod of 16/8 h (light/dark) in a closed transplant production system. Hyperspectral images for paprika seedlings were acquired for 21 days by using two hyperspectral cameras over the 400-2,500 nm wavelength range. The correlation coefficient spectrum, the stepwise multiple linear regression (SMLR), the principal component regression (PCR), and the partial least square regression (PLS) were applied to investigate the feasibility of determining the chlorophyll content of paprika seedlings. Significant wavelengths of 519, 557, 590, 732, and 846 nm were selected for quantifying the chlorophyll content. The results from the calibration models built by SMLR, PCR, and PLS showed strong relationships between predicted and measured chlorophyll content. Determination coefficients for calibration and validation data sets were 0.84 and 0.81, respectively. Standard error of calibration and standard error for prediction were 2.41 and 2.04, respectively. It was concluded that hyperspectral reflectance imaging could be a good potential for quantifying the chlorophyll content of paprika seedling leaves.

Environmental Assessment of a Close Hydroponic Greenhouse system

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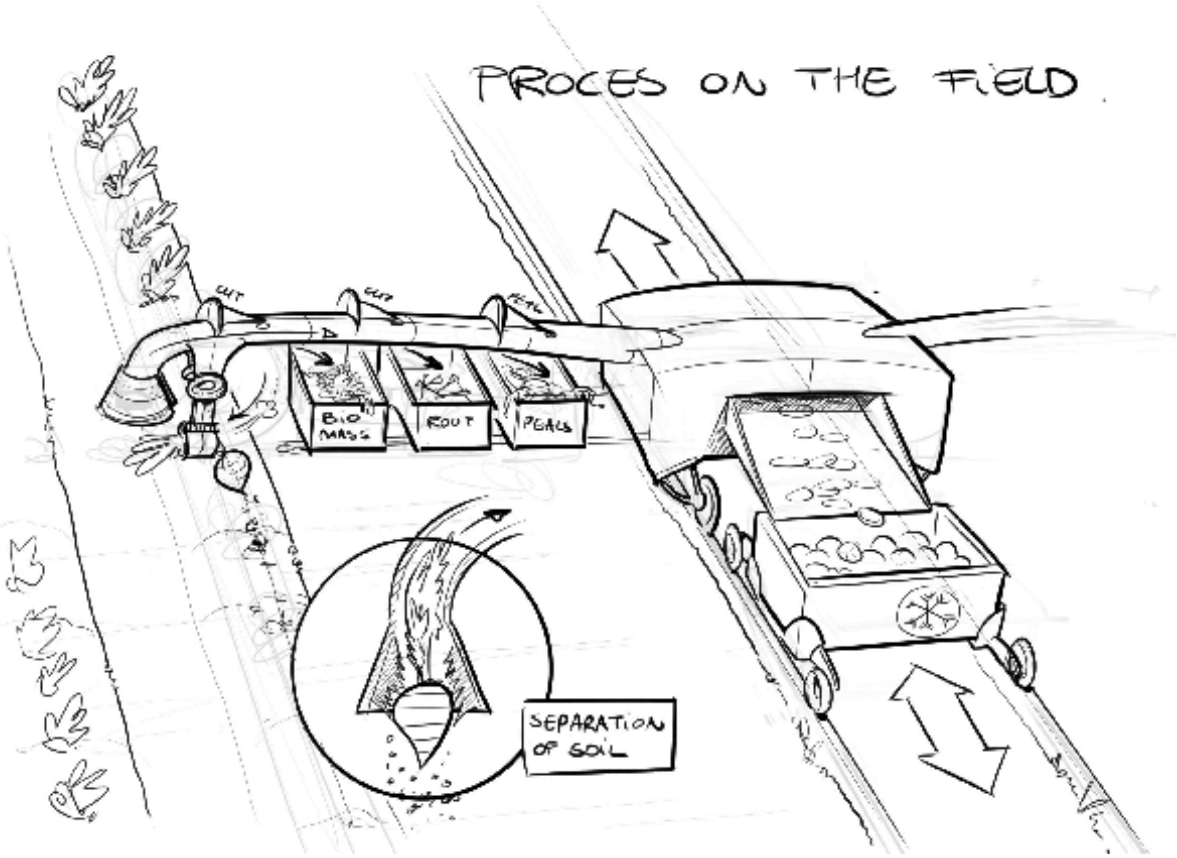
The assessment of the environmental impact of agricultural production has received increasing attention over the last years, because agriculture appears to have a major impact on the environment. Modern, intensive crop production is regarded as a source of solid, liquid and gaseous emissions, which can be both a nuisance and environmentally harmful. Plastic, waste water and greenhouse gases, coming from direct or indirect sources, are the most important effluents for polluting the air, the ground and surface water (nitrates and phosphate emissions), causing climate change, acidification, eutrophication and ecotoxicity (soil enrichment with heavy metals). Regarding protected cultivations, there are some environmental studies that are restricted to the use of national or EU level guiding policy or in improving farm management by supplying information to the farmer or advisor. To reduce pollution sources from intensive agriculture production systems to the environment many technologies have been developed and applied, like close hydroponic systems, close greenhouse, degradable plastic covering materials etc. However, till today information and studies concerning a complete environmental assessment of greenhouse cropping system are limited. Therefore, there is an increasing interest in product-oriented and life cycle based environmental assessments (LCA), because there is a need to evaluate global emissions and impacts from the whole production chain in relation to types and amounts of products consumed. Life cycle assessment (LCA) is a generally accepted method to evaluate the environmental impact during the entire life cycle of a product. In the present paper, we built upon the results of previous EU projects rational irrigation strategies in greenhouse and using the LCA method through the SIMAPRO software we evaluate the environmental impact on close, semi-close and open greenhouse hydroponic systems.


PROCES ON THE FIELD
CUT
CUT
PEAL
BIO MASS
ROOT
PEALS
SEPARATION OF SOIL

Topic 10: Post-Harvest Technologies (PH)

Technology and management systems to monitor and control the quality of products, and for sorting, food processing, packaging and storage. Contributions can address nutrition, flavour and shelf life, and include various types of sensors, actuators, packaging materials and controlled-atmosphere techniques.

Post-Harvest Technology

Hyperspectral Imaging for Foal Meat Classification Based on Ageing Time

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Assessment of meat quality parameters is a major concern in the food industry due to the continuously demand for superior quality of meat. Therefore, it is crucial to assess meat quality parameters correctly and also, do it using sustainable and efficient methods. In this respect, hyperspectral imaging (HSI) technique has been regarded as a smart and promising tool for analyses conducted in research and industries. It integrates both spectroscopy and imaging to directly identify different components and their spatial distribution in the tested product. Thus, a quality evaluation based on HSI would be beneficial to the meat industry. In this study we evaluated the usefulness of HSI to classify foal meat steaks based on ageing time, an aspect that greatly influences meat tenderness.

The dataset used comprised 88 foal steaks from twenty-four hours post-mortem Triceps Brachii muscles. Samples were aged 0, 4, 8 and 12 days at 4±1°C and then frozen at -18± 2ºC until analyses. Steaks were scanned using a hyperspectral camera (Xenics, Xeva-1.7-320) with a 320x256 pixel resolution and a spectrograph (ImSpector N17E, Specim) in the 900-1700 nm spectral range. A Partial Least Squares-Discriminant Analysis (PLS-DA) method was used to classify steaks in 3 classes according to their ageing time (high, medium and low quality). High class was composed of steaks aged 0 and 4 days, medium class comprised steaks aged 8 days and, low class included the rest (steaks aged 12 days).

Good classification results were obtained for high and low quality classes (76.9% and 66.7%, respectively) in the prediction sets and a low percentage of correctly classified samples was achieved for the medium quality class. Such misclassification for the latter was expected as this was a mixed quality class in which some steaks still maintained an acceptable quality for consumption while others may had lost it.

Simultaneous Production of Functional Lipids and Natural Antioxidants From Passion Fruits Seeds

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Passion fruit species *P. setacea, P. alata, and P. tenuifil*a, are native to the Brazilian biomes, particularly Atlantic Forest, Cerrado, and Caatinga The seeds waste generated after passion fruits juice extraction contain functional polyunsaturated fatty acids, and phenolic compounds with high anti-oxidant capacity. The main objectives of this study were to obtain the functional lipids, and natural antioxidants from passion fruits seeds, applying sustainable technology. Passion seeds oils were obtained using a lab-scale continuous press. The oxidative stability of oils was evaluated using RANCIMAT method. Regarding the phenolic compounds extraction from pressed cake, a statistical factorial design was applied to select the solvent polarity and temperature of extraction. The antioxidant capacity (TEAC) of all extracts were the main response to select the best operational conditions. The higher antioxidant capacity extracts was found using ethanol-water solutions (70:30) at 30 ºC. In these cases, the total phenols, expressed as gallic acid equivalent, from *P. setacea, P. alata, and P tenuifila* cakes were approximately 1800, 600 and 900 mg/100 g of extract. Using these extracts as natural antioxidant in their respective oils, the induction periods for *P. setacea, P. alata, and P tenuifila* seeds oils increased of 7.3 to 9.6 hours, 3.52 to 11.7 hours, and 6.87 to 10.27 hours respectively. Therefore, the passion fruit seeds of the selected species can contribute to increase the supply of vegetable polyunsaturated oils with high oxidative stability.

Evaluation of a Citrus Mobile Platform Using a Wireless Impact Recording Device

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Manual citrus harvesting is an expensive operation that represents between 25-40 % of the total production costs. A mobile platform prototype to assist in the harvesting of citrus fruits designed by the IVIA (Spain) has been tested in order to reduce fruit damages. The mobile platform is fitted with conveyor systems. The multilevel platform can accommodate 4 to 8 workers who pick the fruit and place it on a conveyor belt. The picked fruit is transported to central conveyor belt on which the fruit is transported to the in-line sorting system that classifies the fruit in two categories using a computer vision system and directs the fruit to one of the two different bin-fillers. During this process the fruits are subjected to mechanical stress causing physical injuries, including skin punctures, pulp and cell rupture. An impact recording device was used to evaluate damage produced to citrus fruits. The critical points at which damage occurs were determined, and the damage levels assessed. The highest damage level was produced from the bin-fillers to the bins. Seven different shocking absorbing materials were tested in order to reduce fruit damage. Five of the seven tested materials were capable to reduce the recorded impact.

Hyperspectral Imaging Analysis Of Potato Flesh For Industrial Processing Aptitude

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Potatoes stand out as one of the most important crop worldwide both in terms of consumption and production. Tubers are cultivated according to established quality parameters like colour, dry matter or starch content. In the last years, producers have introduced the aptitude for industrial processing as a new quality parameter. In this respect, potatoes are classified as having

boiling, frying or baking aptitude, among others. We understand that using a non-destructive analysis, specifically hyperspectral imaging, could facilitate the classification process, leading to a cheaper, faster classification of tubers and, consequently, to a wider adoption of the quality parameter. However, this faces technical problems, a very relevant one being the heterogeneity of the potato flesh, which might hamper the correct classification of tubers. The objective of this study is to determine whether the analysis of different parts of the tuber (e.g. more centric or peripheral flesh) can influence its classification as a whole. In this regard, we are interested in an evaluation of the level of homogeneity along the flesh.

For this, 20 different potato cultivars (4 tubers per cultivar) identified as either suitable for boiling or frying were used. Tubers were scanned with a hyperspectral camera (Xenics, Xeva 1.7-320) with 320x256 pixel resolution sensitive in the 900-1700 nm spectral range. The images were automatically segmented, and each tuber was divided into four non-overlapping, concentric regions of interest, each of them encompassing the same number of pixels. Each region produced a representative spectrum, later processed using Partial Least Squares Discriminant Analysis.

The results showed that, the reflectance of the centre was the lowest but no clear zone hierarchy was appreciated among the different cultivars. Therefore, this indicates a lack of homogeneity along the flesh of the tuber which could negatively influence the classification of cultivars based on aptitude for industrial processing.

Mathematical Modeling of Thin Layer Solar Drying of Parsley

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Using renewable energy in food industry and especially in drying process is drastically growing. This paper is concerned with the mathematical modeling of thin layer solar drying process of parsley. For this purpose, a solar dryer with auxiliary heat pump was developed and equipped with instrumentation to collect data for evaluation. All experiments were conducted at air temperatures of 35 ºC, 45 ºC and 55 ºC and air velocities of 1, 2 and 3 m s^{-1}. The drying data was fitted to five different mathematical models. Among the models, the Midilli et al. model with the coefficient of determination 0.997 was found to best explain thin layer drying behavior of the parsley leaves. The performance of these models was investigated by comparing the determination of coefficient (R^2), reduced-chi square (χ^2) and root mean square error (RMSE) between the observed and predicted moisture ratios.

Post-Harvest Storage Conditions

Design of an Innovative Plant for Fast Freezing of Potato Dumplings

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Fresh food when harvested and/or processed continues to undergo changes that involve spoilage and deterioration of the product. The food deterioration, due to enzymes and bacteria, is related to texture and nutrients losses and colour changes. Freezing is a valuable technique of food conservation to extent food shelf life. The recommended temperature for frozen foods is -18°C as this is the temperature at which enzymes and bacteria stop growing.

When the temperature of the food drops below freezing point, the unbound fraction of water freezes and expands. The ice crystals could cause the cell walls rupture and, consequently, nutrients losses during food thawing. Quick freezing, assuring the formation of small ice crystals in foods, can reduce or avoid cells wall damage.

The design of an innovative plant for fast freezing of potato dumplings at very low temperatures (even lower than -80°C) is here presented. The designed plant is constituted by two separate loops: the first loop, where the cooling energy is obtained at low temperature, is based on a reversed Brayton cycle while the second loop where, the dumplings are frozen, is a forced-air freezer room. Optimal plant parameters, such as temperature and velocity of the freezing medium (air), to obtain the required fast freezing time of the dumplings are evaluated. Depending on the requested freezing time and on the mass per hour of dumplings to be processed, the suitable plant solution, as batch or continuous process, can be identified and finely designed.

The proposed solution overcomes limits of traditional freezing plants, such as ones operated by vapour compression cycles, which cannot reach such low temperatures without exceeding in complexity and number of stages. For this reason, the plant is proved to be a viable, cost-effective alternative to traditional freezing plants used in food industries.

Influence of Physical and Chemicals Characteristics from Pumpkin for its Mechanized Processing

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Dealing with agro-industrial product processing can start from a basic treatment up to a full transformation Thus, it is essential to previously know the physical, chemical and biological characteristics from the raw mass that enters into the process. It is also important to choose processing tools made from suitable materials, as they influence the efficiency of mechanical forces application and its resistance to organic chemical compounds. A study for monitoring the interaction between processing tools with different materials for their blades acting on the raw mass under processing would give data that could orient towards diversification of product transformation, as well as their attributes to generate healthy and well balanced nutritious food products. In this work, a procedure was directed to certain constituents of pumpkin (Cucurbita spp.) in order to obtain bioactive lipids. It started with recording basic data, as dimensions, weight and densities, as well as its physical and chemical attributes from this raw mass before processing. When the mass was processed to obtain flour from pumpkin's seeds with cover and when utilized for cooking, it was recorded a reduction in losses of oil up to 15%. Equally, when its chemical attributes are associated to a proper processing, they contributed to improve the extraction efficiency, as well as the quality and trait for the obtained acid lipids; from 20% for oleic and 51.9% for linoleic coming from the same raw mass.

Effect of Accelerated Storage Conditions on Pearl Millet Based Fried Snack

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GBPUA&T, PANTNAGAR, India

The storage life of pearl millet based deep fried ready to eat snacks packaged in aluminum laminated polyethylene of thickness 58 micro mm (with and without nitrogen) was evaluated under accelerated storage conditions of 32+ degree C and 90% Rh moisture content, FFA, peroxide value, and crispness of the snack was determined throughout the storage period. Moisture content and peroxide value increased with increase in storage period but the increase was less in package flushed with nitrogen gas. The crispness and sensory scores decrease with increase in storage period in both with and without nitrogen packages. However, the decrease was less in nitrogen flushed pack. FFA and peroxide values were strongly correlated with moisture content of the snack. The storage life at accelerated conditions was found to be 45 and 60 days in packages without and with nitrogen, respectively. The predicted storage life of snack was determined as 254 and 294 days, respectively in without and with nitrogen packages.

Wall Pressures on Oblique Hoppers of Steel Silos

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Silos are special structures used to store different kind of products that exhibit a complex behavior because of the existence of specific phenomena such as the “silo effect”. EN 1991-4 is a European standard, which is the reference code, employed worldwide to calculate the actions on silo walls produced by the stored material. Bin – hopper geometries are one of the main silo typologies existing, especially for steel silos in farm facilities and food industries, and they sometimes have an eccentric outlet in order to improve the flow of material during discharge. The current version of EN 1991-4 considers Walker theory in order to calculate pressures on concentric hoppers, but oblique hoppers are not covered by it. This paper presents a Finite Element Model developed to predict the wall normal pressures expected in oblique hoppers. It has been considered the effect of several parameters, e.g. the ratio of eccentricity, the ratio of radius to the hopper height or the circumferential location, on normal pressures. Results of this research are expected to be of interest in the future updating of EN 1991-4.

Feasibility of Non-thermal Plasma for Extending Strawberry Shelf Life

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Microbial growth plays an important role in reducing the quality of the fruits and vegetables. Strawberry is a product with a great nutritional value but soft fruits such as strawberry have a short shelf. During the past two decades, demand for fresh and ready-to-eat foods having high nutritional value without preservatives and additives has increased. The cold plasma is a novel non-thermal and dry processing technology without any need to chemicals treatments, which is able to work continuously at atmospheric pressure. It can potentially clean the surfaces of the products by inactivating the microorganism. In this study the atmospheric pressure dielectric barrier discharge plasma with air gas was used for treatment of the strawberry samples. The barrier discharge plasma is created by applying a 12 kV pulsed high voltage. Two levels of 7% and 14% duty cycle and four durations of 0, 5, 10 and 20 min for apply the plasma on the samples were used. Microbial load of aerobic bacteria and yeasts/molds were enumerated immediately after the plasma application. Structural variation in the microorganisms on the surface of the samples was analyzed using scanning electron microscopy (SEM). Results of microbial load in the treated samples showed that the plasma reduced the total aerobic bacteria, and the yeast/molds 1.46 log CFU/g and 2.75 log CFU/g, respectively. The destruction of microorganisms on the surface of the plasma treated sample was clearly observed compared to the control samples by the SEM images. It is possible to reduce strawberry losses before packaging by applying non-thermal plasma. Further studies are needed for effect of cold plasma on nutritional value of fruit and vegetables.

Maximization of Whey processing in Drying Units with Spare Capacity: Brazilian Dairy Cluster Case Study

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Whey produced by small to medium cheese makers in the state of Minas Gerais, Brazil, is currently being underutilised and carries an economic burden due to losses to the environment. The current study provides a diagnostic of whey utilisation in a selected cluster of 100 dairy companies located in Zona da Mata and Campo das Vertentes and economically assesses potential value addition scenarios for regional development by considering the potential whey uptake by two established drying plants with spare capacity. A detailed regional survey determined that 76 dairies produce 756 m^3 whey/day, of which 69.7% are provided as animal feed, 15.8% are used in the manufacture of other products, 9.2% are sold to third parties, 5.3% are disposed as an effluent and 1.3% are disposed in the environment without treatment. From the total whey, 11.8% were of acceptable quality with no required infrastructure on cheese maker sites. The decision-making model indicated that the most economical scenario includes the installation of whey collection centers where whey is pre-pasteurised and concentrated, and selects optimal locations among a set of cheesemaker candidates. With a minimum regional development investment of US$ 14.2 million, the model selects the Ponte Nova plant as the recipient of the cluster’s whey (mostly in pre-concentrated form) to produce 40% demineralised whey powder with a return of investment in 2.9 years. Changes in transportation costs did not affect the model output recommendations. This study demonstrated the economic viability for whey recovery into whey powder following the formation of a cluster of associated small to medium cheesemakers.

Mandarin Mold Inactivation of Storage at Ambient Temperature by Non-thermal Plasma Treatment

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Inactivation efficiency of mandarin mold was evaluated at room temperature storage using cold plasma based on dielectric barrier discharge (DBD) technology. Tangerine variety (*Citrus unshiu*) samples were purchased from an orchard in Jeju, Korea. Samples

were divided from treatment (N=240) and control (N=240) group. The plasma treatment was carried out by the non-thermal plasma actuator with time control condition as 15sec ON, 15min OFF and measured inactivation gas concentration with ozone (O_3) and nitrogen dioxide (NO_2) detector. In this study, two non-destructive and destructive practices were derived. Samples were stored for 5 weeks and physical properties such as weight, color, hardness and sugar contents were measured with 10 samples in each group. Non-destructive inspection (weight and color) was carried out with 60 samples. As a result, weight and hardness of fruit decreased with time in both groups, but color and sugar contents change was insufficient to evaluate.

Monitoring Watercress Shelf-life with VNIR Hyperspectral Image through Packaging Film

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The aim of the present work is to monitor the shelf-life of watercress *(Nasturtium officinale*) by means of hyperspectral images through packaging films. Fifteen watercress leaves were randomly selected from a commercial bag, put inside Petri dishes covered by plastic film and stored at 4ºC for 16 days. Hyperspectral images (VNIR 400-1000 nm) were taken during this storage, getting five acquisitions for each leaf. The average spectrum of each image was computed; several models were obtained from these average spectra. A radiometric correction was applied in order to avoid the variation in transmittance of the plastic film along storage in the hyperspectral images. Afterwards, three spectral pre-processing procedures (no pre-process, Savitsky–Golay and Standard Normal Variate, combined with Principal Component Analysis) were applied to obtain different models. These specific models for watercress along with other models previously developed for spinach were applied and compared. The artificial images of scores obtained, applying each model to the original and complete images, were compared by means of Analysis of Variance and Wilks-λ. Radiometric correction allowed the supervision of shelf-life in leafy vegetables through commercial transparent films All models applied were able to monitor the aging of the leaves. However, the models developed specifically for watercress spectra were more suitable for monitoring the shelf-life of this vegetable leaf along the storage. There were some differences between the models applied for spinach and for watercress leaves. In spite of it seems to be necessary to study the spectra of each leafy vegetable independently for developing prediction models more able to monitor the aging of the leaves, hyperspectral imaging could be used for monitoring the freshness of watercress and/or mix of salad leaves during their shelf-life. Multispectral indexes based on results of PCA and spectral patterns, could contribute to the transference of the technique to industry.

Post Harvest Technologies and Simulations

Wireless Sensor System for Real-Time Measurement of Respiration Rate of Fresh Produce

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Fruit and vegetables continue to respire even after harvest. The most crucial factor to extend their keeping quality is to minimize the respiration rate as used in dynamic controlled atmosphere storage based on respiration quotient (DCA-RQ). DCA-RQ system monitors and identifies the critical O2 concentration at which the stored product reaches anaerobic respiration. However, measurement of respiration of DCA stored fresh produce is still challenging. In this study, a modular respirometer was developed using an in-house built O2 and CO2 measurement sensor (sphere). The sphere records (every 1 minute) and wirelessly transmits measured data to the receiver connected to the computer. The respirometer (3.3L) consisted of a specially designed glass jar with water seal at the bottom for leak proof (Δ0.01%/h). The sensor sphere was placed inside the respirometer along with the product. The collected data was used to calculate real-time respiration rate using in-house built software. Experiments were performed to test the effectiveness of the newly developed respirometer under air and modified atmosphere conditions for mango. For modified atmosphere, respirometer was flushed with gas mix containing 21, 15, 8, 2 and 1% O2 and balance nitrogen. First results showed that the respirometer was able to quickly measure respiration rate of mango under air (30.1 ml O2/kg.h and 38.73ml CO2/kg.h) and also under low O2 concentration (10.8 ml O2/kg.h and 53.7 ml CO2/kg.h). It was also possible to detect RQ change from aerobic respiration (1.3) to anaerobic respiration (5.0) at low O2 concentration. Collection of such detailed data provides exact information on the respiration process, RQ, low O2 limit, thus, will enable a more knowledge intensive design and control of RQ based DCA system for fresh horticultural produce.

A CFD-Simulation Approach for the Identification of Indoor Airflow Patterns in a Wine Cellar

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One of the most important phases in quality wine production is the wine-ageing: during this phase important chemical reactions occur in wine, improving specific qualities such as, color, aroma and taste. Usually wine is aged in indoor rooms and kept in traditional containers such us bottles or wooden barrels. Since temperature affects chemical reactions and the wine containers are usually unconditioned, the room temperature plays a crucial role in the ageing procedure. Moreover, if the wine is kept in wooden barrels also humidity should be controlled: low humidity levels can ease the wine evaporation (loss of product), on the other side high humidity values can favor the mold formation (spoiling the container and the wine). Recent studies showed how air velocity can accelerate wine evaporation and mold transportation, besides having a fundamental role in temperature and humidity distribution and control inside the cellar. Several cellars are provided with temperature and humidity control systems, however air velocity is usually uncontrolled. In this regard, CFD simulations represent suitable tools to study these phenomena.

The aim of the study is to identify the patterns of natural ventilation within a representative study case of wine-ageing cellar in the Emilia-Romagna region (Italy), characterized by a concentration of wine farms with average production of 1500 hl/year and worldwide export. The selected farm has features in line with the average conditions of that area. The built environment of the farm includes a two-storey building with an underground cellar for wine aging. The cellar is naturally ventilated through the access door and a single window. Indoor airflows have been studied through CFD simulations validated against experimental trails. Various scenarios have been assessed through simulation and the benefits and critical aspects of different ventilation solutions have been discussed.

A New Method to Calibrate Discrete Element Models of Fibrous Agricultural Materials

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Discrete element method (DEM) is widely used to analyse technological processes (e.g. discharging of silos, ploughing) in relation to bulk agricultural materials such as grains and soil but fewer applications can be found in connection with DEM models of crop stems. However, the mechanical and physical behaviours of stems and pile or swath of stems and stalks play an important role in several phases of agricultural production, e.g. during harvesting, mowing, baling, preparation of forage etc. In practice, there is no suitable method to calibrate DEM models of crop stems and stalks, and our study aims to fill this gap by focusing on the development of a new calibration method.

The paper first analyses the mechanical structure of fibrous agricultural materials in relation to typical agricultural processes. The steps of the calibration method were defined, that provide comparison among the measured and simulated quantitative and qualitative properties. Second, the specific laboratorial tests (transversal compression, three-point bending and dynamic cutting) were conducted on maize (Zea Mays) stalks. Maize was selected for the study as a typical fibrous agricultural material. Third, a suitable discrete element model about an internodal section of a maize stalk was formed and the calibration method was carried out.

As a result, a new calibration method for complex DEM models about fibrous agricultural materials was formed and validated on an internodal section of a maize stalk. The results of the validation clearly demonstrate that the new calibration method; that consists of quantitative and qualitative comparison among the observed and simulated values and phenomena of laboratorial tests and simulation results; can be extended to complex DEM models about any fibrous agricultural materials.

Application of the Inert Pressing Process for White Wines

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The aim of the research was to study the pressing process of white grapes cv. Catarratto using a pneumatic press in two different modes, one called “Nitrogen Pressing” (NP), the other “Air Pressing” (AP) with the aim of highlighting the influences of the production technique on the main qualitative aspects of the wines obtained. The machine used during the tests was the Prexa N model pneumatic press (by Willmes, Germany) with vertical stainless-steel juice channels and the mash completely surrounded by a lateral membrane. This press also allows to perform the pressing process under inert gas (nitrogen) inside the pressurized tank during the working cycle (NP test). Analytical determinations were made on musts and wines samples through Foss Integrator WineScan ™ (FOSS Italia, Italy), in particular alcohol, density, sugar, pH, total acidity, volatile acidity, malic acid, citric acid, tartaric acid, potassium, polyphenols, ash, gluconic acid, methanol, CO_2, absorbance at 280 nm, absorbance at 325 nm, catechins and the oxygen concentration for the musts. Finally, the volatile component of wines was evaluated using gas chromatography / mass spectrometry (GC / MS). The results obtained indicate that using the pneumatic press in NP mode, i.e. working the grapes under nitrogen, some qualitative aspects of the product were significantly preserved, such as total acidity, volatile acidity, polyphenols, catechins. Even the aromatic component of the wines obtained at the end of the winemaking process has been positively affected by the use of the innovative technique, specifically some primary and secondary aromas were enhanced by the use of the pneumatic press in NP mode, allowing to obtain a better product compared to the wine obtained with the same machine used in traditional mode.

Development of a Machine for the Production of Liquid Wine Yeast to Induce Grape Juice Fermentations

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During the winemaking process, the alcoholic fermentation can be carried out either spontaneously or by inoculating commercial dried yeasts. Commercial yeasts ensure effective and quick juice colonization, allowing a better control of the fermentation. Thus, they are usually preferred by winemakers to reduce the fermentation quality-related risks. However, the spontaneous fermentation can produce wines with sensory properties typical of a certain region or even of a specific cellar. This characteristic is particularly appreciated by those winemakers that wish to produce a wine easy to recognize.

To keep the advantages of both approaches, a machine able to produce on-demand a liquid yeast biomass from selected local yeasts was studied and developed. In this way, producers can inoculate a quantity of yeasts able to reduce the fermentation risks, with a local selected strain able to give wines typical properties.

The machine is composed by two parts: a tank and a centrifuge. The tank is where the yeasts increase in number. It is equipped with to supply systems for water and nutrients. The water supply system includes an UV-lamp for water sterilization and a heat exchanger to set the temperature of the medium water. The feeding system continuously doses the nutrients to keep a low sugar content into the medium, promoting yeasts respiration instead of fermentation. This increases the yeast-growing rate. Furthermore, the fermenter is equipped with a heating/cooling jacket to maintain the set temperature, and with an air supplier to mix the medium and provide the adequate oxygen. At the end of this cycle, the medium is separated by the yeast biomass with a vertical centrifuge.

The machine was tested during the 2017 vintage. The produced yeast was used to inoculate must fermentations at industrial scale. The inoculated yeast strains carried out the alcoholic fermentation, as confirmed by the microbial molecular analysis.

Microencapsulated Functional Lipids by Association of Pomegranate Seed and Soybean Oils

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The main objective of this study was to develop an affordable bioactive food ingredient from a blend of pressed pomegranate seed oil and soybean oil microencapsulated by spray drying. A statistical mixture design was applied to select the best carrier material composition from modified starch, maltodextrin and gum arabic; and the best formulation was used to assess the

influence of different drying temperatures on antioxidant capacity. Furthermore, phenolic and fatty acid composition, antioxidant capacity and microcapsules morphology were assessed. The selected carrier agents were modified starch 50% added to equal parts of either maltodextrin or gum arabic. In this case, the microencapsulated powder can be stored at room temperature for 90 days with minor loss of antioxidant capacity and oxidative stability. A drying temperature of 130 °C, lower than is commonly used in literature, presented high encapsulation efficiency (95%), indicating that it is possible to obtain functional microcapsules with lower energy consumption. Compared to liquid oil blends, the microencapsulated blend presented higher oxidative stability (about 50%) due to the effective protection of the carrier agents and higher antioxidant capacity due to the antioxidant characteristic of the applied carrier material, proving to be an adequate alternative to associate the pressed pomegranate seed and soybean oils.

Post Harvest Product Quality

Design and Calibration of a Low-Cost NIRS-Based Device for Avocado Ripeness Assessment

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The assessment of avocado fruit ripeness is typically based on skin color and hardness by workers in greengrocers or supermarkets. These parameters are not directly associated with their maturity and a bad classification could lead to an incorrect storage. A correct classification of avocados will impact in a greater consumer satisfaction and less waste generation.

Traditionally, maturity stage of avocados is measured using destructive, expensive and time-consuming methods. Near-Infrared Spectroscopy (NIRS), in combination with multivariate analysis, has been proven to be an effective method for assessing the maturity of the fruit in a non-destructive way.

Laboratory NIR spectrometers have a long spectral range and a high resolution and can be used to obtain large datasets and calibration models. Nevertheless, they are expensive and non-portable, not suitable for industry applications.

The aim of this work is the design and calibration of a NIRS-based low cost portable device to measure maturity stage of the fruit on a process line for improving the postharvest management. For the design, the spectral range of interest, the spectral resolution and the light source, among others, were considered.

For calibrating the device, a calibration transfer was made between a laboratory device and a portable, low cost one. Transferring models from laboratory datasets avoids repetition of the calibration procedure, which saves time and money, and reduces impacts related to optics and light sources, environmental changes, and variations in sample characteristics, such as size or roughness. Since prediction models developed on the master instrument (laboratory) cannot be applied directly to the slave instrument (low-cost device), especially due to spectral differences, different transfer techniques were tested and compared, such as Model Update, Repfile, Piecewise Direct Standardization, Transfer by Orthogonal Projection. Good prediction results were obtained, with a determination coefficient (R^2) of 0.77 and an error (RMSECV) of 1.87.

Detection of Astringent and Deastringent Persimmon Fruit Using Hyperspectral Imaging Technology

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Persimmon fruit cv. 'Rojo Brillante' is an astringent cultivar due to its content of soluble tannins. Traditionally, the consumption of this cultivar has been only possible when the astringency has been naturally removed before harvest, when fruit is overripe and the manipulation is very delicate. In recent years, new postharvest treatments which allow astringency removal while preserving high flesh firmness have been developed. Among them, the most widely used in commercial settings is based on exposing fruits to high CO2 concentrations for 24 h–36 h. This method promotes anaerobic respiration in the fruit, giving rise to an accumulation of acetaldehyde and insolubilizing tannins at the end of the treatment.

The effectiveness of this treatment is controlled by means of methods which are destructive, time-consuming and only a few samples per batch can be analysed. For this reason, the objective of this work is to study the application of hyperspectral imaging technology in the detection of astringent and deastringent fruits non-destructively. A total of 300 fruits were used and exposed to CO2 during different time to obtain fruit with different content of soluble tannins. The hyperspectral images of the fruits were acquired using a VIS-NIR hyperspectral system which covers the spectral range 450-1040 nm. Reference analysis of soluble tannins was performed in order to find out if the fruits were astringent or deastringent. The spectral information of the two thirds of the fruits was used to build the classification models by means of partial least squares (PLS) and support vector machine (SVM) discriminant analysis methods. The remaining third was used to validate the models as test set. As result, 92.6% astringent and 84.4% deastringent fruits were classified correctly using the SVM method. This shows the great potential of hyperspectral imaging technology for monitoring the astringency removal in industrial setups.

Non-destructive Assessment of Quality Traits in Tomato Fruit by Hyperspectral Imaging

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Quality of tomato fruit plays a central role in consumer acceptance and therefore in breeding programs. It is usually evaluated by measuring total soluble solids (TSS), titratable acidity (TA), percentage of juice and firmness with invasive methods, destructing the fruit and requiring work and time. Thus, there is an increasing interest in replacing these methods with non-invasive technologies that preserve the fruit and allow simultaneous measurements. Among them, hyperspectral imaging (HSI) presents the advantage of provide spatial and spectral information simultaneously. In this study we used visible/near infrared (VIS-NIR) and near infrared (NIR) HSI in reflectance mode to analyse freshly-harvested tomato fruit belonging to113 genotypes.

Hyperspectral images from 9 fruits per genotype were recorded in wavelengths ranging between 400 and 1000 nm for VIS-NIR and 900 and 1700 nm for NIR. TSS, TA, percentage of juice and firmness were measured in the same fruits. Average spectra for each individual tomato were extracted from the HS images, excluding background and fruit surface that exhibits specular reflection. Pre-processed spectra were employed to develop calibration models by partial least squared regression using leave-one-out cross-validation. The accuracy of the models was evaluated according to the coefficient of correlation (r^2) and the root mean square error of cross-validation ($RMSE_{CV}$). We found for all the attributes similar performance between models built from VIS-NIR and NIR spectra. The most accurate models were found for TSS with values reaching 0.94 for r^2 and 0.4 for $RMSE_{CV}$ with both VIS-NIR and NIR. For TA, percentage of juice and firmness models obtained presented a r^2 ranging between 0.78 and 0.61 for VIS-NIR and 0.87 and 0.60 for NIR. These preliminary results indicate that HSI could be successfully incorporated as non-invasive selection tool in tomato breeding programs. This work was funded by TKI project 2013-002, ENZA Zaden, Fresh Forward and Phenovation.

Three Dimensional Internal Structure Analysis Using Magnetic Resonance Image Data of Agricultural Products

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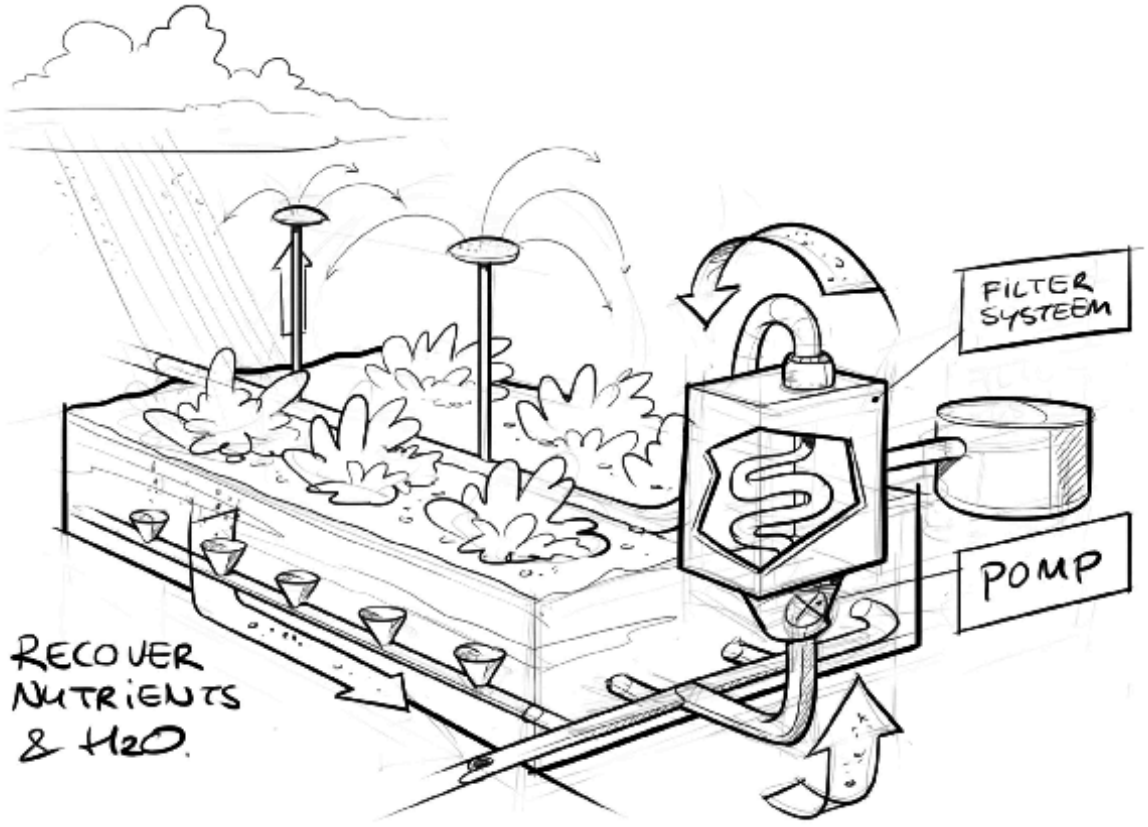
Magnetic resonance imaging (MRI) system is widely used as a diagnostic tool in medical areas recently. MRI technique is a three-dimensional technology (3D) originally. It provides series of two-dimensional (2D) image data but users usually utilize them as 2D image data to get internal information of objects. Agricultural products having high water content are good examples for utilizing an MRI technique. The objectives of this study are to develop a 3D visualization technique using MRI data, and to investigate the internal structure changes of intact cherry tomato fruits with six different growth stages and to monitor the internal structure changes of intact kiwi fruits due to storage time variation in 3D space.

We used a 1 Tesla industrial grade MRI system with a permanent magnet to acquire magnetic resonance (MR) image data sets of target fruits nondestructively. Cherry tomatoes with six different growth stages and kiwi fruits with different storage times were investigated. 'Gradient Echo' pulse sequence was used to acquire 3D data sets of intact fruits in the study.

Three dimensional visualization technique suitable for analyzing series of 2D MR images was developed to characterize and quantify internal structure of intact fruits. In the cherry tomato experiment, MR images of samples with different growth stages from green to red were acquired and the data sets were analyzed. We found the internal structural change from the pericarp area observed clearly from the 3D analysis. In the kiwi experiment, samples were stored at 17 ^{o}C with 50% RH condition for 19 days and monitored during the storage. Internal tissue breakdowns were observed with an increasing storing period.

This study suggested that MRI with 3D image analysis is a powerful method to investigate the internal structure change of intact agricultural products nondestructively. This technique could be applied to all agricultural products.


FILTER SYSTEEM
POMP
RECOVER NUTRIENTS & H2O.

Topic 11: Nutrient Management and Waste Treatment (NM)

Research and application of technology and systems to manage and recycle organic wastes in plant and animal production systems. Contributions may include organic matter and nutrient management on arable farms (e.g. with cover crops) and on animal farms (e.g. processing of animal manure) and include emissions and other nutrient losses.

Nutrient Mangement and Waste Treatment

Recycling Nutrients in a Circular Economy

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Planet Earth already exists for over 5 billion years, while humans have been around for only a small period of time. The impact of human activity on the natural ecosystem has increased dramatically over the last few hundred years, consuming natural resources at high rate.

Modern agriculture, with the use of fertilizers and agrochemicals, has increased productivity drastically and has loosened the connection between location of production and location of consumption. As a result local/regional accumulation of nutrients occurs in terms of waste streams with negative impact on the environment, in combination with regional depletion elsewhere.

The circular economy has been generally accepted now by most scientists, policy makers and entrepreneurs, as concept and new paradigm for organizing the food production – consumption cycle. As a consequence any stream of material within that cycle should be considered as an input elsewhere in the cycle, notably for nutrients and organic matter.

As socio-economic, environmental and cultural conditions differ from one place to the other on the planet there is not one single solution that fits all for organizing a circular economy. Therefore, a mix of several solutions may occur side by side. This diversity will contribute positively to the robustness of the system towards fluctuations due to impacts generated either by nature or by mankind. Initiatives are taken to bring together different stakeholders in order to exchange ideas and to explore common grounds for future cooperation. Position papers are written to stimulate partners to move away from their own comfort zone and think about new types of solutions. As the world changes, new techniques become available and new generations prefer to make different choices. What was good in the past might no longer be good enough for the future. Here the first results from this approach are reported.

The Best Application for Rice Husk towards Agricultural Sustainability

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Rice husk is a major waste in the mill industry of husking rice, which is produce in very high volume and in the past, has not specifically applied and had many environmental degradation affects, too. Due to physical and chemical importance of rice husk, use of this peripheral product can have many economic and environmental impacts based on sustainable development objectives. The purpose of this research was to investigate and identify the most appropriate application of rice husk, in order to achieve the goals of rice cultivation sustainability in Guilan province. Using Multi-criteria decision making (AHP) and using of expert and specialist advice are the most important uses of rice husk in industries, energy production, animal feed, soil remediation, mulching and disintegration through burning considering the indicators of sustainable development (economic, social and environmental) were analyzed. The results showed that among the studied indices, the respondents chose environmental health more than other indicators to the choice of the most appropriate application of rice husk. In terms of economic indexes, respondents selected use of rice husk in industries as the first priority. In terms of environmental index considered preference for using rice husk in soil improvement. Finally, in terms of social indicators, it reapplied in the related industries. According to three indicators, use of rice husk in industrial sector and energy production were as priority options by experts.

Development of an Empirical Model to Prepare Nutrient Solutions with the Use of Controlled Release Fertilizers

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The use of controlled release fertilizers serves to cover crops needs during the plants growth period. The release of nutrients depends on solution temperature and fertilizers polymer coating, which can control the diffusion of nutrients. However many other parameters may affect the evolution of nutrients elements concentration in aqueous solutions. The aim of this study was to investigate the effect of nutrient solution's pH, EC and volume as well as the time from its preparation on the evolution of NO3, NH4, PO4 and K concentrations and to develop an empirical model to describe the evolution of the above elements concentration during 16 days period. For this reason, 0.5g and 265g of Multicote fertilizer 14-14-14 dissolved in 100 ml and 2000 ml of deionized water respectively. The solutions remained at 24 oC and their pH was adjusted every day at 5.5 during a period of 16 days. The EC of the nutrient solutions was measured every second day, while the volume after sampling and the concentration of the above mentioned elements was measured every two days. A linear empirical mathematical model was developed for the prediction of the above mentioned nutrients concentrations (CX) in relation to the volume removed after sampling (Vs), the pH and the EC of the nutrient solution and the time (T) from its preparation. Values of the above mentioned parameters were measured in six nutrients solutions (three with volume of 100 ml and three with volume 2000 ml) and were used for the validation of the model. For the evaluation of the model data from nutrient solutions prepared with the use of 14-14-14 CRF fertilizer with volume of 2000 ml was used. The predicted concentrations of PO4, NH4, K and NO3 compared favorably with the measured one.

Annual Legume Cover Crops Enhance the Sustainability of Rainfed Olive Orchards: From Leaf Ionome to Tree Physiology

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The olive sector has an important economic, social, cultural and ecological relevance in the Mediterranean region, where tillage and herbicides application still are generalized practices, although the recommendations of UE policy for a more sustainable agriculture. Cover crops with self-reseeding legumes of short-cycle, with mulch of dead vegetation during the dry season, is our option for soil management in olive tree rainfed orchards, as they provide protection against erosion, improve the physical and chemical properties, nitrogen fixation and soil moisture, enhance biodiversity and landscape beautification, while contribute to mitigation and adaptation to climate change and enable the organic production mode. The experiment was carried out during 2016 and 2017 on a commercial orchard (cv. Cobrançosa) in Northeast Portugal. The treatments laid out were: (1) ordinary tillage techniques used by local growers (two tillage trips per year) and (2) a mixture of 11 self-reseeding annual legumes (AL). The results revealed that cover crops influence positively the tree water status during the drought season, as well the nutritional status, namely the foliar concentrations of nitrogen, magnesium and manganese, both during the winter resting period and in summer, at endocarp sclerification. As a result, AL trees presented greater physiological performance during the summer, as evidenced by higher net photosynthetic rate, mainly due to inferior stomatal limitations, lower investment of resources in defensive metabolites, and enhanced yield. These results indicate that cover cropping should be included in the portfolio of adaptive management strategies against climate change, contributing to the sustainability of rainfed orchards.

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Determination of Ca2+ Absorption Rate of Young Rose Plants Grown in Hydroponic System

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During this work, experiments were conducted to determine Ca^{2+} absorption in relation to transpiration rate of young rose plants growing in closed hydroponic system. For these reason 96 rose plants (*Rosa hybrida* L. cv. Iceberg) were installed in a closed hydroponic system following the Deep Flow Technique. After a period of twenty days from the planting, the pH of the nutrient solution, the Ca^{2+} concentration in the different plant organs (roots, shoots and leaves) and in the nutrient solutions, as well as plants transpiration, were measured every 24 h for a period of seventeen days. The results of these experiments reviled a correlation between the transpiration rate and leaves Ca^{2+} content (% dry weight), as well as Ca^{2+} increment in the entire plant. The equations describing the above mentioned correlations were included in an empirical model to predict the concentration of Ca^{2+} in the recycled nutrient solution of the soilless culture (R^2=0.97). This method can be used to assess the adequacy of calcium in a nutrient solution used for the irrigation of a rose crop established in closed hydroponic system.

Influence Of Forced Aeration Rates On Maturation Of Composting Poultry Manure And Wood Shavings In Closed Reactor System

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The poultry industry is growing in South Korea, but there are problems associated with the management of poultry manure, and composting is one solution that could be valuable for crops and forage if managed properly. For achieving successful compost, aeration rate must be optimized to provide favorable condition for composting process. We investigate physicochemical properties i.e. Temperature, pH, EC, organic matter and seed germination index, in the composting of poultry manure with wood shavings under different aeration rates in closed reactor system. Three cylindrical reactors with total volume 60 L were used in this experiment. The aeration rates in 3 reactors were 0.25, 0.50 and 0.75 L/min kg OM. All parameters were monitored over 30 days of composting. The highest temperature in each treatment was 56.9, 55.8 and 48.1 C for 0.25, 0.50 and 0.75 L/min kg OM, respectively, appearing on the 3rd day at center of compost. Aeration rate of 0.25 L/min kg OM corresponded to a higher and longer thermophilic phase than other two reactors which had aeration rate of 0.50 and 0.75 L/min kg OM. The maximum organic matter degradation accrued with 0.25 L/min kg OM of aeration rate which provided adequate oxygen concentration for microorganisms. With 0.75 L/min kg OM of aeration rate lowest GI were recorded at day 30, suggesting severe phytotoxicity in the substrate. In all 3 reactors, aeration rate of 0.25 L/min kg OM provided most favorable condition for composting poultry manure with wood shavings in closed reactor system.

The Spreadwise System for Predicting Spread Patterns of Centrifugal Fertilizer Spreaders

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Optimizing fertilizer inputs on agricultural fields is an important strategy to achieve high yields while reducing their large envionmental impact. Centrifugal fertilizer spreaders are by far the most commonly used granular fertilizer spreaders due to their small size, low cost and large working width. For this type of spreader however, the spreading process is difficult to control since it depends on various parameters such as the physical properties of the particles, spreader settings and external conditions such as wind. In practice, this can lead to local under- and overapplications of fertilizer on the field. The "Spreadwise" system was developped to assess spreader perfomance and calibrate these fertilizer spreaders in practice. With this system, two-dimensional patterns can be determined in an automatic, accurate, cost- and space-efficient way by simulating individual particle trajectories and determining their landing positions. For this, a four-camera stereovision system was used to determine the ejection parameters of the particles after being spread by the spreading disks. Spreading experiments with commercially available spreaders were executed. The system showed a high repeatability and predicted spread patterns were similar to spread patterns determined in the field.

Slurry Application Efficiency Evaluation

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The presented work will address a survey of different sizes slurry wagons time efficiency through a one-year season. A continuous key objective for any contractor or farmers in an arable farming context, is to improve the economic viability. The purpose of this paper is to present an efficiency study of slurry application and show how to predict slurry operations time and distance on field scale.

A 24 m3 (W24) and a 33 m3 (W33) slurry wagon in the southern part of Jutland, Denmark, was chosen for the study and operated throughout the 2017 slurry season (from 1. February to 1. October). Both used a 30 m trail hoses boom, and W33 also used a 7 m injector. Data collection was done with an implemented module that logged the GPS position and recorded outputs from the wagons slurry flow sensor. Based on these data the wagons activities where divided into 7 categories: Transporting empty, transporting full, applying slurry, transporting in-between applying slurry (partially loaded), collecting slurry, stopped and parked.

During the season the W24 trailer applied 38452 m3 slurry onto 1188.6 hectare and trailer W33 applied 32576 m3 slurry onto 980.6 hectare. W33 had a higher need for maintenance during the season which gave W24 the overall highest time efficiency. However, in-field there was no difference between the time efficiency of the wagons. Statistical modelling of the wagons efficiency showed that the total distance and time usage can be predicted with high accuracy using predetermined factors.

Both wagons operated with a similar time efficiency on all categories per field, indicating a generally high efficiency independent on field size. Same in-field time efficiency was observed between the two wagons, though W33 is 37.5% larger. W33 was able to improve distance and time efficiency when transporting slurry to the field.

Fertigation Equipment and Control Techniques: A Review

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Due to the lack of fertigation control reviews available in literature, this paper presents an overview on these systems used both in scientific research and commercial equipment. The increase in population and consequently on food consumption requires the use of water and nutrients with greater efficiency as well as the reduction of soil and water pollution. The excessive use of fertilizers and plant protection products is a major contributor to excessive standard values concentrations in about one-third of groundwater bodies in Europe. Traditional methods usually involve applying a standard nutrient solution without any concern for environmental aspects. One way to protect the environment is through the irrigation water treatment and/or recirculation. Fertigation techniques have potential to provide optimum nutrients concentrations according to the crops needs, enabling a more efficient use of both water and fertilizers. Plants need several macronutrients and micronutrients, which are not easy to monitor. Typically, the control of Nitrogen, Phosphorus and Potassium (NPK), which are the main nutrients, is recommended. The vast majority of fertigation systems are based on Electrical Conductivity (EC) and pH sensors to allow nutrient solution dosing. However, despite these variables being related with nutrient concentrations, they do not provide precise measurements of NPK contents. Moreover, current available technologies for NPK measurement have several drawbacks, such as, frequent need of maintenance and calibration, large cost, unfeasible sampling time for feedback control, among others. In this context, the European project Agrinupes comes up with the goals of developing new optical-based NPK sensors to solve these drawbacks. These sensors will be integrated in an easy-to-use, robust and fault-tolerant fertigation controller, and evaluated under several demonstration cases. Besides presenting a fertigation control systems review, this paper identifies current challenges and future trends within this context.

Effects of Crop Rotation and Fertilization on Soil Fertility and Plant Nutrition

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The objective of research was to investigate the effects and interactions of crop rotations and different fertilization on soil fertility and barley yielding and mineral nutrient composition. The research were carried out at the Warsaw University of Life Sciences-SGGW Experimental Station in Skierniewice. The long-term fertilizer experiments in Skierniewice were founded in the years 1922- 24 and are conducted without disturbances still today. The soil of Skierniewice Experimental Station is mainly stagnic luvisol (according to FAO classification).

The experiment was conducted in arbitrary rotation (without legumes) and five-field crop rotation (potatoes, spring barley, red clover, winter wheat, rye). The fertilizer treatments applied are CaNPK, CaPK (PK), CaPN (PN), CaKN (KN) and Ca (0). The content of C, N, P, K, pH was determined in the soil samples as well as barley yield and nutrient concentration in plant material was investigated. Soil samples analizys indicated that five-field crop rotation treatments reduced soil acidity, increased soil total N and C_{org} content when compared to arbitrary rotation.

Significantly higher yields of barley were obtained in five-field rotation, in which the forecrop were potatoes grown on manure than in arbitrary crop rotation where the forecrop were other cereals. These results demonstrate a beneficial effect of five-field crop rotation upon soil fertility and barley mineral nutrition. This study was supported by the project No 8762/E-385/SPUB/2016/1 „Wydziałowa Stacja Doświadczalna im. prof. Mariana Górskiego w Skierniewicach – od 1922 r. wieloletnie doświadczenia agrotechniczne”, sponsored by Ministry of Science and Higher Education– Poland.

Increasing the Fertility of Marginal Soils by the Utilization of Waste Organic Matter

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The aim of the research was to evaluation of the possibility of using organic waste from agriculture to restore marginal soils to agricultural production. The field experiment was established on a field set aside for 20 years on sandy soil with low organic carbon content and low water holding capacity. Compost and pellets produced from waste organic matter (spent mushrooms substrate, straw and the digestate from biogas plant) were used for the research, The test plant was maize grown on a green mass. The experiment included the following combinations: Control, Mineral fertilization 100 and 200 kg N/ha, Compost 100 and 200 kg N/ha, Pellet 100 and 200 kg N/ha, Compost 100 and 200 kg N/ha + 50 kg N mineral, Pellet 100 and 200 kg N/ha + 50 kg N mineral.

Compost and pellets had a beneficial effect on soil properties in relation to mineral fertilization. The results indicate that higher organic carbon content in the soil was obtained in compost compared to pellets application. The largest increase of organic carbon content occurred in compost application in a dose 100 kg N ha^{-1}.

The largest increase in water holding capacity of soils occurred under aplication of pellets in dose 200 kg N / ha + 50 kg N mineral (23.7%) in comparison to the control object (18.29). The highest yield of maize was obtained on the combination of pellets 100 kg N/ha + 50 kg N mineral - 38.31 Mg d.m. ha^{-1}.

This study was supported by the project Intensify production, transform biomass to energy and novel goods and protect soils in Europe (INTENSE) funding by ERA-NET CO-FUND FACCE SURPLUS

GO EFLUENTES – A New Approach for Animal Waste Management in Portugal

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This approach aims at valorisation of a resource, focused on different interests that converge in the production and integrated management (social, political, economic, technical and environmental) of the flows generated in the farming systems ensuring the sustainable development. In all steps related to the management of these flows (production, collection, storage, recovery and re-use under local conditions), the aim of recovery will not to eliminate them but to reduce the exploitation of natural resources. Identification, quantification and hierarchization of flows will be fundamental, allowing nutrient balances at farms and consequent sustainable management.

The "GO_Efluentes" Operacional Group act across the entire production system. Taking into account the different specificities, it seeks to typify the main variables of the flows generated in the animal production systems, testing efficient operational strategies for their sustainable valorisation and management.

In the management of livestock effluents from intensive farms of cattle, pigs and poultry, the solutions already developed and of robust and proven use in these productive sectors will be inventoried and a route of applicability will be defined according to the characteristics of the farms and other regional constraints. At the same time, the impact of the introduction of emerging solutions in the treatment of effluents (separation of solids associated with the acidification of liquid fractions or the addition of biochar and solid fraction composting) will be evaluated experimentally, as well as the reduction of emissions pollutants (ammonia and greenhouse gases), as well as the effects on the management of effluents, the economic feasibility of applying these technologies to farms.

The development of a Operacional Group of this typology allows an approximation between partners in the scope of the agronomic and energy valorisation of the flows generated in the agricultural activity, which until now appears as distant, with evident benefits for all the parties.