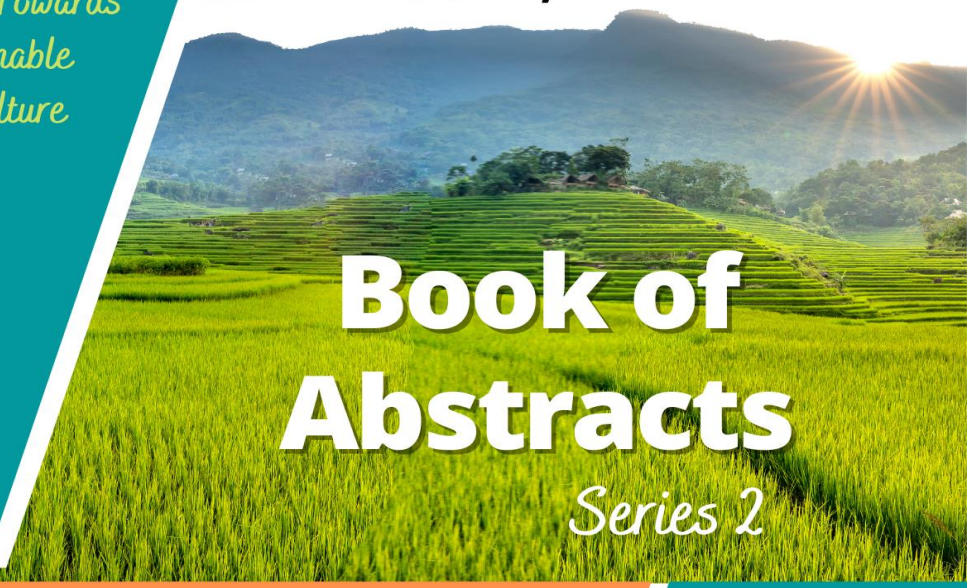
THE 2ND INTERNATIONAL SYMPOSIUM ON CLIMATE-RESILIENT AGRI-ENVIRONMENTAL SYSTEMS

ISCRAES 2022

28-31 August 2022
Dublin, IRELAND

Implementing the New Green Deal: The Path Towards Sustainable Agriculture



Book of Abstracts

Series 2

Edited by

Mohammad I. Khalil, Bruce Osborne and Astrid Wingler

ISSN No. 2737-727X

This book contains all abstracts presented at the conference and published in 2022 by the ISCRAES 2022 Organising Committee in collaboration with Prudence College Dublin

Organising Committee

Convenor

Dr. M. Ibrahim Khalil, Prudence College Dublin and University College Dublin, Ireland.

Members

Prof. Bruce Osborne, University College Dublin and Prudence College Dublin, Ireland.
Prof. Astrid Wingler, University College Cork, Ireland
Prof. Ken Byrne, University of Limerick, Ireland.
Prof. Chaoseng Zhang, National University of Ireland, Galway.
Mr. Dale Crammond, Department of Agriculture, Food and the Marine
Prof. Laurence Shalloo, Agriculture and Food Development Authority
Dr. Catherine Farrell, LIFE on Machair, Ireland.
Dr. Dario Fornara, Agri-Food Bioresources Institute, Northern Ireland.

Scientific Committee

1	Prof. Christoph Müller	Justus-Liebig University, Giessen, Germany
2	Prof. Pascal Boeckx	Ghent University, Belgium
3	Prof. Kazuyuki Inubushi	Tokyo University of Agriculture, Japan
4	Prof. Jim McAdam	Queen's University Belfast, NI, United Kingdom
5	Dr. Lutz Merbold	Agroscope, Switzerland
6	Dr. Matthew Saunders	TCD, Ireland
7	Prof. Jorge Pérez Quezada	Universidad de Chile, Chile
8	Dr. Ágnes Szepesi	University of Szeged, Hungary
9	Dr. Anna Wlakiewicz	Institute of Agrophysics, Poland
10	Dr. Junliang Zou	Northwest A&F University, China
11	Dr. Jagadeesh Yeluripati	James Hutton Institute, United Kingdom
12	Prof. Tim Clough	Lincoln University, New Zealand
13	Dr. Joanne Fitzgerald	IT Carlow, Ireland
14	Dr. James Humphreys	Teagasc, Ireland
15	Dr. Katja Klumpp	INRAE, France
16	Dr. Bart Kruijt	WUR, Netherlands
17	Prof. Oslan Jumadi	Universitas Negeri Makassar, Indonesia
18	Dr. Elizabeth Pattey	Agriculture and Agri-Food Canada
19	Dr. Inge Jonckheere	FAO, Italy
20	Prof. Stephen Mureithi	Nairobi University, Kenya
21	Prof. Landry C. Ntaboba	Catholic University of Bukavu in DR Congo
22	Prof. Jean Baptiste Ettien	Centre Suisse de Recherches Scientifiques en Côte d'Ivoire
23	Dr. Rosa Teira-Estmatges	UDL, Spain
24	Dr. Ciniro Costa Junior	Climate Change, Agriculture & Food Security, CGIAR, Brazil
25	Dr. Sheetal Sharma	Sustainable Impact Platform, IRRI, India

CONTENTS

Edited by M.I. Khalil, B. Osborne and A. Wingler; ISCRAES Book of Abstract Series 2; Published in 2022 by the ISCRAES 2022 Organising Committee in collaboration with Prudence College Dublin.

The Climate-Resilient Agri-Environmental Systems (CRAES) group was formed by Dr. M. Ibrahim Khalil in co-operation with other University College Dublin (UCD) colleagues through a UCD Earth Institute Strategic Priority Award. The main aim was to foster agri-environmental research, modelling and technology development, with an emphasis on the need for carbon-neutral and pollution-free agricultural systems that do not compromise food security. These objectives also link to the provision of strategic education and training, and addresses the global challenge associated with climate change and environmental degradation by harnessing UCD's multidisciplinary expertise and engaging with national and international collaborators and stakeholders.

The specific objectives were to:

a. Form a multidisciplinary research group initially with experts from various academic/research disciplines within UCD and now nationally and internationally.
b. Publicise the group in general and its research expertise to attract national and international academics/researchers for collaborations/partnerships.
c. Demonstrate the importance of the group's activities to other academics/researchers and stakeholders for strengthening their engagements and cooperation.
d. Develop the group by co-opting and/or collaborating with relevant experts from national and European/International academic and research organizations.
e. Arrange regular meetings for discussion on project activities, and exchange research ideas, address knowledge gaps and explore collaborative opportunities.
f. Provide the critical mass that is required to respond to national and international research calls for securing funding for innovative research and the development of integrated system models for researchers, policy makers and end users.

As an important contribution to these activities, a national organising committee was formed to organise this Second International Symposium on Climate-Resilient Agri-Environmental Systems (ISCRAES 2022). The key theme of this symposium is "Implementing the New Green Deal: The Path Towards Sustainable Agriculture". This is to address the central goals linking mainly to creating a sustainable food system, preserving biodiversity, boosting the circular economy and above all Climate Change Mitigation and Adaptation whilst reducing environmental pollution. To achieve the Green Deal, like UN-SDGs, a multi-disciplinary systems-based approach involving academic, industrial, and policy-related collaborations for development of scientific knowledge and advancement of technologies and the exploration of ways for their practical implementation is imperative. This symposium provides a platform to discuss the scientific and technical aspects of the range of cross-cutting issues associated with the environmental impact of agriculture and associated land uses, including public perception, and regulatory and socio-economic factors.

The main objective of the symposium is to bring academics, researchers, and stakeholders together to provide creative and innovative ideas that could provide a basis for the testing and subsequent adoption of strategic ways for implementing sustainable GHG mitigation and environmental solutions taking into account the need for:

- coherent environmental solutions, through a systems-based approach.
- economically viable and socially acceptable options.
- a systems-based decision-support tool.

Arable cropping systems

Globally, there are a large number of arable cropping systems based mainly on climate and land types/topography (e.g., dryland/upland, wetland-dryland/upland, and wetland) that have resulted in the adoption of different cropping patterns (e.g., cereal only, cereal-legume, and cereal-vegetable). Arable crops are mainly associated with tillage-related cultivation systems, which vary from region to region, and are among the most important land uses influencing soil properties and causing environmental and ecological degradation. Land use (cereals, vegetables, etc.), soil/land types and management practices (inorganic and organic fertilizers, as well as the addition of organic residues) within a system controls the extent of emission of GHGs, air pollution and leaching losses. Inappropriate cropping and cultivation techniques, as well as excessive use of fertilizers, can exacerbate these problems. Many soils may be susceptible to erosion, and the loss of organic matter leading to poor structure, biodiversity loss, and pollution due to pesticides and herbicide residues and the accumulation of heavy metals. This session will therefore focus on research work in arable cropping systems that have assessed potential solutions to coupled air, water, and soil pollution.

Grassland Systems

Grasslands (pasture, hay and silage) dominate the total global agricultural area. Livestock is grazed mostly on pasture and meadows. Grazing intensity and fertilizer (organic and inorganic) management play an important role in soil health and productivity while also contributing to a large share of total agricultural GHG emissions and pollutants (e.g., NH_3, NOx, NMVOCs and particulate matters and/or water (e.g., NO_3^- and PO_4^-) through leaching, volatilization and runoff. Livestock itself accounts for about half of all anthropogenic emissions, i.e. a quarter of methane emissions through gut fermentation and the

decay of excreta. The projected increase in livestock numbers will not only impact on the production of manure by ~60% by 2030 but also methane emissions. These environmental pressures warrant adoption of sustainable management for grassland systems that depend on both livestock numbers and the fertilizer form and amount, and their contribution varies on climate conditions, available resources, ecosystem/biodiversity services, and avoidance of events leading to environmental pollution. In this session, the main focus is to find solutions to coupled air, water, and soil pollution, referring to both grazed and ungrazed grassland systems.

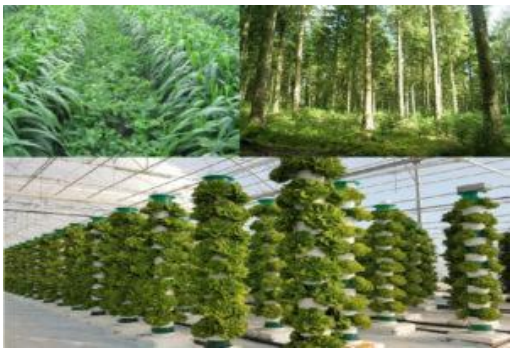
Agro-Silvo-Pastoral Systems

Mixed farming systems are very popular in both developed and developing nations and are generally divided into four systems (i) Agro-pastoral systems (arable ley), (ii) Agro-Forestry systems, (ii) Silvo-pastoral systems, and (iv) Agro-Silvo-Pastoral systems. Other than agro-forestry, livestock (cattle, sheep and goats) grazing is common in mixed farming systems. The number of agro-silvo systems associated particularly with beef/meat and dairy production has been increasing globally. In these mixed systems, as in grassland, the application of organic and inorganic fertilizers to improve crop/biomass production may increase GHG emissions and environmental pollution. Conversely, these systems may, through the utilization of crop by products, improve nutrient recycling and reduce methane production. Accordingly, mixed farming as an approach to satisfy the global demand for food, meat and milk could have some advantages in reducing the environmental and carbon footprint. However, applied research and extension are of critical importance if the environmentally compatible elements of the system are to be adequately exploited. Considering the fundamental changes required and the inclusion of livestock as a mechanism to promote system flexibility, identification of technologies and policies for simultaneous reduction of GHGs and environmental pollution will be the focus of this session.

Decision Support Systems

Limited field measurements and excel-based national inventory methods (IPCC Tiers), focussed mainly on the developed nations, are being used for accounting, and form the basis for mitigating the environmental consequences of GHGs, air pollutants and leaching losses. However, these approaches often struggle to provide an adequate assessment of the impact of agricultural management practices, particularly for mixed farming systems. There are substantial difficulties in incorporating any mitigation strategies and often these are unable to provide immediate feedback on the consequences of management actions/decisions. As measurements covering all ecosystems and soils are not feasible, the use of model-based decision-support tools could be an alternative option to cover diverse agricultural systems. Any verified and validated model should be used as a decision support tool to provide assessments at a local/regional level but should also be applicable to the regional scale. This would help raise local awareness, provide prospects for actions, aid in refining and implementing emission mitigation techniques, and demonstrate the effects of innovative actions. A further benefit is that they can help to identify environmental hotspots, evaluate indicators of sustainability, provide alternative management scenarios, identify practices having a positive impact on net GHG emissions and the environment and provide options for assessment of the economic effects of interventions at all scales. This will be the topic of this session.

Novel Farming Systems



Concerns about the environmental footprint and sustainability of current industrial farming practices have resulted in an increased interest in novel farming systems (NFS). Essentially these systems are focused on the growth of crops in places and under conditions that have not traditionally been regarded for agricultural production. This could provide an attractive solution to many of the environmental concerns, including those related to water and energy consumption, greenhouse gas (GHG) emissions and environmental pollution, including circular bio-economy approaches. Many of these approaches have the added advantage of maximising the use of available space, and limiting resources (e.g. light, soil, and water). The NFS include Indoor farms, which are generally based on the up scaling of horticultural facilities using hi-tech greenhouses (e.g. vertical farming), insulated indoor spaces like warehouses and shipping containers, and hydroponics under controlled environmental conditions. These are currently being used to grow food closer to consumers, and drastically reduce the inputs/ingredients (e.g. light, water, and nutrition) necessary in comparison to outdoor agriculture.

Insect-Worm farms have been identified as an increasingly important alternative protein source for both animals and humans, and a more sustainable alternative to high quality animal protein. These could substitute for wild-caught fish to counter overfishing, and include crickets, fruit flies, grasshoppers, and mealworms. Aquaculture is a long-standing industry with enormous potential to produce edible protein from seafood and sea vegetables, including algae and plants not traditionally used as crops (e.g. azolla and duckweed). This includes fish farming along with oysters, scallops, shrimp, mussels, and other shelled organisms. Algal farming represents an underdeveloped sector within NFS but with great market potential and most single-celled microalgae must be grown in a controlled setting. This includes aquaponics where vegetables or other crops are integrated with fish farming, so that the waste generated by the fish can be used to fertilize plants.

Microbes are used for the production of protein mainly in the brewing industry but have the potential for a diverse range of applications in the food and beverage industries. Cultured yeasts or bacteria can also be used in the flavour, fragrance and food industries substituting for natural alternatives. What is unclear, however, is what overall impact NFS have on the environment and resource availability and to what extent they contribute to a reduction in GHG emissions as this has received little attention. This, including their contribution to the circular bioeconomy will be the main focus of this session.

Carbon Farming and Nature-based Solutions

Given that managed land dominates the earth's surface, agriculture has a key role to play in mitigating GHG emissions and reducing environmental pollution whilst also providing food, fibre and materials for an ever-increasing population. The EU vision for transitioning to a climate neutral economy by 2050 (A Clean Planet for All) linking also to the Green Deal requires contributions from all sectors, including agriculture and forestry. Agriculture (grassland, cropland, agroforestry, peatlands, and relevant land uses) and land management activities need to significantly reduce GHG emissions while reversing the loss of agricultural soil and other carbon stock losses currently associated with farmed land. Increasingly, carbon farming is being proposed as an integral part of overall farm management, with the potential to make important contributions to broader climate and

agricultural policies. This will require farmers to implement results-based carbon farming schemes, through incentivised interventions, to meet national climate mitigation ambitions, while still contributing to the bioeconomy, and the delivery of ecosystem services.

Nature-based Farming Solutions (NBFS) are actions that protect, sustainably manage, and restore natural or modified ecosystems and are likely to have the greatest potential impacts on adaptation and resilience-building. These measures encompass agroforestry, improved land (crop, grass and peat) management, agricultural diversification, integrated water use, and forest management. They take into consideration both traditional and local knowledge as well as scientific evidence to support the optimum use of natural resources for agricultural production, whilst also maintaining or even enhancing native biodiversity.

The approaches associated with NBFS include the adoption/promotion of organic agriculture, agroecological approaches, and conservation farming with the objective of reducing the environmental footprint of farming activities. An emerging approach, directed at these objectives is the use of perennial crops, which have the potential for ensuring the greater capture and conservation of resources through photosynthesis, and improvements in nutrient recycling. A range of alternative management practices, such as mixed cropping, can potentially derive considerable benefits from the integration of perennials, as opposed to traditional seasonal crops. There are six evidence-based ecological principles proposed for the design and implementation of an effective NBFS, including a reduction in biodiversity loss, delivery of location-specific ecosystem services, the use of targeted interventions, strengthening links between people, producers and nature, and longer-term flexible planning. Hence, this session is centred on Carbon Farming and Nature-based Solutions. The focus will be on how to increase carbon storage, improve/maintain water quality, soil health, biodiversity and the role of pollinators. Novel pest control methods that have climate, water quality and nature-related benefits, will also be examined, that minimise carbon loss and contribute to improved farm livelihoods.

Dr. Pippa Hackett

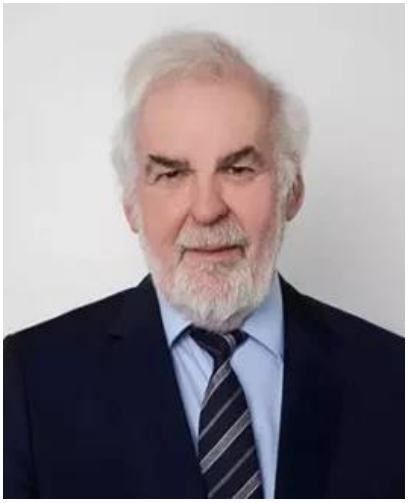
Senator and Minister of State for Land Use & Biodiversity, Ireland.

Dr. Pippa Hackett is an Irish Green Party politician who has been serving as Minister of State for Land Use and Biodiversity since June 2020 and is a spokesperson for Agriculture, Food, Forestry, Heritage, and Animal Welfare. She has been a Senator in Seanad Éireann at Houses of the Oireachtas for the Agricultural Panel since November 2019.

Dr. Hackett holds a BSc in Agriculture from the University of Essex, a postgraduate diploma from University College Dublin, and a PhD in Sports Biomechanics from the University of Limerick. She has been actively involved in many community-based and school projects. Her roles include youth club secretary and leader, local newsletter editor, Mountlucas parkrun director, and board member of local sports committees. She is passionate about healthy living, environmental issues and animal welfare.

Mr. Tom Arnold

Chair, EU Commission's High Level Expert Group on Food Systems Science, Ireland.



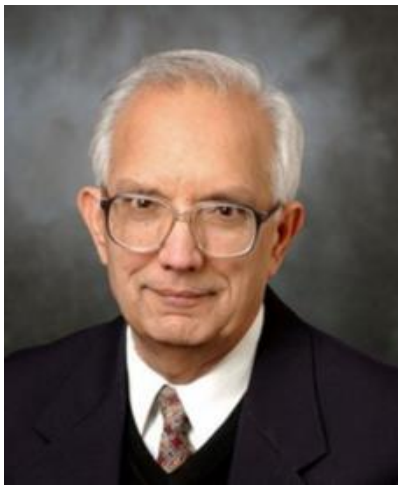
Mr. Tom Arnold, an agricultural economist and public policy advisor, currently serves as Chair, of the EU Commission's High Level Expert Group to assess the need for an International Platform for Food Systems Science; the Irish Government's Special Envoy for Food Systems; Member of the Champions Network for the UN Food Systems Summit; Global Panel on Agriculture and Food Systems for Nutrition; Board of Global Alliance for Improved Nutrition; Malabo Montpellier Panel; and Sight and Life Foundation.

He has previously served as Chair, Irish 2030 Agri-Food Strategy Committee, the EU Commission's Task Force Rural Africa, OECD Committee of Agriculture, and Irish Constitutional Convention; Coordinator, Scaling Up Nutrition Movement; Director General, Institute of International and European Affairs; Chief Executive, Concern Worldwide; Chief Economist and Assistant

Secretary General, Department of Agriculture, Food and the Marine; and Administrator, EU Commission.

Prof. Rattan Lal

Distinguished Professor, The Ohio State University, USA.



Professor Rattan Lal is a distinguished University Professor of Soil Science at Ohio State University. His work focuses on regenerative agriculture, through which soil can help resolve global issues, such as climate change, food security and water quality . His research led to a better understanding of how farming practices can restore degraded soils, increase soil organic matter by sequestering atmospheric carbon, and help combat rising CO2 levels. He is highly respected in his field and has written or edited 151 books and made over 650 keynote speeches.

Prof. Lal was awarded the 2019 Japan Prize 'for the sustainable management of soil for global food security and mitigation of climate change'. In June 2020, Professor Lal was the recipient of the prestigious World Food Prize.

Prof. Maria J. Santos

OECD Advisor and Professor of Earth System Science, University of Zurich, Switzerland.

Professor Maria J. Santos is Professor of Earth System Science, Department of Geography, University of Zurich (UZH), Switzerland and Scientific Advisory Board Member, The Organisation for Economic Co-operation and Development (OECD). Her research focuses on understanding co-evolution in social-ecological systems, and on how to reduce the impacts of anthropogenic change on species and ecosystem distributions, while maintaining livelihoods.

To answer these questions, Prof. Santos focuses on what (species and ecosystems), when (time), where (space), how (conservation actions) and why (policies and drivers) of conservation actions. Her research incorporates field methods, GIS, remote sensing, statistical modeling, historical archival research and conservation planning.

PLENARY SPEAKERS

Prof. Roslyn Gleadow

President, Global Plant Council and Head of Plant Science, Monash University, Australia

Professor Roslyn Gleadow is the Head of Plant Science, School of Biological Sciences at Monash University. She has expertise in the field of climate change and food security, particularly how environmental factors affect the nutritional value of crops. Her focus is on plants that make cyanide as a herbivore defence, examining the issues from the molecular through to the ecosystem, and even global scales.

Prof. Gleadow is a past President of the Australian Society of Plant Scientists. She is currently the President of the Global Plant Council, a board member of Eucalypt Australia, the Agricultural Biotechnology Council of Australia (ABCA) Expert Scientific Panel and member of Public Policy and Communication Committee, Royal Society of Victoria.

Dr. Anne Mottet

Livestock Development Office, Food and Agriculture Organisation of the United Nations (FAO), Italy

Dr. Anne Mottet is a livestock development officer with the FAO of the UN. For some time, she has supported policy makers and stakeholders for the transition to sustainable food systems. She has developed tools and assessment measures on global topics related to livestock systems, natural resources, climate change and agroecology. She is a published author, an elected member of the FACCE-JPI, and an invited reviewer of IPCC reports and guidelines.

Dr. Mottet is currently coordinating a program of work providing technical support and guidance to countries and International Funding Institutions (e.g. World Bank and IFAD) on low carbon livestock development, using an on-line GHG calculator called GLEAM-i. She is the co-leader in developing TAPE, the Tool for Agroecology Performance Evaluation.

Prof. Dave Frame

Director of NZCCRI, Victoria University of Wellington and University of Canterbury, New Zealand.

Professor Dave Frame is Director of the New Zealand Climate Change Research Institute (NZCCRI) at Victoria University of Wellington and currently at University of Canterbury, New Zealand. He has a background in physics, philosophy and policy. Prior to joining the NZCCRI Dave spent the bulk of his career at the University of Oxford, working in the Departments of Physics and Geography, and later at the Smith School of Enterprise and the Environment.

He also has policy experience, having worked at the New Zealand Treasury, and having served on secondment at the UK Department of Energy and Climate Change. He has been a Lead Author on the Fifth and Sixth Assessment Report of the Intergovernmental Panel on Climate Change, and his research has often been published in the world's leading scientific research journals, as well as in the specialist climate literature.

Translating Science into Action: Why Does It Take So Long?

Gleadow R.*

*Monash University, Australia. *Corresponding author: ros.gleadow@monash.edu*

It has been 30 years since the publication of the first IPCC report. It was clear from that report that collectively the people of the world needed to reduce the amount of carbon dioxide being released into the atmosphere. The IPCC in itself was set up in response to growing concern about global warming. Why does it take so long for science to translate into action? In fact, as a rule of thumb, it is 50 years between the discovery of the science and the implementation of policy. Is it that scientists can't communicate efficiently? Or that the science is often behind paywalls and not accessible? There is something inherent in humans that means we hang onto naïve views of the world and actively resist change. Scientists are surprisingly conservative when it comes to challenges to certain paradigms. That discoveries in medicine are sometimes adopted more quickly show that change is possible but can still take decades. There is considerable research in the social sciences about how to change opinions and influence policy. One approach to speed up the knowledge exchange, is to leverage existing trusted communities and networks. The Global Plant Council is a coalition of plant science institutions and research organisations from around the world. Our aim is to facilitate the development of plant science for global challenges, to foster international collaborations and enable the effective use of knowledge and resources and to provide an independent and inclusive forum to bring together all those involved in plant and crop research, education and training. This talk will present some strategies that can be implemented by individuals, The Global Plant Council, and other organisations to help communicate the need for addressing issues of sustainability, biodiversity decline, 'plant blindness', and food security with a view to enabling real change.

Keywords: Global warming, scientific challenge, knowledge exchange, collaboration, food security.

Contribution of global livestock sector to the Sustainable Development Goals: Opportunities and challenges

Mottet A.*

*Food and Agriculture Organization of the United Nations (FAO), Italy. *Corresponding author: anne.mottet@fao.org*

Livestock farming is found in a variety of ecosystems around the world. Permanent pastures and grasslands cover about 25% of the world's land. Production systems and products are also very diverse. Meat, milk and eggs account for 34% and 17% of the global protein and calorie consumption respectively. They are also dense in a variety of essential micronutrients. Livestock also make a significant contribution to food security through manure production, animal traction and transport and income. They have a key role to play in women's empowerment and gender

equality, both in rural and urban areas. Demand for meat, milk and eggs is increasing due to population growth, rising incomes and urbanization. This trend is expected to continue, particularly in low- and middle-income countries. The sector consumes large amounts of natural resources, including feed, but the ability of livestock to convert grass and swill into protein is an opportunity to increase its efficiency. Contrary to often cited figures, only about 3 kg of cereals are needed to produce 1 kg of meat on average globally. Monogastrics are relatively less efficient than ruminants; the consumption of forage and non-edible food by humans is included in the balance. Another way to look at natural resource use is based on land used: the global livestock sector uses about 2.5 billion hectares, 77% of which are grasslands, with a large part of it non-cultivable and therefore only usable by grazing animals. Livestock contribute to greenhouse gas emissions, particularly through enteric fermentation, but the sector has a high mitigation potential, notably reducing methane emissions but also carbon sequestration. Strengthening the role of livestock in the circular bioeconomy can result in reduced emissions too, by promoting the use of by-products and residues as feed for livestock and recycling manure for energy and nutrients. Livestock are a key component of sustainable food systems, and this requires adequate policies. There are already a variety of mechanisms available, including regulations, conditionality systems, payments for environmental services and research and development. To be aligned with the Sustainable Development Goals, priority areas for policy makers can include: (i) food security and nutrition, (ii) economic development and livelihoods, (iii) animal and human health, and finally, (iv) the environment, climate and natural resources.

Keywords: Greenhouse gases, mitigation, diets, nutrient recycling, Livestock farming, SDGs

Split gas approaches: reflections on New Zealand's bumpy ride

Frame D.*

*University of Canterbury, Christchurch, Canterbury, New Zealand. *Corresponding author: dave.frame@vuw.ac.nz*

The customary way of comparing greenhouse gases using "CO_2-equivalence" masks important differences that arise from the stock nature of CO_2 (and other) emissions, and the essentially flow pollutant nature of short-lived pollutants such as methane (CH_4). The distinction matters domestically, where issues of sectoral fairness may become significant, and also internationally where food security concerns and pro-poor climate policy are important existing commitments. New Zealand policy has taken account of recent research which highlights the different dynamics of warming from short-lived and long-lived emissions by developing a split target in its climate targets. Furthermore, building on a number of innovative two-basket suggestions from domestic policy think tanks, New Zealand is developing a strategy for pricing agricultural CH_4 emissions in a distinctive scheme, expected to be in operation by 2025. This talk will review aspects of the New Zealand experience.

Keywords: Greenhouse gases, CO_2-equivalence, two-basket approaches, New Zealand.

Theme 1: Arable Cropping Systems

Keynote presentation

The future of conservation agriculture in dryland areas

Mrabet R.*

*National Institute of Agricultural Research (INRA), Morocco. *Corresponding author: rachid.mrabet@inra.ma*

The impacts of agricultural production on our environment are increasingly recognised. Agriculture Drylands account for about 41% of the Earth surface and are expected to increase in extent and aridity in coming decades. These biomes support 50% and 44% of the world's livestock and cultivated ecosystems. The current intensification of agricultural practices is already resulting in the unsustainable degradation of soils leading to clear environmental harm and higher economic and social costs. In other terms, the long-term ability of drylands and ecosystems to provide humans with services, including future food production, is severely tumbling. Conservation Agriculture (CA), which includes no-till farming in conjunction with residue mulching, cover cropping, integrated nutrient and pest management, complex and diversified rotations, and integration of crops with trees and livestock, is becoming a prime pillar for real-life regenerating food systems. This is due to its potential to successfully tackle and reverse the threat of soil erosion globally, minimize climatic risk, sequester carbon in ecosystems, and improve soil quality and water availability. In other terms, CA systems were recognized as genuine options for fixing broken cycles and mechanisms. Reduced erosion rates and flood mitigation are widely observed after adoption of CA and partly up to one order of magnitude lower than in conventional agriculture. Soil organic matter is critical for soil functioning and security, and it was found to increase significantly with medium to long-term adoption of CA systems under contrasting soils, cropping systems and climates within drylands. CA systems are alternative pathways for dryland agriculture to be more conducive to durable food systems and longer-term sustainability. Relative to the world's total area cropped, the most recent statistics show that CA systems represent almost 15% which is expected to increase to 50% in mid-century. If history is any guide and for a bright future ahead, a crucial part will be unarguably to stay in business as usual. Moving to the future, significant barriers to CA adoption should be removed while farmers must be incentivized to adopt these systems. Hence, for wide-spread and deep-scaling, CA systems should be finetuned in the context of biophysical factors and human dimensions.

Keywords: Conservation agriculture, Drylands, Soil security, Food sovereignty, Environmental sustainability, Resilience, Climate change.

Session I: Oral presentations

Soil characteristics as affected by slurry and derived products application on a Mediterranean rainfed winter crops rotation

Domingo-Olivé F.*, J. Vallverdú, I. Caballé and E. González-Llinàs

*IRTA Mas Badia–Sustainable Field Crops. Catalonia. *Corresponding author: francesc.domingo@irta.cat*

Manure, slurry and derived products are broadly used as fertilizers for arable crops. They may contribute to enhanced crop productivity and quality. When applied in the long-term, they may also contribute to modifications in some soil characteristics. We carried out a six-year field trial using raw pig slurry (PS), liquid fraction (LF) and solid fraction (SF) of pig slurry, at the same N application rate, to fertilize a rainfed winter crops rotation under a semi-humid Mediterranean climate on a moderately deep, calcareous, loamy soil. After six cropping seasons we sampled top-soil in each treatment to characterise different properties. After this period no significant differences were detected on soil bulk density, organic matter content, water retention at field capacity and microbial biomass organic carbon, but some tendences were observed. Organic C in microbial biomass was lower when LF had been used as a fertilizer (2.63 mg C kg^{-1} dry soil) in comparison to PS (3.20 mg C kg^{-1} dry soil). The same tendency was detected for water retention at field capacity. Top-soils retained less water in the LF treatment (18.32 g water 100 g^{-1} dry soil) than in the PS one (19.97 g water 100 g^{-1} dry soil). Conversely, soil bulk density was higher for the LF treatment (1315 kg m^{-3}) than for the PS one (1248 kg m^{-3}). The use of PS as a fertilizer contributed more to soil quality than LF, at similar rates of N application.

Keywords: bulk density, fertilization, nitrogen, organic carbon, water retention.

Digital tools: Helping farmers to manage crops and reduce GHG emissions through timely and site-specific advisories

Bharti P.*, E. Cabrera and S. Sharma

*International Rice Research Institute, India. *Corresponding author: p.bharti@irri.org*

Agriculture contributes significantly to climate change due to emissions of greenhouse gases through various farming and management practices. The Intergovernmental Panel on Climate Change (IPCC), 2018 report mentions the urgency to introduce realistic ways to mitigate GHG emissions from agriculture without compromising food security. A number of technologies and better management practices have been researched and introduced by scientists worldwide but adoption at farm level is required to bring the desired reduction in GHG emissions. The International Rice Research Institute (IRRI) has been working towards promoting actionable mitigation solutions among rice growing farmers worldwide through its improved crop management technologies. These technologies are user-centric and focus on simplifying the actions to be taken at farm scale so that the farmers can easily adopt the technology. In order to make the technology scalable and accessible, these scientific solutions have been programmed and developed as digital tools. Rice Crop Manager is one such tool which is based on a Site-Specific Nutrient Management (SSNM) approach. SSNM is an approach for supplying plants with nutrients to optimally match their inherent spatial and temporal needs for supplemental nutrients (Buresh and Witt 2007). Rice Crop Manager (RCM) is used to calculate field-specific requirements for fertilizer nitrogen, phosphorus, potassium, and zinc based on scientific principles with the aim to increase nutrient-use efficiency. Farmers get the advisory using the RCM tool after answering a set of questions related to their farming practices. Chatbot is another tool developed for farmers to

provide advisories in a conversational way. The bot gives the feeling of conversing with humans and answers the crop management queries asked by farmers in regional language. It is hosted on Facebook Messenger and WhatsApp for easy access.

Keywords: Nutrient management, field-specific advisories, Chatbot

Hypusination and salt stress in tomato: a metabolic post-translational modification by polyamines and hypusine

Szepesi Á.*, H. Kovács, P. Pálfi, L. Sípos, D. Szabó, L. Bakacsy

*University of Szeged, Hungary *Corresponding author: szepesia@bio.u-szeged.hu*

Salinity stress is one of the most threatening stress factors causing huge yield losses in agriculture. To decipher new methods to enhance salt stress tolerance of crop plants, we have to elucidate mechanisms involved in plant salt stress responses. Hypusination is a rarely known metabolic posttranslational modification of eIF5A, the eukaryotic protein translational factor 5A. During this process, hypusine, a rare amino acid, is synthesized by two enzymes: deoxyhypusine synthase (DHS) and deoxyhypusine hydroxylase (DOHH). DHS is responsible for biosynthesis of deoxyhypusine at lysine of eIF5A, in the presence of NADH and spermidine, while DOHH hydroxylases the deoxyhypusine forming hypusine. Despite enormous data in animals and humans about the role of hypusination and eIF5A mediated processes, there is little information about their role in plants, especially in agriculturally important crop plants. Our research group is focusing on the role of enzymes involved in hypusination by pharmacological approaches in tomato (Solanum lycopersicum) and common thale cress (Arabidopsis thaliana). In our study, we examined the effect of GC7 for enzyme activity of DHS and ciclopirox (CPX) for DOHH under control conditions and after sodium chloride (NaCl) stress in different plant growth stages. As we expected, the CPX treatment caused more drastic growth inhibition by reducing DOHH activities and level of hypusine. However, GC7 induced an increase of polyamine content during salinity stress improving growth and salt tolerance of plants. After NaCl stress, GC7 treated plants showed improved plant parameters, such as tomato fruit number and fruit biomass. Our results indicate the importance of hypusination not only in development but also in the stress response of crop plants, suggesting another target for enhancing yield and stress tolerance in crop plants. This project is funded by NKFIH FK129061.

Keywords: salt stress, hypusination, polyamines, tomato.

Ameliorative effects and soil carbon sequestration potential of organic and inorganic amendments in salt-affected soils

Farooqi, Z.U.R.[1,2]*, M. Sabir[1], H.R. Ahmad[1], J. Smith[2], G. Murtaza[1] and M. Arfan[1]

*[1]University of Agriculture, Faisalabad, Pakistan, [2]University of Aberdeen, Scotland, UK. *Corresponding authors: ziaa2600@gmail.com; cmsuaf@gmail.com*

This 45-days incubation study assessed the effectiveness of the application of gypsum, organic amendments and their combinations in the reclamation and increasing carbon stocks of marginally salt-affected areas (Dijkot, Uchkera and Jhang) in Pakistan. Gypsum along with organic amendments of farmyard manure, poultry manure or green manure was used to reduce the salinity of the soils. Treatment 1 received 100% of the recommended soil gypsum requirement, while the other treatments received 50% of the recommendation with equal amounts by fresh weight of farmyard manure, poultry manure or green manure. The control received no gypsum or organic amendments. All the amendments effectively ameliorated the salt-affected soils and increased soil

carbon stocks. Soil pH was reduced by 19% in Dijkot and Jhang. Electrical conductivity was reduced by 28% in Jhang. Sodium adsorption ratio was reduced by 71.55% in Jhang. The cation exchange capacity was increased by 39% in Dijkot. Soil organic matter was increased by 65% in Uchkera. Total nitrogen was increased by 96% in Jhang. The soil organic matter increased by 62%, from 4.45 t ha^{-1} in the control to 12.59 t ha^{-1}, in the 50:50 gypsum: farmyard manure treatment. The results obtained suggest that gypsum in combination with organic amendments can effectively reduce the salt concentration in salt- affected soils using 50% of the recommended rate of gypsum and can also help to build soil organic matter to support increased crop production and carbon sequestration.

Keywords: Salts, high temperature, water scarcity, wastewater irrigation, climate change, soil reclamation.

Direct seeded rice for resource conservation and GHG emissions reduction in Odisha, India

Chaudhary A. [1*], A.K. Mishra [2], S. Sharma.[2] and V.V. Ramanan[1]

*[1]Indira Gandhi National Open University, New Delhi, India; [2]International Rice Research Institute, New Delhi, India. *Corresponding author: anjali0666@gmail.com*

Rice is the predominant crop in Odisha which is mostly cultivated using the Manual Puddled Transplanted (PTR) system. This establishment method requires about 150±10 ha-cm of water along with a suitable variety and the recommended dose of fertilizers to realize yield levels of above 6 t/ha. Therefore, due to declining water tables, increasing water scarcity, water, labor and energy-intensive nature of the puddled transplanted system, high labour wages, adverse effects of puddling on soil health and succeeding crops and high methane emissions, this production system is becoming less profitable. Direct Seeded Rice (DSR) is a promising option which can replace the traditional transplanted system. DSR requires less water and labour (12- 35%), reduces methane emissions (10-90%), improves soil physical properties, involves less drudgery and production cost (USD 9-125 per hectare) and gives comparable yields. In a field experiment in Odisha, head-to-head trials of conventional practice and improved practice was carried out. Direct seeding of paddy var. Lalat yielded 5.4 t/ha that was close to the transplanted coarse rice of 5.6 t/ha. Also, with DSR there was a saving of about Rs 3200-4500 per hectare in labour cost and irrigation water. However, extra expenditure was required for herbicide applications. The data was received from a questionnaire-based survey that was conducted among 100 farmers (50 DSR and 50 TPR). GHG emissions were calculated using the CCAFS CFT-MOT model. Methane emissions were less in DSR as compared to PTR systems. However, nitrous oxide emissions were a little higher due to the aerobic conditions in DSR. Secondary data for modelling was used from the farmers' survey. It was concluded that developing site and soil-specific integrated packages will help in the broader adoption of DSR and reduce the environmental footprint of PTR.

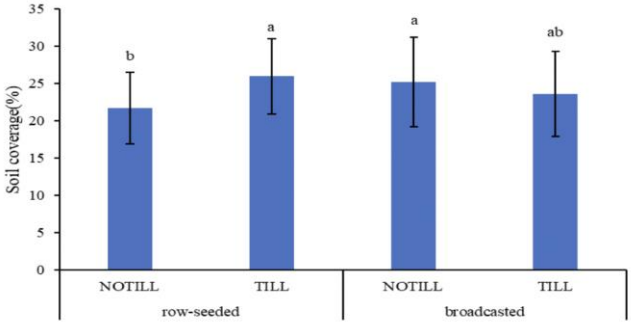
Keywords: Direct seeded rice, puddled transplanted rice, greenhouse gas emissions, CFTMOT model, resource conservation technologies.

Evaluating the feasibility of camelina (*Camelina sativa* ssp) as a winter cover crop in rainfed Mediterranean farming systems

Berzuinia S., F. Zanettia*, E. Facciollaa, A. Vecchia and A. Montia

*University of Bologna, Italy. *Corresponding author: federica.zanetti5@unibo.it*

In the Mediterranean basin rainfed cropping systems are mostly related to cereal-based rotations with a lack of alternative options for winter cultivations. The introduction of cash cover crops could reduce fallow periods and increase economic incomes for the farmers. Moreover, cover crops can promote agroecosystem benefits, such as a reduction of leaching, runoff and increased carbon sequestration and a reduction in weed pression. In this scenario, winter camelina (*Camelina sativa* ssp.) has been identified as a suitable cash cover crop because of its high rusticity and high tolerance to drought. In particular, in the Mediterranean basin camelina can be sown from mid-October and it can ensure soil coverage before the beginning of the winter. Finally, camelina is well suited to conservative agriculture in order to promote minimum soil disturbance and water conservation. In the framework of the 4CEMED project, financed by the PRIMA foundation, a two-year trial (2020-2021) was set up in Bologna in order to observe soil coverage in response to different abiotic conditions. The experimental design was a strip split plot with four replicates. The tested factors were: two sowing methods (row-seeded plots vs. broadcasted plots) and two tillage methods: minimum tillage (disking and harrowing before sowing) vs. notill (direct sowing). The variety Alba (Camelina Company, Spain) was sown at the beginning of October. The Canopeo app (Oklahoma State University) was used every 15 days from emergence until mid-December to survey soil coverage in the initial stages of crop growth. Results reported a significant interaction between sowing method and tillage method: row-seeded plots reported higher coverage values in minimum tillage plots rather than in no- tillage (25.98% vs. 21.70%, respectively) while broadcasted were not significantly different between minimum tillage and no-tillage (25.20% and 23.61%, respectively) (Figure.1). Soil cover will continue to be monitored until stem elongation, and final productivity parameters will be surveyed.



Keywords: Oilseed crops, crop diversification, minimum soil disturbance.

Monitoring cropland carbon dioxide exchange with high resolution satellite imagery

Gottschalk P.[1,*], A. Kalhori[1], Z. Li[2], I. Wiekenkamp[1], C. Wille[1] and T. Sachs[1]

[1]Helmholtz Centre Potsdam GFZ, Germany; [2]Helmholtz Centre for Environmental Research – UFZ Germany. Corresponding author: pia.gottschalk@gfz-potsdam.de

Combining satellite data with local eddy covariance (EC) CO2 flux data is commonly used to upscale the C-exchange from point to regional scale. Low spatial resolution products like MODIS limit their applicability to larger homogeneous areas which do not account for the small-scale arable

field system. To improve spatial and temporal accuracy, we tested a simple approach based on the combination of field scale EC C-flux data and spatially matched Landsat 8 derived vegetation indices (VIs) for its applicability to monitor field scale C-fluxes from space. To establish the link between EC flux data and VIs we assessed the ability of a range of VIs to estimate daily net ecosystem exchange (NEE), gross primary productivity (GPP) and ecosystem respiration (Reco) for 1 ½ growing seasons (winter rape and winter wheat) based on simple regression models. The suitability of VIs to estimate GPP and NEE varied between C-flux and length of observation period. While GNDVI (Green Normalised Difference VI) performed best to estimate NEE for the whole observation period, growing season NEE of WW was best estimated by NDVI (Normalised Difference VI) and SAVI (Soil Adjusted VI) showing slight overestimations of C-uptake. Respective total differences between measured and estimated C-fluxes were 5.5 (-1%), 12 (-2.3%) and 11.9 (-2.3%) g C m-2. The worst estimates were provided by EVI for the whole period and the growing season only, with overestimations of 40.2 and 77.9 g C m-2 respectively. Estimations of GPP generally showed larger discrepancies. Since correlations between Reco and VIs were statistically not significant no attempt was made to directly predict Reco from VIs. Differences between measured and estimated C-fluxes are mainly explained by the diversion of the C-flux and VI signal during winter. C-fluxes stayed at low levels and VI values increased due to a relatively high crop LAI.

Keywords: NEE, GPP, ecosystem respiration, remote sensing, NDVI,EVI2, GNDVI

Intercropping's effect on soil health on the Canadian prairies

McAuley, W.P.*, K.A. Congreves, and M. Bourgault

*University of Saskatchewan, Saskatoon, Canada. *Corresponding author: wpm722@usask.ca*

Growing multiple crops within the same field in an intercrop can have a positive impact on light interception, biomass accumulation, water use, weed competition, and insect and disease pests. Little is known, however, about how intercropping affects soil health. Using the Saskatchewan Soil Health Assessment, legume-based intercrops were compared to monocrops to determine if there was a change at 0-15 cm among five soil health indicators: organic carbon, active carbon, total nitrogen, soil protein, and soluble nitrogen. We also compared faba bean intercrops with typical intercrops found on the Canadian Prairies to determine if there were yield advantages in faba intercropping. Yield differences were examined using the land equivalent ratio (LER) concept. The crops tested were faba bean (*Vicia faba* L.); oats *(Avena sativa* L.); canola (*Brassica napus* L.); flax (*Linum usitatissimum* L.); wheat (*Triticum aestivum* L.); pea (*Pisum sativum* L.); lentil (*Lens culinaris* Medik.); and chickpea (*Cicer arietinum* L.). Treatments include all crops individually and intercrops of faba-wheat, faba-flax, faba-oat, faba- canola, pea-canola, chickpea-flax, and lentil-wheat. Preliminary results showed that intercropping with legumes can provide an LER >1, with faba-wheat (1.09), faba-flax (1.5), and faba-oat (3.2) showing that intercrops can be more productive overall than sole crops in some mixtures. The faba-oat result was due to the competitiveness of oats for limited soil water, leaving the faba-flax as the highest overyielding faba intercrop tested. Likely due to the drought in 2021, organic carbon, active carbon, and soil protein displayed no significant differences between mono- and intercrops in a one-year timeframe. As no nitrogen fertilizer was added to the intercropped systems, the total nitrogen level during the year may indicate that the legumes were able to provide adequate soil nitrogen for the non-legume crop. Results will be repeated in 2022 to determine if intercrops affect soil health in a one-year period.

Keywords: intercrop, soil health, soil carbon, soil nitrogen, LER

Ammonia emission measurements after application of urea-based fertilizers in wheat crop

Wesołowska M.M. [1,2*], P. Baranowski[1], M. Mikos-Szymańska[2]

*[1]Institute of Agrophysics, Polish Academy of Sciences, Lublin, Poland; [2]GRUPA AZOTY Zakłady Azotowe Puławy, Poland. *Corresponding authors: monika.wesolowska@grupaazoty.com, mwesolowska@ipan.lublin.pl*

The emissions of ammonia after nitrogen fertilizers application mainly depend on soil properties and climatic conditions. The average losses from urea are reported at the level c.a. 18% of applied nitrogen [Skorupka M., 2021]. Depending on data sources, N losses can be at the level of 2–43% for arable land and 10–58% for grassland [Wesołowska M, 2021]. The research was focused on ammonia emission measurements after application of modified urea- based fertilizers. To measure gas emission levels, the static chamber method with a portable FTIR analyser (Gasmet DX 4040) was used. The NH3 emissions from modified urea-based fertilizers were reduced in the range from 20 to almost 35% of the daily flux, so they should meet the requirements of the EU Directive 2016/2284 (the NEC Directive) and the Polish Act (May 2020). The results show that the emissions depend on type of fertilizer modification as well as the properties of the soil to which they were applied. The emissions may vary by about 20% depending on humidity and compaction of the soil in the experimental tube. Based on incubation studies, it was possible to select the fertilizer type showing the lowest ammonia emissions. This fertiliser was tested in the pot experiment with spring wheat, which confirmed the reduction of NH3 emissions in relation to unmodified urea.

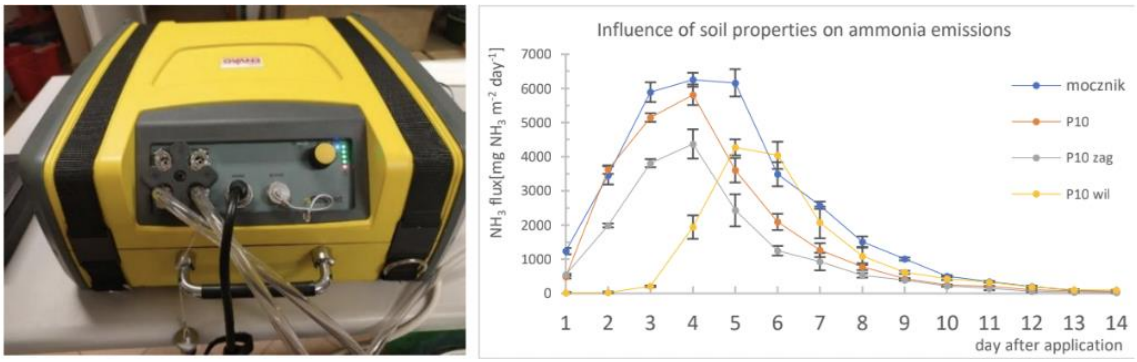


Fig. 1. a) Gasmet DX4040 analyzer b) Daily ammonia fluxes after N fertilizer application

This work is carried out as part of the " Implementation Ph. D. " programme of the Polish Ministry of Science and Higher Education, contract number: 006/DW/2018/002

References: 1. Skorupka M., et al., 2021, Agriculture, 11(9), 822; 2. Wesołowska M., et al., 2021, International Agrophysics, 35, str. 11-24. 3. National Emissions Ceilings (NEC) Directive (2016/2284/EU)

Keywords: SRF, NH_3 emissions, emissions measurement

FixOurFood: The impact of regenerative farming on soils in Northern England

Wade R.*, G. Reiss, P. Chapman, S. Banwart and L. Collins

*University of Leeds, United Kingdom. *Corresponding author: r.wade@leeds.ac.uk*

There is an urgent need to transform the UK's food system to meet the demand of our growing human population whilst adapting to and mitigating climate change. Current food production that supplies UK diets is unsuitable: 33% of UK soils are assessed as degraded where 3 m tonnes of

topsoil is eroded each year, with intensive agricultural practices associated with the loss of 60% of soil carbon. Furthermore, agriculture is responsible for 10% of UK's greenhouse gas emissions as well as over half the UK's methane emissions and ¾ of N2O emissions. Regenerative farming seeks to address the historic global decline in soil stocks and fertility, C and N sequestration, terrestrial biodiversity and water quality, as well as offer increased agricultural productivity with societal benefits. Working with a network of growers in the north of England, we present examples of regenerative farming in the local area and compare gas emissions, soil stocks and structure in fields using regenerative practices, with fields using conventional practices. Practice-based options such as a mixed crop cover, novel livestock-crop rotations, greater crop diversity and reduced tillage, will be trialled at the University of Leeds farm and at local farms to quantify the impacts of the regenerative farming practices on soil quality, crop production and greenhouse gas emissions. This work aims to determine the impact of regenerative farming changes on whole-life cycle GHG emissions, long-term profitability and environmental sustainability.

Keywords: Regenerative agriculture, soil quality, greenhouse gas emissions, farmer network

Analysis of the agroecological transition in Spain

Franco-Grandas T.I., J.J. Santiago-Freijanes, N. Ferreiro-Domínguez, F.J. Rodríguez-Rigueiro, V. Álvarez- López and M.R. Mosquera-Losada*

*Polytechnic School of Engineering of University of Santiago de Compostela, Spain. *Corresponding author: mrosa.mosquera.losada@usc.es*

There are currently numerous socio-economic and ecological challenges facing European agri-food systems. These challenges stem from a food system that is exhausting its production capacity, along with an emergence and increase in extreme events and associated changes in climate. Challenges that need to be addressed through context-specific measures and solutions, jointly supported through policies, such as the Green Deal, and the common agricultural policy (CAP). The Green Deal, and the CAP, will facilitate a more sustainable production model over time capable of solving the real challenges of production, as well as other aspects developed in the 2030 Agenda and the 17 Sustainable Development Goals (SDGs). Agroecology can be defined as any scientific discipline, agricultural practice, or social or political movement capable of addressing these challenges. This study analysed the transition of the Spanish industrial production model to agroecology, during the period 2019-2021 in the context of the global pandemic due to COVID-19. To analyse the evolution of the transition to agroecology, the SILVOPAST research group of the University of Santiago de Compostela conducted a study through a systematic review in the Web of Science, using the selection of country, corresponding author Spanish and keywords: organic farming, agroecology and agroecology & organic farming as key elements of bias in the search engine. The analysis of 298 articles showed an increasing tendency to fund and study production projects oriented to conservation, sustainable management of soil and ecosystem health based on the analysis of ecological processes, biodiversity and cycles adapted to local conditions. This was followed by studies based on principles that allow optimizing interactions in an ecosystem while taking into consideration social aspects that must be addressed to achieve a sustainable and fair food system.

***Keywords*:** Organic farming, Food security, Sustainability transitions, Governance, Climate change

Posters

Methane uptake in fertilized soils - effect of NH_4NO_3 at different soil O_2 levels

Walkiewicz A.[1]*

*[1]Institute of Agrophysics, Polish Academy of Sciences, Lublin, Poland. *Corresponding author: a.walkiewicz@ipan.lublin.pl*

Soil contributes to global warming e.g. as a source or sink for greenhouse gases (GHGs). Given the mitigation potential, the capability of methane (CH_4) consumption by soil is often under scientific consideration. Methanotrophs can oxidize CH_4 produced in deeper soil layers or in anaerobic microsites, thus reducing its emission from soil, or by consuming atmospheric CH4. Land use influences CH4 uptake capacity and is often changed by nitrogen (N) fertilization. Nitrogen is highly dynamic in soil and the addition of ammonium (NH_4^+) may result in nitrate (NO_3^-) accumulation due to nitrification. The aims of our study were to determine: (1) CH_4 consumption and (2) N transformations in three arable soils of different types incubated with NH_4NO_3 at different O_2 levels. We showed that soil hypoxia was favourable for methanotrophy in control soils. After soil enrichment with NH_4NO_3, CH_4 uptake was not strongly influenced by O_2 level: the inhibition or reduction of the process significantly depended on the soil type and the N rate. Based on the available literature and the results of our studies, different changes in methanotrophic activity (inhibition, stimulation, or no effect) depending on the chemical N form are likely to be found, e.g. competitive inhibition by NH_4+ , formation of toxic nitrite (NO_2^-), salt effects, especially at high NO_3 - concentrations, use as a nutrient N source, and use of NO_3^- as an electron acceptor in O_2 deficiency conditions. Interactions between N and CH_4 uptake are still not fully explained and the elucidation of these effects in fertilized soils may be helpful in identifying methods to enhance CH_4 uptake.

The work was conducted under the project financed by Polish National Centre for Research and Development within 2021 Joint Call Era-Net Cofund Programme ("ReLive").

***Keywords*:** Methane uptake, arable soil, greenhouse gas, N fertilization.

The use of near-infrared reflectance spectroscopy (NIRS) in the prediction of soil carbon stock in Northern Italy cropping systems

Prà A.D. [1,2], **M. T. Pacchioli[2]***, A. Immovilli[3], P. Mantovi[2], F. Ruozzi[3], F. Ferrero[4], G. Borreani[4] and E. Tabacco[4]

*[1]Istituto di BioEconomia, Consiglio Nazionale delle Ricerche, Italy; [2]Centro Ricerche Produzioni Animali – CRPA spa, Italy; [3]Fondazione CRPA Studi Ricerche ETS, Italy; [4]Università degli Studi di Torino, Dipartimento di Scienze Agrarie, Forestali e Alimentari. *Corresponding author: m.t.pacchioli@crpa.it*

The European Union assigns a key role to carbon farming (CF) for reaching a climate-neutral economy. CF involves the management of both land and livestock, and while advanced methods for assessing carbon emissions are available, the LIFE Forage4Climate project highlighted the inadequacy of predictive models of carbon stock (CS) changes at farm level. The project recommends measuring soil organic carbon (SOC g/kg), soil texture as a percentage of loam, sand and clay, and soil bulk density (BD, dry soil weight/total soil volume) to calculate CS (Mg/ha). While chemical analysis remains time consuming, costly, and polluting regarding SOC, NIRS is widely recognized as a reliable predictive technique for chemical and physical parameters. A study was carried out on 365 soil samples from Northern Italy in order to calculate NIRS prediction models for dry matter, SOC, texture (clay and sand). Samples were chemically analysed for SOC,

evaluated for sand and clay, and scanned with SpectraStar Near-Infrared analyzer (2400 RTW model). The calculated prediction models have coefficients of determination for calibration (R2) of 0.905, 0.743 and 0.859 for SOC, clay and sand respectively. 30 samples not included in the calibration were used to validate the models, with the following correlation coefficients (R2) between analysed and predicted: SOC 0.7627; clay 0.8217; sand 0.821. The same 30 samples were also evaluated for BD and soil carbon stocks (CSs). Field CSs were calculated from chemically analysed SOC and directly assessed BD with volumetric rings, than compared to calculated CSs from NIR predicted SOC, and BD predicted from SOC, clay, sand, and loam utilizing most performable pedo-transfer function (PTF) from the literature. The correlation coefficient (R2) of CS evaluated with analysed vs predicted parameters is 0.8198. Results indicate a promising use of NIRS for CS evaluation and also as a basis for direct assessment for payment of carbon credits.

Work financed by LIFE15/CCM/IT/000039

Keywords: Carbon stock, NIRS, LIFE15/CCM/IT/000039

ISFERALDA project: Using organic amendments based on date palm residues to enhance soil fertility in Oases agroecosystems

Morvan X.[1], B. Boumaraf[2], V. Kavvadias[3], M. Moussa[4], H. Lamine[5], M. Sbih[6], F. Bendjeddou[7], A. Zaakir[8], M. Gommeaux[1], N. Karbout[4], I.R. Zoghlami[4], E. Le Guyader[1], V. Miconnet[1], K. Guimeur[2], A. Tirichine[5], A. Adelfettah[5], B. Marin[1] and the ISFERALDA project team.

[1]University of Reims, REIMS, France, [2]University Mohamed Khider of Biskra, Algeria, [3]Hellenic Agricultural Organization /Institute of Soil and Water Resources, Greece, [4]University of Gabès, Arid Regions Institute of Medenine (IRESA), Tunisia, [5]National Institute of Algerian Agronomic Research, Algeria, [6]University Hadj Lakhdar of Batna, Algeria, [7]Technological Institute for the development of the Saharan Agriculture, Algeria, [8]Palm Compost, Algeria. Corresponding author: xavier.morvan@univ-reims.fr

Soils in drylands of North Africa are generally considered as low fertility soils, notably because of their low organic matter content. In these regions, oases are the main driver of the economy. Date palm cultivation is the main source of income for farmers. Within the oases, only a minor part of the by- products of date palm cultivation is valorised. Their valorisation as bioresources, with a potential effect on soil fertility, has received little attention to date. In this context, the ISFERALDA project aims to increase the climate change resilience of the agro-ecosystem while providing comparable or higher incomes to local farmers in semi-arid and arid areas. The project aims to develop the use of organic amendments based on traditional production (composting, pyrolysis) and on local agricultural wastes, particularly date palm residues, in agreement with the objectives of circular economy. Innovative farming systems will be developed and will contribute to a sustainable management of date production, generating income and creating jobs, while improving environmental parameters. The innovation potential of the project is based on a multidisciplinary and strongly integrated approach. A socio-economic analysis, based on surveys, will familiarize farmers with the economic interest of producing and using the proposed organic amendments. The proposed research activities include a detailed description of each amendment studied, laboratory experiments to describe and explain the evolution of the soil properties depending on studied amendments, and field experiments, in five different sites representative of the drylands in Algeria and Tunisia. Contacts with stakeholders, particularly farmers, will promote the acceptance of these practices if they are deemed beneficial from an economic and agronomic point of view. They will allow the dissemination of this new knowledge to the main actors of the agricultural sector and the applicability of this method on a regional and national scale in the whole Mediterranean basin.

Keywords: Soil, Organic amendment, Oasis agroecosystems, Date palm

A modern way for delineate soil mapping units using latest geospatial technologies

Kolovos C*., G. Zagklis, G. Tsitselis, S. Kavasilis, E. Roukounaki, A.V. Papadopoulos and M.K. Doula

*[1]Benaki Phytopathological Institute Kifisia, Greece. *Corresponding author: ch.kolovos@bpi.gr*

Soil surveys describe and evaluate the various soil types and their properties, in specific regions, classifying them using internationally recognized soil classification systems. Soil surveys are based on Soil Mapping Units (SMUs), which delineate soil resources, in areas with similar physical and chemical properties. These properties are represented with the mapping symbol. The present work serves the purpose of a more precise demarcation of the various soil types using latest geospatial technologies. The first steps in composing a soil survey include identifying the SMUs, while the boundaries demarcated on an orthophotography. In addition, slope, vegetation, geology, and color tone are also taken into consideration. In the present work the repeatable tasks and the complex processes were executed in ArcGIS Pro. (ESRI Inc.) The preliminary, detailed SMUs were delineated by creating polygons using as the main background the ESRI imagery and a UAV aerial image, a digitized geological map, a land uses layer from the CLC2018 (vector), as well as a slope classes layer, derived from the DEM, all combined and processed with the intersect geoprocessing tool. The resulting polygon layer was used for the delineation of the SMUs. The finalization of SMU limits is carried out in the field by identifying certain morphological soil properties, and by laboratory analyses of soil samples. For this purpose, a customized mobileGIS application was developed, using the ArcGIS FieldMaps environment, hosting the SMUs layer. The app offers the capability for the modification of the SMUs boundaries, as well as entering the identified properties, by selecting predefined values and taking geotagged photos. The final detailed SMUs, processed and compared with older digitized SMUs, demonstrate the capacity of innovative new geospatial technologies to provide us with the most reliable and accurate soil data possible leading to more precise decision making.

Keywords: SMU, Soil mapping units, GIS, Soil survey, mobile GIS

Theme 2: Grassland Systems

Keynote presentation

Nitrogen cycling in savanna systems and the role of livestock in creating hotspots of N_2O emissions

Butterbach-Bahl K.[1,2*], L. Merbold[1] and V. Carbonell[2,4]

*[1]Aarhus University, Denmark; [2]Karlsruhe Institute of Technology, Germany; [3]Agroscope, Switzerland; [4]International Livestock Research Institute (ILRI), Kenya. *Corresponding author: Klaus.butterbach-bahl@agro.au.dk*

Agricultural use of semi-arid savannas in Sub-Saharan Africa (SSA) is dominated by livestock production in pastoral systems. While it is well established that overuse of savanna ecosystems by grazing may lead to deterioration of these vulnerable ecosystems due to land degradation, soil erosion and loss of soil fertility, astonishingly little is known about nitrogen (N) cycling, storage, and loss pathways, and the role livestock may play as mediator and driver of ecosystem N cycling. In this talk, we will show that livestock drives nutrient re-allocation in savanna systems, with tremendous effects on landscape N cycling. Current knowns and unknowns of N cycling will be summarized in a tentative nitrogen budget for a virtual pastoral farm. Our results indicate that N inputs in savanna systems are dominated by atmospheric N deposition (~80%), while inputs due to biological nitrogen fixation seem to play a smaller role. Major N loss pathways are linked to nitrogen leaching (nitrate > DON) from pastures (33%) and likely as well from bomas, i.e. temporal enclosures where animals are kept during the night. Moreover, these bomas are playing a dominating role as sources of atmospheric N_2O in savanna landscapes, which so far were not considered. We estimated that the overall contribution of such livestock enclosures or bomas to the continental agricultural N_2O budget may be as high as 10%. Our research points to various weaknesses in understanding nutrient cycling in savanna systems, which can only be resolved by an expansion of the collection of experimental data and linkage of such data collection to remote sensing. This information is urgently needed to better understand the effects of current management on the environment and how changes in environmental conditions and herd management are affecting nutrient availability and GHG fluxes under changing environmental conditions.

Keywords: Savanna, Nitrogen Cycling, Livestock, soil N_2O fluxes.

Session II: Oral presentations

Adaptation policies and measures to cope with climate change in Alpine mountain farming

Piccot, A.[1]*, G. Argenti[2], G. Bellocchi[3], P. Brien[4], E. Cremonese[5], M. Della-Vedova[4], C. Dibari[2], M. Galvagno[5], S. Ghidotti[6], C. Napoléone[7], L. Stendardi[2], S. Targetti[7], G. Trombi[2], P. Varese[6] and M. Bassignana[1]

*1Institut Agricole Régional, Italy, [2]University of Florence, Italy, [3]UCA, INRAE, VetAgro Sup, UREP, France, [4]PNE, France, [5]ARPA-VdA, Italy, [6]PNGP consultant, Italy, [7]INRAE-Ecodéveloppement, France .*Corresponding author: a.piccot@iaraosta.it*

Alpine pastures are very vulnerable ecosystems to climate and socio-economic changes. In this work, we propose effective adaptation policies and measures to cope with climate change in two study areas (Écrins National Park-FR, Gran Paradiso National Park-IT), elaborated from a review on the best adaptation options for mountain grasslands at European, national and regional levels, a modelling approach and participatory processes with farmers, agricultural experts and officials of local bodies and protected areas. The proposed strategies are included in the LIFE PASTORALP project web platform, a dynamic repository to promote climate-proof policies, effective practices and capacity building on climate-related issues.

Keywords: climate change, adaptation policies, adaptation strategies, Alpine grasslands, pasture management

N_2O emissions from grazed pasture - Effect of urine patch characteristics and environmental drivers

Barczyk L. [1,2],* K. Kuntu-Blankson[1,2], P. Calanca[1], J. Six[2] and C. Ammann[1]

*[1]Agroscope, Switzerland, [2]ETH Zürich, Switzerland. *Corresponding author: lena.barczyk@agroscope.admin.ch*

In pasture soils, urine patches associated with grazing animals form hotspots of nitrogen (N) supply and are subject to N losses like nitrate leaching and emission of the important greenhouse gas nitrous oxide (N_2O). According to the IPCC soil N_2O emissions are quantified as the fraction of N inputs denoted as an emission factor (EF). Studies reveal a wide range of EF values for grazing related N inputs. To better understand this variability, we examined N_2O fluxes and corresponding EFs of artificially applied urine patches in relation to urine patch characteristics (urine N concentration, urine volume, patch area, urine composition) and environmental drivers (soil moisture, temperature). Ten urine application experiments were performed from July 2020 to June 2022 on a real pasture field located in Eastern Switzerland. N_2O fluxes were measured by a manually operated chamber connected to an online gas analyser. We present and discuss the results of these measurements. This is the first study in Switzerland investigating patch-scale N_2O fluxes by controlled application of synthetic and real urine.

Keywords: Urine patch, nitrous oxide, pasture

Production of a national Irish paddock map for intensive grasslands

Zimmermann, J.*[1] , R. O'Hara [1,2] and S. Green[1]

*[1]Dept. of Agrifood Business and Spatial Analysis, Teagasc, Ireland. 2Terrain-AI, Maynooth University, Ireland. *Corresponding author: jesko.zimmermann@teagasc.ie*

A lack of spatial data on grassland management intensity causes uncertainty in greenhouse gas accounts and modelling of pollution pressures associated with the Water Framework Directive. We report results of a recent study to map the locations of intensively managed grasslands in Ireland. Using a statistical modality test of a time-series of Sentinel 2 satellite images, the locations of fields managed as paddock enclosures were mapped exploiting changing pixel intensity in response to rotational grazing over time. Our results suggest that ~ 304,500 fields, or 31% of pasture fields nationally, have paddock enclosures indicative of intensified grassland production. Overall thematic accuracy was 84.58% (95% CI 80.93%, 87.78%).

***Keywords*:** Land use, intensification, earth observation, sentinel, multimodal

Optimizing grass production with dairy manure from precision animal feeding

Domingo-Olivé F.* and E. González-Llinàs

*IRTA Mas Badia–Sustainable Field Crops. Catalonia. *Corresponding author: francesc.domingo@irta.cat*

Intensive dairy farms not based on grazing may contribute to increasing nutrient use efficiency in farming systems by implementing precision animal feeding according to cow needs at different periods. Manure obtained from these systems has different characteristics than conventional ones, namely a lower proportion of ammonium N in respect to total N. Its use as fertilizer for forage crops must be accordingly managed. We have carried out an on-field fertilization trial comparing both types of slurry (from conventional and precision feeding) on an Italian ryegrass crop (three cuts: January, April and May) under Mediterranean rainfed conditions in a moderately deep, calcareous, sandy clay loam soil. Both kinds of slurry have been applied either full rate (170 kg N ha-1) at pre-sowing (September) and split rate between pre-sowing and side-dressing (January, after the first crop cut). Crop yield varied among the three cuts, the second being the most productive (5132 kg DM ha-1) one and the third the less (2270 kg DM ha-1) productive. Using slurry from precision feeding significantly increases protein content in the plant but does not generally influence yield. A split application of slurry at pre-sowing and side dressing increases DM yield (5-20 %), compared to a single application at pre-sowing, for the second cut period for both types of slurry. It also increased protein content (20-25 %) in the same period. Crop yield did not differ significantly when mineral fertilizer, at a rate of 100 kg N ha-1, was applied at pre-sowing and after the 1st and 2nd cut (300 kg N ha-1 in total) but crop protein content significantly increased (30-50 %) in the three cuts. A combined use of slurry and mineral fertilizer may increase crop performance, and particularly crop quality. Preliminary results on ammonia emissions indicate lower N losses from precision feeding slurry when applied to the field.

Keywords: Fertilization, nitrogen, protein content, ryegrass, slurry.

Warmer autumn temperatures triples carbon losses from an Irish grassland on a drained organic soil

Valmier M.[1]* , M. Saunders[1] and G. Lanigan[2]

*[1]Trinity College Dublin, Ireland; [2]Teagasc, Johnstown Castle, Ireland. *Corresponding author: valmierm@tcd.ie*

Grassland-based agriculture in Ireland contributes over one third of the national Greenhouse Gas (GHG) emissions. Furthermore, the LULUCF sector is also a net GHG source, primarily due to the ongoing drainage of peat soils. Reducing the Carbon (C) losses from organic soil has been highlighted as a key action for Ireland to reach its climate targets, and improved grassland management can help to further offset GHG emissions without compromising productivity. However, research is required to assess the best management practices for optimum environmental and agricultural production outcomes. Despite their spatial extent and relevance to both the national emission inventories and climate mitigation strategies, only two studies on GHG emissions from Irish grasslands on peat soils have been published. Here we present 2 years of data from a former peat extraction site located in the Irish midlands, now drained and managed for grass-based silage production. For the first time in such agri-environmental systems on Irish soil, the eddy covariance technique was used to continuously monitor the Net Ecosystem Exchange (NEE) of carbon dioxide (CO2). The grassland site was a C source in both years, as might be expected from a drained organic soil system, with three times more carbon released in 2021 compared to 2020. Autumn temperatures were on average 2°C warmer in 2021, which reduced the rate of C uptake from -1.8 in 2020 to -0.6 t C ha^{-1} in 2021 due to higher rates of ecosystem respiration. C export through harvest were 4.7 and 5.4 t C ha^{-1}, resulting in a net C loss of 2.9 and 4.8 t C ha^{-1} in 2020 and 2021, respectively. This work indicates the potential for emission savings to be made from these systems and highlights the impact that inter-annual variability associated with future climate change can have on their net C sink/source strength.

Keywords: Peat Soil, drained organic soil, SOC, carbon balance, silage

Climate implications of dairy expansion and beef co-production displacing suckler beef production in Ireland

Henn D.[1],* , J. Humphreys[2], C. Duffy[1,3], R. Prudhomme[4], J. Gibbons[5] and D. Styles[1,6]

*[1]University of Limerick, Ireland; [2]Teagasc Moorepark, Ireland; [3]James Hutton Institute, Scotland; [4]CIRAD, France; [5]Bangor University, Wales; [6]National University of Ireland Galway, Ireland. *Corresponding author: daniel.henn@ul.ie*

The production of beef and dairy products has a long tradition in Ireland but incurs a significant environmental burden. Over the past decade, total cattle numbers have risen significantly following the abolition of EU milk quotas and subsequent expansion of the profitable dairy sector. This led to a 15 % increase in annual national greenhouse gas (GHG) emissions between 2011 and 2019. Further growth in dairy cow numbers is projected for the upcoming decade. This goes against national efforts to reduce GHG emissions from agriculture by up to 30 % by 2030, and to achieve climate neutrality across all sectors by 2050. Dairy expansion has increased the number of surplus calves that are used for beef production and considered a “by-product” of dairy production. However, dairy calves offer significant potential to displace suckler-beef production that tends to have large GHG emissions and low profitability. The GOBLIN model enables the calculation of GHG and land balances from the agriculture, forestry and other land use (AFOLU) sector within national inventory boundaries. Using this model, we are investigating the impacts of different scenarios entailing varying levels of dairy expansion, optimization of cross-bred beef production, and reductions of the suckler herd in terms of total national emissions, national milk and beef GHG

footprints, and agricultural land use. A key model component is its cohort structure, which assigns unique live weight gains and cull ages to cattle cohorts based on their age and breed, allowing for precise determination of energy and feed requirements as well as land use connected to them. This approach will enable us to identify the best outcomes in terms of land use and lowering GHG emissions from agriculture while maintaining dairy and beef production, indicating how herd structure can contribute to closing the gap towards 2030 climate targets.

Keywords: : Livestock emissions, greenhouse gas, dairy intensification, climate targets

Climate change mitigation strategies for the small ruminant sector: Insights from the SheepToShip LIFE project

Duce P.[1]*, A. Franca[1], P. Arca[1], G. Molle[2], A.S. Atzori[3], M. Vannini[3], G. Cocco[4], D. Usai[5] and E. Vagnoni[1]

*[1]National Research Council, Italy; [3]Agricultural Research Agency of Sardinia, Italy; [4]University of Sassari, Italy; [6]Department for the Environment Protection, Italy; [7]Sardinian Regional Agency for the Implementation of Agricultural and Rural Development Programmes, Italy. *Corresponding author: pierpaolo.duce@ibe.cnr.it*

Based on 3 million sheep raised in about 10,000 active farms operating in traditional and innovative farming systems, Sardinia (Italy) produces around 13% of the EU sheep milk. Almost all milk is processed into sheep cheese, destined for world trade. The Sardinian dairy sheep sector is also responsible for ca. 1,600 kt CO_2eq/year, or 60% of the regional livestock total. The SheepToShip LIFE project (EU-LIFE Climate Change Action 2014- 2020) represented a regional case study to test emission mitigation strategies. The project approach combined the LCA method and a systems perspective, which may enable a transition in the small ruminant sector towards a more sustainable bioeconomy-based society. In particular, the project included: i) A life cycle thinking approach, used to evaluate environmental and socio-economic traits and impacts of 18 sheep farms; ii) On-farm implementation and demonstration of eco-innovative techniques, indicating the most viable actions to reduce impacts; iii) Participatory networks for detecting beliefs and reactions of the main stakeholders; iv) A territorial plan based on a Systems Dynamics approach, which explored insights for a regional policy aimed to reduce by 20% in 10 years the GHG emissions of the Sardinian dairy sheep supply chain. The mitigation actions performed during a 2-year period in demonstration farms resulted in an 8.5% reduction of methane and CO2eq emissions per kg of milk. The key saving mechanisms were represented by improvement of animal management, changes in feed supply strategy, changes in feed crop cultivation techniques, and reduction of energy consumption. The System Dynamics model showed that an effective mitigation plan for the entire regional sector should be based on dairy flock efficiencies, care for ecosystem services and deep stakeholder capacity building investments. SheepToShip LIFE provided an effective methodological blueprint to be applied and extended to other regions with similar features and sustainability challenges.

Keywords*:* Sheep farming, climate change mitigation, ecoinnovation, life cycle assessment, systems thinking.

The effect of an engineered biostimulant derived from Ascophyllum nodosum on grass yield under a reduced nitrogen regime

Quille P.[1]*, A. Claffey[2], E. Feeney[3], J. Kacprzyk[4], C. Ng[4] and S. O'Connell[5]

[1]Munster Technological University, Ireland, [2]*Grennans & Sons, Ireland,* [3]*Brandon Bioscience, Ireland,* [4]*University College Dublin, Ireland,* [5]*Brandon Bioscience, Israel. *Corresponding author: patrick.quille@mtu.ie*

Nitrogen (N) is the most important macronutrient used in modern agricultural systems to enhance crop yields. However, a significant amount of applied N is not taken up by the crop and is lost to the environment, leading to water and air quality issues. Improving the nitrogen use efficiency (NUE) of crops can curb these environmental losses, while concurrently delivering economic gains. A stated goal of the European Commission's Biodiversity Strategy for 2030 sets out specific targets, including a 20% reduction in fertilizer use and reducing fertilizer losses by 50%. Plant biostimulants have the potential to improve NUE in agronomic settings. In this research, a granular N containing fertilizer coated with the biostimulant PSI-362, an extract from the brown seaweed *Ascophyllum nodosum*, was applied to grass managed under different production systems to assess its impact on NUE. The role of soil type on the efficacy of the biostimulant in improving NUE was assessed using soil filled lysimeters. Six different soils were evaluated. A significant increase in grass yield (29%) was found with PSI-362 addition at 75% N rate over the 75% N control (8854 kg of DM/Ha vs 6610 kg of DM/Ha) over two years of trials under a simulated grazing platform of six rotations. The NUE increased to 96.6 % for the PSI-362 treated grass compared to 82.8 % for controls. Field based evaluations demonstrated no decrease in yield and quality from harvested and grazed grass treated with biostimulants when the N rate was reduced by 20 to 25%. Based on these results, the application of PSI-362 allows a reduction in nitrogen input by up to 25% without losses on grass yield or quality.

Keywords: Nitrogen use efficiency, biostimulant, grass silage, grassland pasture

Lowering greenhouse gas and ammonia emissions from pasture based dairy production

Cashman O.[1]*, M. Sorley[2], I. Casey[1] and J. Humphreys[2].

*Teagasc, Ireland, Waterford Institute of Technology, Ireland. *Corresponding authors: owen.cashman@teagasc.ie, james.humphreys@teagasc.ie*

Dairy farming in Ireland accounted for 15% of national greenhouse gas emissions (GHG) in 2020. Agricultural activities are responsible for 99% of national ammonia emissions. By 2030 the agricultural sector in Ireland must reduce its greenhouse gas emissions by between 22 and 30% relative to 2018 levels. The objective was to investigate the economic impact of pasture-based dairy systems incorporating various practices for lowering GHG and ammonia emissions including pasture legumes to replace fertilizer N in grassland, NBPT protected urea, Low Emission Slurry Spreading (LESS) and dairy cattle with high Economic Breeding Index. This study was conducted at Solohead Research Farm (52˚30'N, 08˚12'W) between 2019 and 2021. There were three systems with 27 cows per system per year at an average annual stocking rate of 2.53 cows' ha-1. The control received an annual average of 274 kg ha-1 of fertilizer N applied as urea and calcium ammonium nitrate, and slurry was applied using a splash plate. The WC90 system was a clover-based system receiving 90 kg ha-1 of fertilizer N each year applied as NBPT-urea and slurry was applied using LESS. The WC0 system did not receive fertilizer N and slurry was applied using LESS. The average EBI of cows on the control and WC90 was €147 and on WC0 was €185. Life cycle assessment was used to determine the GHG and ammonia emissions per kg fat and protein corrected milk (FPCM). GHG emissions were 0.9, 0.78 and 0.69 kg CO2eq. kg-1 FPCM for the

Control, WC90 and WC0, respectively (SEM = 0.143; P<0.001). Ammonia emissions were 3.60, 2.71, and 2.16 kg t-1 FPCM (SEM = 0.348; P<0.05). Net margins were €1470, €1561 and €1695 per ha (SEM = 43.3; P=0.066). The WC0 system has lower GHG and ammonia emissions and similar net margin relative to the other systems.

Keywords: Carbon footprint, ammonia, life cycle assessment, clover

Are there memory effects on greenhouse gas emissions (CO_2, N_2O and CH_4) following grassland restoration?

Lutz Merbold[1,2,a], Charlotte Decock[3,b,] Werner Eugster[1], Kathrin Fuchs[4], Benjamin Wolf[4], Nina Buchmann[1], and Lukas Hörtnagl[1]

[1]ETH Zurich, Switzerland, [2]International Livestock Research Institute (ILRI), Kenya, [3]ETH Zurich, Switzerland, [4]Karlsruhe Institute of Technology (KIT), Germany, [a]Agroscope, Switzerland [b]California Polytechnic State University, USA. Corresponding author: lutz.merbold@gmail.com.

A 5-year greenhouse gas (GHG) exchange study of the three major gas species (CO_2, CH_4 and N_2O) from an intensively managed permanent grassland in Switzerland is presented. Measurements comprise 2 years (2010 and 2011) of manual static chamber measurements of CH_4 and N_2O, 5 years of continuous eddy covariance (EC) measurements (CO_2–H_2O – 2010–2014), and 3 years (2012–2014) of EC measurement of CH_4 and N_2O. Intensive grassland management included both regular and sporadic management activities. Regular management practices encompassed mowing (three to five cuts per year) with subsequent organic fertilizer amendments and occasional grazing, whereas sporadic management activities comprised grazing or similar activities. The primary objective of our measurements was to compare pre-plowing to post-plowing GHG exchange and to identify potential memory effects of such a substantial disturbance on GHG exchange and carbon (C) and nitrogen (N) gains and losses. In order to include measurements carried out with different observation techniques, we tested two different measurement techniques jointly in 2013, namely the manual static chamber approach and the eddy covariance technique for N_2O, to quantify the GHG exchange from the observed grassland site. Our results showed that there were no memory effects on N_2O and CH_4 emissions after plowing, whereas the CO_2 uptake of the site increased considerably when compared to pre-restoration years. In detail, we observed large losses of CO_2 and N_2O during the year of restoration. In contrast, the grassland acted as a carbon sink under usual management, i.e., the time periods 2010-2011 and 2013-2014. Enhanced emissions and emission peaks of N_2O (defined as exceeding background emissions 0.21 ± 0.55 nmol m^{-2} s^{-1} (SE = 0.02) for at least 2 sequential days and the 7d moving average exceeding background emissions) were observed for almost 7 continuous months after restoration as well as following organic fertilizer applications during all years. Net ecosystem exchange of CO_2 (NEE_{CO2}) showed a common pattern of increased uptake of CO_2 in spring and reduced uptake in late fall. NEE_{CO2} dropped to zero and became positive after each harvest event. Methane (CH_4) exchange fluctuated around zero during all years. Overall, CH_4 exchange was of negligible importance for both the GHG budget and the carbon budget of the site. Our results stress the inclusion of grassland restoration events when providing cumulative sums of C sequestration potential and/or global warming potential (GWP). Consequently, this study further highlights the need for continuous long-term GHG exchange observations as well as for the implementation of our findings into biogeochemical process models to track potential GHG mitigation objectives as well as to predict future GHG emission scenarios reliably.

Keywords: Carbon budget, eddy covariance, global warming potential

The role of red clover, a forage legume, in mitigating nitrous oxide emissions from a perennial grassland

Bhattarai H. R.[1*], P. Manninen[1], S. Lind[1], P. Virkajärvi[1], H. Ruhanen H.[1], V. Nieminen[2], M. Kiljunen[3], S. Hallin[3], W. Wanek and N.J. Shurpali[1]

*[1]Natural Resources Institute Finland (Luke), Finland, [2]University of Jyväskylä, Finland, [3]Swedish University of Agricultural Sciences, Sweden, [4]University of Vienna, Austria.*Corresponding author: hemraj.bhattarai@luke.fi,*

Agricultural nitrous oxide (N_2O) emissions account for 60% of anthropogenic greenhouse gas emissions. For sustainable agriculture, it is essential to reduce the emissions of N_2O from agricultural soils. Leguminous crops are a crucial source of nitrogen (N) to the soil as they support the proliferation of N_2 fixing microbes in their root nodules. However, recently a leguminous crop, soybean, has been found to reduce atmospheric N_2O, suggesting that leguminous crops can perform the dual functions of fixing atmospheric N and consuming N_2O. This study suggests that soybean plants help reduce the requirement of plant N demand via biological N-fixation, and they can also reduce the agricultural N_2O footprint by supporting the N_2O respiring microbial communities in the root system. Besides leguminous food crops, various forage legumes are in use globally for sustainable and profitable forage production, and red clover (*Trifolium pratense*) is one such plant species. We hypothesized that red clover could exhibit a similar N_2O reduction potential, similar to soybean. Thus, as a part of the ENSINK project funded by the Academy of Finland in 2020, we aimed to assess and quantify the N_2O flux dynamics (gross emission and gross uptake rates) for different compartments (above-ground biomass, below-ground root, and root nodules, and soil influenced (rzhio vs. bulk) by the root-system of red clover using stable isotope techniques, $^{15}N_2O$ isotope pool dilution technique and ^{15}N tracer approach. To better explain the gross rates of N_2O flux, ENSINK further investigated the diversity and abundance of N_2O respiring microbial communities, microbes with *nos*Z genes carrying the nitrous oxide reductase (nor) enzyme in each of the compartments mentioned above. These assessments in ENSINK are carried out under both laboratory and field conditions. Here, we will present some preliminary results from the experiments conducted thus far in the project.

Keywords: Sustainable agriculture, climate change, short rotation legume grasslands, denitrification, nitrous oxide uptake, nitrogen cycle

Sustainability of boreal, mixed crop and livestock farming under changing climatic conditions

Shurpali N.[1*], H.R. Bhattarai[1], D. Forster[1], P. Manninen[1], S. Lind[1], A. Sairanen[1], M. Liimatainen[1], A. Mustonen[1], J. Rinne[1], O. Peltola[2], P. Korhonen[1], T. Palosuo[3], M. Järvinen[1], P. Virkajärvi[1], S.S. Sundet[2] and A. Kaukovirta[4]

*[1]Natural Resources Institute Finland (Luke), Finland, [2]Research Infrastructure Services, Finland, [3]Bioeconomy and environment / Ecosystems and modelling, Finland, [4]Production Systems, Luke, Finland. *Corresponding author: narasinha.shurpali@luke.fi*

A sustainable future for all requires that agricultural and food production systems be economically, socially, and environmentally sustainable, especially in times of crises (such as Covid, Conflict and Climate Change) in which supply chains may be threatened. Milk and beef production are the backbone of Finnish agriculture. Due to the restructuring of agriculture, the number of farms is decreasing, and their size is constantly growing in Finland. Nevertheless, the profitability of Finnish farms has remained low. New technology and scientific knowledge, together with public awareness and the growing demand for sustainably produced food, may benefit all stakeholders. The

challenge ahead is enormous, as it requires an understanding of the complexity of systems based on a robust research data synthesis. The necessary transformations require the design and implementation of comprehensive solutions. Such agricultural sustainability issues are being addressed at Luke in research projects funded by the Academy of Finland and the Finnish Ministry of Forestry and Agriculture under the 'Catch the Carbon' program. The overarching aim of our research is to provide research-based data that anticipates changes and provides solutions for milk and beef production in Finland to (1) reduce the total emissions of carbon dioxide and other greenhouse gases from grasslands and livestock (2) recommend best farming practices to increase carbon sinks and storage. Our research activities utilize the state-of-the-art GHG monitoring systems based on eddy covariance and chamber methods covering several agroclimatic zones in Finland, agroecosystem modelling, a systematic understanding of the soil processes involved in the production, consumption, and transport of GHGs, field lysimeters for studying soil nutrient leaching losses, use of digital technologies in agriculture, life cycle and socio-economic analyses of milk and beef production with links to leading dairy and beef industries in Finland. An overview of our ongoing research activities will be presented in this paper.

Keyword: Agroecosystem modeling, climate smart grassland management, GHGs, SOC sequestration, Eddy covariance

Posters

Increased severity and frequency of fodder production deficits under future climate conditions in Ireland

Leahy P.G.*, A. Wingler and K. Hickey

*[1]University College Cork, Ireland; *Corresponding author: paul.leahy@ucc.ie*

Irish agriculture is heavily centred on dairy and livestock farming, with the vast majority of the agricultural area used for grass production or rough grazing. The temperate and humid climate of Ireland is well-suited to grass production. Animals spend most of the year outdoors and grass silage is widely used as fodder. However, in recent years, several "fodder crises" have been reported, where fodder supplies run low resulting in threats to farms' economic performance and productivity and to animal health. Fodder crises are multifactorial in nature, but weather conditions at the seasonal or multi- annual scale are a significant driver. For example, severe shortages of fodder occurred in summer 2018, when warm and dry conditions between May and mid-July led to significant soil moisture deficits by mid-June, with deficits in the southeast of the country reaching over 95 mm. The total rainfall at the Enniscorthy station during the months of May, June and July was only 37% of the long-term average. This study uses simulated rainfall data from CMIP5 models (NorESM1-M model, RCP8.5 scenario) to examine changes in May-June-July rainfall between past (1981-2010) and mid- 21st century (2041-2070) climate change scenarios. The results show that events similar to that of 2018 will increase in frequency and severity by the mid-21st century. Average 2041-2070 May-June-July rainfall will decrease by c. 13% relative to 1981-2010. Rainfall values similar to those of the 2018 fodder crisis will become approximately twice as likely by 2041-2070. Grass-based agricultural systems in Ireland are therefore likely to become more frequently stressed in the future, and changes in management will be required in order to improve resilience to disruptions from extreme weather conditions.

Keywords: Fodder crises; resilient agriculture; climate change; grassland systems.

Availability of soil inorganic nitrogen under different grassland swards and nitrogen fertilizer treatments

Odetayo O.A.[1,2]*, C. Grace[2], J. Kennedy[2], R. De Goede[1] and E. Hoffland[1]

*[1]Wageningen University and Research, the Netherlands; [2]Devenish Research Development and Innovation, Ireland. *Corresponding author: omotola.odetayo@wur.nl*

Soil nitrogen (N) availability is important for promoting primary productivity in many agricultural systems. Multispecies swards, especially those with legumes, can increase the soil inorganic N pool either due to N fixation or higher biomass production, which may alter soil N availability. However, the extent to which multispecies grassland swards affect the soil N pool may depend on the type of N fertilizer treatment applied to the swards. In this study, the interactive effect of multispecies grasslands and different N fertilizer treatments on soil inorganic N (NO_3 and NH_4) was investigated in spring. We hypothesized that soil inorganic N will be highest in multispecies swards managed with inorganic N fertilizer. The hypothesis was tested in a grassland experiment established at Dowth, County Meath, Ireland and consisted of four sward types, namely: a six-species mixture, a twelve-species mixture, a highly species-rich native permanent pasture and a perennial ryegrass monoculture as baseline. Three N fertilizer treatments used in this experiment were: chemical N fertilizer, organic N fertilizer and a combination of both. All treatments were established on four replicated blocks (n = 48) in a randomized complete block design. In spring of the second experimental year, composite soil samples in the 0-10 cm layer were collected, extracted with 1M KCl and measured on a segmented-flow analyser. The effect of sward type and N fertilizer treatment as well as their interaction was tested on soil nitrate and ammonium concentration. There was a significant effect ($p<0.05$) of both sward type and N fertilizer treatment on nitrate concentration but no significant interaction between them. Nitrate concentration was highest in the chemical fertilizer treatment and the multispecies swards. These preliminary findings show that both sward type and fertilizer treatment influence the availability of soil inorganic N. However, the implication of these findings on N losses to the environment should be further investigated.

Keywords: Multispecies swards, Nitrogen fertilization, Soil nitrogen availability

Building drainage systems for the future: How drainage material selection plays an important role in optimal system functionality

Byrne, I. [1, 2], M.G. Healy[2], O. Fenton[1] and P. Tuohy[1]

[1]Teagasc, Ireland, [2]National University of Ireland, Galway, Ireland. Corresponding author: ian.byrne@teagasc.ie

On poorly drained farms in Ireland, stone aggregates are the only drainage envelope material used by contractors. Byrne et al. (2022) showed that the most popular drainage aggregate size available in quarries nationally is too large i.e. 50 mm. Such a size is likely to decrease system performance and the lifetime of these systems due to sediment ingress. The objectives of this laboratory study were to, a) select a gradation of aggregates suitable for use in clay textured soils, and b) assess the performance of commonly used aggregates based on their hydraulic and 'filter' function. A bespoke laboratory setup consisting of replicated units that contained clay textured soil with a series of aggregates size ranges was created. The treatments were 9 aggregates between the size range of 0.7 and 62 mm used in combination with a clay soil texture, replicated three times. Each unit had a 40 cm head of water and was maintained above the top of the soil surface for 38 days. The following parameters were measured: Flow rate of water through the drainage pipe outlet as an indicator to determine the hydraulic functionality of the envelope; total suspended

solids to determine the filter functionality of the envelope and destructive sampling of the envelope post experiment in order to determine the ingress of sediment into the envelope. Results showed that an aggregate of 0.7 – 3 mm performed best from a flow rate perspective. From a sediment loss perspective, the best performing aggregate was in the 2 – 10 mm range. Overall the results showed that an aggregate range from 2 – 10 mm is optimal for a clay textured soil. However, aggregate sizes up to 20 mm would be acceptable. The adoption of more appropriate material specifications will optimise performance and extend the lifetime of installed drainage systems in mineral soils.

Keywords: Drainage materials; Drain envelopes; Hydrology; Land use; Soil management.

Artificial drainage nutrient loss risk classification system for grassland farms to inform future mitigation management

Opoku, D.G.[1,2], M.G. Healy[2], O. Fenton[1], K. Daly[1], T. Condon[1] and P. Tuohy[1]

[1]Teagasc, Ireland, [2]National University of Ireland, Galway, Ireland. Corresponding author: daniel.opoku@teagasc.ie

Open drains are an integral part of any poorly drained grassland farm infrastructure. Drainage systems provide advantages in terms of managing the water table height to enable grass production, however they also create a conduit for nutrient [phosphorus (P) and nitrogen (N)] losses to receiving waters. Recently, a farm-scale connectivity risk ranking for P loss along agricultural open drains was developed. The objective of the current field study was to incorporate N into this classification system, while classifying the impacts from in-field drains, groundwater upwelling and spring interactions. This will help guide future agricultural open drain management. An extensive fieldwork campaign was conducted across 10 heavy textured soil farms. In each farm, open drain networks were mapped and ranked in terms of their connectivity risk of P and N loss. In-field drains and connectivity to open drains and outlets, and groundwater interactions were noted. Using this information, an overall conceptual picture of the dominant loss pathways for both P and N was developed for each site. Spatial and temporal water samples were collected at key locations along the network and analysed for dissolved reactive P, particulate P, nitrate and ammonium. All the data were transferred to GIS and an integrated map of each farm was developed. A new classification system for the entire drainage network will be presented.

Keywords: open drains, nutrient loss, open drain classification, heavy textured grassland, drainage management

Theme 3: Agro-Silvo-Pastoral Systems

Keynote presentation

Agroforestry - European extent, policy and climate change

Mosquera-Losada, M.R.*

*University of Santiago de Compostela, Spain. *Corresponding author: mrosa.mosquera.losada@usc.es*

Agroforestry, the combination of woody perennials and an associated herbaceous vegetation, is considered a sustainable way to manage farming systems by international bodies. The woody perennials can be either fruit trees, shrubs or forest trees. Agroforestry practices can be split into two main practices: alley cropping or silvoarable and silvopasture, that were extended to riparian buffer strips usually linked to the protection of water bodies, forest farming associated with forest lands and home gardens related to urban areas. The analysis of the extent of these practices shows that silvopasture is used in around 10% of the European Union, while alley cropping can only be found in the 0.01% of the EU. Agroforestry has a huge potential to increase biodiversity at plot and landscape level, as it generates spatially variable micro-sites with different microhabitat conditions that lead to the coexistence of a range of different species. For example, below a low-density tree stand the grass appears below the trees and the legumes far away from the tree due to the different temperature requirements (higher for legumes than for grasses) and the better fertility below the tree, a consequence of the higher litterfall. Biodiversity is a basis for mitigating climate change as several species may be better at efficiently using resources, including light, compared to a monoculture. The higher photosynthesis rate per unit of land found with agroforestry is associated with the large amount of leaves per unit of land, making it possible to increase the capture of CO_2 per unit of land, therefore increasing the potential of climate change mitigation compared with tree-less or monoculture systems. The increased biomass production per unit of land linked to the understory and overstory is the basis for increasing the amount of soil carbon, and contributes to mitigating climate change. Agroforestry is also a land use system that definitively helps to adapt the agricultural systems to climate change due to the capacity it has to modify the environment reducing the impact of high temperatures or the desiccating effect of wind.

Keywords: Biodiversity, species richness, CO_2 capture, climate change mitigation

Session III: Oral presentations

Increasing tree cover on Irish dairy and drystock farms: the main barriers and perceptions that impede agroforestry uptake

Irwin R.*

*Teagasc, Ireland. *Corresponding author: rachel.irwin@teagasc.ie*

Forest cover in Ireland is substantially lower than the European average with current afforestation rates remaining low. Although increasing tree cover on farms has been identified as a climate mitigation and adaptation strategy, current policy is failing to entice farmers and landowners to convert proportions of their land to forestry. Agroforestry has been cited as a means to increase sustainability and biodiversity at a farm level while allowing farming to continue on the same parcel of land. However, the lack of uptake of current agroforestry schemes highlights the fact that farmer

decision-making does not follow the assumed economic rationale. To better understand the factors that influence farmer decision-making with respect to tree planting on farms, the main attitudes, influencers, barriers and intentions of the farmers must be identified. To facilitate this, a research project with Teagasc and University College Dublin (UCD) has been set up to analyse farmers' perceptions of and attitudes towards planting trees on farms, and to understand their willingness to engage in this behaviour. The Theory of Planned Behaviour was used as the theoretical framework for the research and is a method used in many social-psychological studies to determine the reasoning behind a farmer's willingness to adopt specific practices. With a data set of 395 farmers distributed nationally across Ireland, the results of the study to date demonstrate that farmers are mainly driven by their attitude and moral norms that, in turn, are shaped through the views of influential people such as advisors and local farmers. The current method of increasing agroforestry uptake is mainly top-down driven and focused on the economic incentives currently in place. New methods to increase agroforestry should focus on encouraging people of influential status within the farming community to promote agroforestry, and through promoting co-design and co-creative systems.

Keywords: Agroforestry, theory of planned behaviour, perception studies, Ireland

Comparing the ameliorative role of corncob residue and its biochar for soil quality under drought conditions

Shahzad T.*, and Z. Zahid

*[1]Government College University Faisalabad, Pakistan. *Corresponding author: tanvirshahzad@gcuf.edu.pk*

Biochar amendment is proposed as a useful strategy to mitigate negative effects of drought on soil quality. However, the efficacy of biochar (BC) and its precursor feedstock to maintain soil quality under drought has not been compared so far. We amended a silt loam soil rich in SOC (~1.9% SOC) and another one poor in SOC (~0.9%) with 2% corncob residue or 2% corncob-derived biochar. Moreover, soil moisture was maintained at 30% or 60% of the water holding capacity (WHC) over 60d incubation. Residues significantly increased C mineralization by 217 to 285% across the soils and moisture contents. However, BC addition did not induce any significant change. Moreover, the response of SOC-poor soil to residues was more pronounced (by 25 to 32%) than SOC-rich soil in terms of C mineralization. Residues significantly increased microbial biomass C (MBC) by 19 to 42% in SOC-rich and 31 to 92% in SOC-poor soil, whereby MBC increased with moisture. However, biochar did not change in case of SOC-rich or induced a net decrease of 27 to 44% in MBC in the case of SOC-poor soil. These results show that the microbial activity as well as the MBC increased in response to the precursor residue addition instead of the biochar. β-glucosidase activity significantly decreased by 33 to 38% across soils and moisture treatments in only biochar amended soils. However, residue addition did not induce any change in the activity of this enzyme. Overall, leucine aminopeptidase activity was 40% higher in SOC-poor soil across the treatments than in SOC-rich soil, whereas it was 20 to 22% higher in residue-amended soils than BC-amended and control soils. This shows that the residue amendment fuelled the microbial activity where the microbes were actively mining for nitrogen. This result is also corroborated by the C mineralization and microbial biomass results. Overall, the results indicate that residues are a better option to make soils resilient against drought.

Keywords: Soil organic matter, extracellular enzyme activity, microbial biomass, C mineralization.

Changes in agricultural practices in southern Chile and their effect on greenhouse gas emissions

Meneses F., N. Montenegro and **J. Perez-Quezada***

University of Chile, Chile. Corresponding author: jorgepq@uchile.cl

In the Los Lagos region (southern Chile), agricultural and livestock activities represent 40% of greenhouse gas (GHG) emissions. Within this region, Chiloé island maintains agricultural traditions that have mixed with modern practices and today three types of agricultural systems coexist: traditional, conventional and agroecological. Our objectives were to describe the agricultural practices of the three different types of agricultural systems of Chiloé island and estimate their GHG emissions. Changes in agricultural practices were identified from bibliographic sources and surveys. To estimate the emissions of CO_2, CH_4 and N_2O, data were collected from 10 farms of each system in the area and used as input for the Cool Farm Tool (CFT). Observed changes are a) replacement of organic fertilizers and pest management products by chemical products, b) disappearance of the 'minga' (collaborative work) and replacement of the workforce by agricultural machinery, c) decrease in crop diversity, and d) decrease in agricultural land use. No significant differences were found in the GHG emissions, which on average were 2,999±1,521, 3,443±2,376 and 3,746±1,837 kg CO_2-eq ha^{-1} $year^{-1}$ (traditional, conventional and agroecological, respectively). This finding has been reported in other studies, as it seems that different agricultural practices have more influence on carbon absorption than on GHG emission. It is necessary to highlight the high emission from fertilization in the agroecological and traditional systems (due to high doses of fertilizers), the high emissions from livestock management in the conventional system (due to higher stocking rates), and finally, the difference in land area covered by agroecological, conventional and traditional systems, which are approximately 75%, 15% and 10%, respectively. Our study shows the need to identify those management practices that can help reduce GHG emissions.

Keywords: Carbon dioxide, Methane, Nitrous oxide, Agro-Pastoral systems, Potatoes, Livestock, Grasslands

Composting of animal mortalities – A sustainable solution for agro-silvo-pastoral systems

Kavasilis S.[1]*, M.K. Doula [2], A.A. Zorpas[1] and L. Cambanis[3]

*[1]Open University of Cyprus, Cyprus; [2]Benaki Phytopathological Institute, Greece; [3]L.Cambanis S.A., Greece. *Corresponding author: stamatios.kavasilis@st.ouc.ac.cy*

Animal mortality management is a difficult procedure and of doubtful appropriateness, mainly because the methods used are not environment friendly, are likely to disperse diseases to humans and animals, and do not promote the circularity of livestock units. The problem of unsustainable management is exacerbated by the lack of national and European legal frameworks, mainly due to pathogen content. Moreover, the management of plant raw materials from gardens, parks, and agroforestry systems is also difficult, due to their high lignin content and the lack of efficient management plans by local authorities. Recycling through composting is a brand-new approach for Europe and may contribute to protecting natural resources from pollution, increasing soil organic carbon, nutrient recycling, and promoting circularity of the Agro-Silvo-Pastoral systems. Thousand tonnes of organic matter are lost due to the improper management of animal mortalities. This study presents a composting methodology as a solution for managing animal mortalities and green wastes with the addition of natural zeolite. Composting of animal mortalities processes differently in comparison to common composting, i.e. no turning and no wetting until mortalities are

composted. Therefore, there is a high risk of producing compost with very high electrical conductivity. Clinoptilolite zeolite has proven to act as ion-absorbent in the literature when added to the feedstock. For this reason, zeolite was used in composting and, as the results revealed, the zeolite-compost was superior to the one produced without zeolite addition. Comparison of the compost properties with the EU standards for the safe use and application of composts/organic materials as soil amendments, indicates that the zeolite-compost can be used without any limitation on soil for plant growth or land rehabilitation. Moreover, the properties of zeolite compost fulfil the requirements for using compost as a growing medium, while the pathogen content (*Salmonella* spp, *Escherichia coli* and Enterobacteriaceae) was within the acceptable limits.

Keywords: composting, animal mortalities, green wastes, zeolite, circular economy

Developing a national monitoring programme for high nature value farmland and forest areas in Ireland.

Carlier J.[1]*, M. Doyle[2], J.A. Finn[3], E. Gill[2], D. O'Huallachain[3], S. Ruas[3] and J. Moran[1]

[1]Galway-Mayo Institute of Technology, Ireland, [2]University College Dublin, Ireland, [3]Teagasc, Ireland. Corresponding author: julien.carlier@gmit.ie

Conserving natural resources and halting biodiversity loss are key environmental objectives of the European Union. High Nature Value farmland and forest (HNVFF) areas are associated with high biodiversity and other public goods. They are headline indicators in Rural Development Programmes, and European regulation requires that HNVFF areas are identified and monitored. Currently, few dedicated HNVFF quality and quantity monitoring systems are implemented in Europe and none in the Republic of Ireland. Here, we present the proposed methodologies to monitor quality, quantity, and change of HNVFF areas in Ireland. The methods were tested using a set of monad sampling cells distributed across a range of representative landscapes in Ireland. Cell habitat cover maps were developed using OSi PRIME 2 and recent orthoimagery, and a subsequent update of the cell maps was performed using historical orthoimagery. This enabled a simulation of a temporal monitoring cycle to compare trends in HNV farmland and forest assessments and habitat change detection. A contrasting trend of decreasing HNV farmland and increasing HNV forest quantity was observed over this monitoring period. Categorical habitat change detection identified a range of HNV habitat loss and gain, driven predominantly by land use intensification, but also as a result of ecological succession and technogenic pressures. To upscale the monitoring to national scale, we also propose a sampling strategy using a novel landscape classification. Finally, we present indicative costs associated with implementing the proposed national HNVFF quality and quantity monitoring system. The designed and costed national monitoring approach presented aims to meet the needs of evolving policy requirements. This provides a useful example for other countries seeking to establish their HNVFF and other land cover monitoring systems.

Keywords: High nature value, land cover monitoring, land use change, rural development programme, landscape classification

Emerging trends in adaptive management of Mediterranean tree-grass livestock systems: monitoring pasture productivity and quality, and soil carbon sequestration

Moreno G.*, A. Carrascosa and V. Rolo

Universidad de Extremadura, Spain. Corresponding author: gmoreno@unex.es

Grasslands make up 46% of the global livestock feed intake. They are fundamental for extensive livestock production, especially for ruminants that can use cellulose-rich resources unsuitable for human foods, growing in lands unsuitable for cropping. Tree-grass agroecosystems (TGA), where scattered trees grow in grasslands, are gaining prominence as climate-resilient livestock production systems because they can provide an effective synergy between climate change adaptation and mitigation through diversification of forages and shelter for livestock and carbon sequestration respectively. With more than 3.5 million ha in Spain and Portugal, dehesas and montados are the best example of TGA in Europe, but unless changes are made to their management, they will continue to suffer from multiple problems that compromise their environmental and economic viability. In this work, we study 9 dehesa farms, comparing pasture production and quality, below- and above-ground functional trait composition, and soil respiration of dehesa plots with native grasslands managed with continuous vs plots managed either with rotational grazing or with permanent legume-rich pastures to explain changes in carbon sequestration. Preliminary results show that both sowing legume-rich pastures and introducing rotational grazing reinforce pasture production and quality, but also, soil respiration, with no significant increase in soil carbon for the moment. Plant functional traits also changed but in divergent and inconclusive directions, and dispersed trees have a buffering effect on the changes produced by the different types of management, favouring the maintenance of a high heterogeneity and the total functional richness of the system, especially in the pastures under a continuous grazing regime and in the dehesas with more unfavourable environmental conditions.

Keywords: Iberian dehesas, legume-rich pastures, rotational grazing, tree effects, soil respiration

Investigating below ground growth of forests on high pH soils and marl sites

Farrell J.P.[1,*] N.L. Wragg[2], B. Ruffing[1], S. Tracy S.[2], C. Harper[2], T. Cummins[2], M. Nieuwenhuis[2] and K.A. Byrne[1]

*[1]University of Limerick, Ireland; [2]University College Dublin, Ireland. *Corresponding author: jill.pitcherfarrell@ul.ie*

An investigation was conducted into soils with high pH material or marl - a calcareous deposit - and the performance of forest stands on such soils. This study included 19 forest stands and 6 species. Split-tube undisturbed root cores of 40 cm length and 7 cm diameter were collected to include the boundary between the calcareous layer and the soil above, predominantly peat. Cores were subjected to X-ray Computed Tomography (CT) scanning, capturing 3D images which were analysed to identify whether roots penetrate the marl. Analysis of root scanning images shows roots penetrate calcareous layers in certain circumstances as seen in Figure 1. The core break method, root washing and WinRHIZO^{TM} 2D scanning and software were also used to quantify the roots in each soil layer. Soil samples were collected at each site and pH, acid-neutralising capacity (ANC), organic matter, and soil water content were analysed along with testing for carbonates indicated by effervescence on applying dilute HCl. Soil pH ranged from 3.09 to 8.92. The effervescence class in the field correlated with pH and ANC as recorded in the lab. This is one of the first studies which applies X-ray CT to in-situ observations of tree roots in forests on peatland

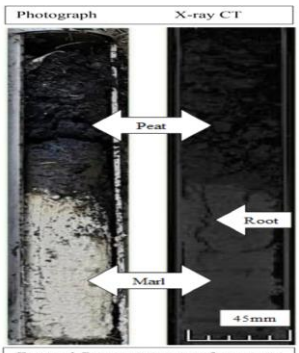


Figure 1 Root core images from a site planted with 27 year old Norway spruce

soils. X-ray CT analysis has the potential to increase our understanding of forests in Ireland, in particular root architecture and growth. It allowed us to understand the below-ground growth of the forest and the methodology was successful in many aspects. The coring was successful for most sites and yielded high quality images with roots and their structures visible as well as soil boundaries and soil pores. Combination analysis of the various methodologies and comparison of root images and soil properties allows for a deeper understanding than the interpretation of one set of results in isolation.

Keywords: X-ray Computed Tomography, Root Architecture, High pH, Split-Core Sampling, WinRhizo

Impact of ecological intensification of Mediterranean wood-pastures on carbon fluxes and functional diversity

V. Rolo*, A. Carrascosa[1] and G. Moreno[1]

*[1]INDEHESA – Forestry School, Universidad de Extremadura, Plasencia 10600, Spain *Corresponding author: rolo@unex.es*

Mediterranean wood-pasture, such as Spanish dehesas or Portuguese montados, are among the largest silvopastoral systems in Europe. Their annual carbon balance is largely controlled by the dynamics of the highly diverse herbaceous layer, mainly composed of annual species with a spring production peak. The low profitability of these systems has given rise to the adoption of a number of practices, such as rotational grazing and sowing of permanent legume-rich pastures, which aim is to intensify its usage but with uncertain consequences for the potential to sequester carbon by the herbaceous layer and their biodiversity levels. At the same time, less profitable farms are being abandoned. The aim of the present study was to assess the effect of grazing abandonment, rotational grazing and legume sowing on carbon sequestration potential and biodiversity levels of the herbaceous layer as compared to continuous grazing. We measured carbon fluxes, functional diversity, including above- and below-ground traits, and soil organic carbon during the peak of biomass production in a set of farms with continuous, rotational and abandoned grazing as well as in recently established and long-term legume sowing. Our results showed a significant effect of management on the gross primary production (GPP) of the herbaceous layer ($P < 0.001$). Plots under rotational grazing and recently established legume-rich pasture show a significant increase in GPP as compared with continuous grazing ($P = 0.002$ and $P < 0.001$, respectively) and an almost doubling of GPP of abandoned plots. This effect was accompanied by a significant increase in functional diversity levels, measured by Rao's Q diversity metric, ($P < 0.001$, respectively) and a slight increase in SOC, but without showing significant differences. Our results suggest that the ecological intensification of the dehesa may constitute a feasible option to balance environmental and economic challenges in an uncertain future.

Keywords: Adaptive management, legume-sowing, rotational grazing, functional diversity, gross primary production

Crop-livestock-bioenergy system for mitigation and adaptation to climate change in a rural smallholder farming setting in South Africa

Moeletsi M.E.[1]* and M.I. Tongwane[2]

*[1]Agricultural Research Council, South Africa, [2]Zutari, Riverwalk Office Park, South Africa. *Corresponding author: moeletsim@arc.agric.za/mmoeletsi@hotmail.com*

Agricultural productivity of smallholder farming in Sub-Saharan Africa is highly vulnerable to changes in climate and must be transformed for the enhancement of coping mechanisms. Climate-smart agricultural practices are needed for both adaptation and mitigation as well as improving food security. The study explores the use of biogas technology to support an integrated crop-livestock farming system that aims at improving the resilience of rural communities. A 6-12 m^3 biogas digester was installed at households with more than six cattle and a backyard field of at least 0.25 acres. Crops of dual benefit were planted with bio-slurry as a source of nutrients and fodder produced for cattle. This farming system has the potential of reducing greenhouse gas emissions from the use of electricity by up to 5% and significantly reducing the use of fuelwood, resulting in up to 2 tonnes CO_2 equivalence annually per biogas plant. The use of bio-slurry has an added mitigation potential of up to 0.5 tonnes CO_2 equivalence annually depending on the size of land and application regime. This significant potential decrease in the carbon footprint of farmers will make a positive contribution towards transforming farming to a low-carbon sector. Increased fodder and crop/vegetable production enhances food security at household level, thereby having a positive impact on the livelihoods of rural farmers. In conclusion, the crop-livestock-bioenergy system can be a solution to help smallholder farmers cope with climate change in areas where the environment is conducive and resources are available.

Keywords: Biogas, bio-slurry, greenhouse gas emissions, food security

The environmental consequences of addressing feed-food competition from Ireland's livestock sectors

Hennessy D.P.[1,2,*], I.J.M.K. de Boer[1] and L. Shalloo[2]

*[1]Wageningen University & Research, the Netherlands; [2]Teagasc, Ireland. *Corresponding author: donagh.hennessy@teagasc.ie*

Feed-food competition occurs when land that is suitable to grow food, is instead used to grow feed for livestock. As a consequence livestock production occurs, which reduces the amount of food produced from that land-area while engendering the negative environmental consequences associated with livestock production. Eliminating feed-food competition in livestock production can be seen as a strategy to reduce GHG emissions while maintaining and increasing the level of food production from our finite land-area. To this end, we have outlined the level of feed-food competition occurring in Ireland's livestock sectors; dairy and its beef, suckler beef, sheep, and pig production. Using the production of human edible protein (HEP) as a functional unit, we can demonstrate whether the livestock systems of Ireland (a livestock intensive agriculture sector) are demonstrably producing more HEP than we could have produced from an alternative crop rotation. We demonstrated that Ireland's dairy sector and sheep sectors are positive producers of HEP with a land-use ratio (LUR) of 0.61 and 0.92 respectively. The suckler beef and pig systems are engendering feed-food competition with their LURs of 1.25 and 1.73. However, these results show that there is a significant level of feed-food competition occurring and we must weigh whether such systems are suitable in our future food system. To this end, eliminating feed-food competition can ensure that all land and livestock are used as efficiently as possible. Ensuring that there is a role for livestock in a circular food system that uses low opportunity cost biomass (like pasture) as feed for livestock. Hence, we have engaged a general linear algebraic based optimisation model to

demonstrate the environmental effects of eliminating/reducing feed-food competition from Ireland's agriculture sector. This can demonstrate the environmental consequences of restructuring the feed systems that Ireland's livestock sectors are currently reliant upon.

Keywords: Greenhouse gas emissions, feed-food competition, land-use efficiency, optimisation modelling, circular food systems

Carbon monoxide fluxes from an intensively managed grassland using eddy covariance

Murphy R.M.[1]* G. Lanigan[1], M. Saunders[2] and N. Cowan[3]

*[1]Teagasc, Ireland, [3]Trinity College Dublin, Ireland. [2]UK Centre for Ecology and Hydrology, UK. *Corresponding author: rachael.murphy@teagasc.ie*

Carbon monoxide (CO) can influence the production of greenhouse gases (GHG) such as methane (CH_4) and ozone by reacting with OH radicals and thus controlling the oxidizing capacity of the atmosphere. CO fluxes were measured using a high frequency quantum cascade laser (QCL) and the eddy covariance method in 2019 (12 months) and 2020 (10 months) from a fertilized and grazed temperate grassland in south-west Ireland. A general additive model (GAM) which incorporated air temperature, photon photosynthetic flux density (PPFD) and water-filled pore space (WFPS) was used to gap-fill CO flux data. A diurnal pattern was observed in the flux data, more noticeably in 2019 compared to 2020, where baseline emissions of CO were elevated between 8 am and 6 pm, and additionally between 8 am and midnight in the spring and winter months. Such times coincide with periods of typically higher traffic and increase fossil fuel consumption during the colder months. Additionally, the GAM model showed less divergence with measured CO fluxes in 2020 relative to 2019 where there were less opportunities for contamination from adjacent sources to the field site due to a national lockdown in response to the COVID-19 global pandemic. Cumulative CO losses in 2019 and 2020 were 73.9 ± 37.9 mg CO-C m^{-2} yr^{-1} and 101.5 ± 27.6 mg CO-C m^{-2} yr^{-1}, respectively. Higher cumulative losses reported in 2020 relative to 2019 were due to higher CO uptake measured in 2019, which was also a drier year comparatively. While soils are typically considered a sink of CO, our results show that managed pastures can act as a source of CO, and suggest that the CO effect from soils as a secondary GHG may be similar to that of soil derived CH_4 and thus have implications for carbon budgets from managed grasslands.

Keywords: Keywords: CO, meteorology, greenhouse gases

Posters

Incidence of silvopastoral paddocks on the environmental performances of Sardinian dairy sheep systems

Arca P.[1], B. Arca[2], A.S. Atzori[3], A. Cannas[3], S. Contini[4], D. Cossu[2], M. Decandia[4], P. Duce[2], M.F. Lunesu[3], G. Molle[4], P. Sau[3], G.M. Serra[4], D. Usai[4], E. Vagnoni[2] and A. Franca[1]

*[1]CNR-ISPAAM, Italy, [2]CNR-IBE, Italy, [3]University of Sassari, Italy, [4]AGRIS Sardegna, Italy, [4]LAORE Sardegna, Italy. *Corresponding author: pasquale.arca@ibe.cnr.it*

In Sardinia (Italy), silvopastoral systems have an important socio-economic role providing rural territories with employment opportunities and a wide range of ecosystem services. The objective of this work was to analyse the relationship between tree coverage level and main productive and environmental performances of Sardinian dairy sheep farms. A survey of twenty-six farms resulted in a range of productive and environmental indicators. Farm paddocks were classified in nine different land uses from remotely sensed images. This classification allowed the identification of two farm categories, with 0-50% (G1 farms) or 50-100% (G2 farms) of the farmland area occupied by tree-covered paddocks. Specific farm data were collected in order to determine the Global Warming Potential (GWP), expressed as kg CO_2-eq/ha Utilized Agricultural Area (UAA). G1 farms were essentially treeless, with on average 15% of farm surface occupied by tree-covered paddock and predominance of treeless temporary grassland (83%). G2 farms were silvopastoral, with on average less than 45% of arable soils (temporary grassland with different level of tree density) and about 50% of permanent grasslands covered by trees. G1 farms showed flock size significantly greater than G2 farms, in terms of total mature ewes, replacement females and rams. Also, milk production level was significantly higher in G1 than in G2 (Tab.1). Finally, the GWP per hectare of UAA of the sheep farms with less tree coverage was significantly higher when compared to the farms with more tree coverage, since higher amount of livestock activities were concentrated in these areas. Our study shows that Sardinian dairy sheep systems characterized by a relevant incidence of tree coverage have significantly lower intense livestock activities and lower GWP per ha compared to farms with less tree coverage.

Percentage of farm land with tree coverage	G1 (0-50%)	G2 (50-100%)
Farms, N.	13	13
Ewes, N.	662a	351b
Replacement females, N.	168a	76b
Rams, N.	15a	8b
Utilized agricultural area (UAA), ha	100	88
Stocking rate, ewes/ha	6.4	4.6
Milk yield, kg FPCM/yr per present ewe	217a	141b
Global Warming Potential, kg of CO_2-eq/ha of UAA	4,618a	3,350b

Table 1. Dairy sheep farm characteristics and Global Warming Potential per hectare of UAA. Within rows different letters indicate significant differences at P<0.05.

Keywords: Global Warming Potential, tree coverage, silvopastoral systems.

Reviving drying water sources through aquifer-centric approaches based on geolithological and geohydrological studies in the Eastern Himalayas

Sharma G.*, M. Luitel, K. Nyima and D.P. Sharma

*The Mountain Institute India, India. *Corresponding author: banstolag@gmail.com*

Over the last couple of decades, agri-environmental stresses due to anthropogenic activities and climate change have resulted in rapid agricultural land-use change and productivity loss jeopardizing the food and environmental security of the Eastern Himalayan Region. Water scarcity due to the drying of springs/rivers/rivulets is one such critical issue. We carried out geolithological and geohydrological studies to identify catchments of springs/rivers/rivulets for their revival in Chibbo-Possyor (220-1252 m), Kalimpong, and Pendam (300-1852 m), in East Sikkim during 2017-2021. A hydrogeological cross-section demarcating the interbedded zones of compact and soft rocks was prepared along the NE-SW section using hydrogeological and geolithological techniques to map aquifers. Apparent dips were calculated and plotted for better understanding along the section. Seven aquifer zones were identified based on hydrological characters of the litho-units present in the Chibbo area. In Pendam, three main zones were mapped: first, comprising of hard and compact rock zone, referred to as confining base layer with a minimum fracture spacing and openings facilitating the accumulation of groundwater; second, soft rock zone, holding comparatively more groundwater; third, soft rock powdered shear zone holding maximum water-bearing capability. Thus, multiple layered aquifer systems were developed, and the catchments of water sources were identified for climate change adaptation measures (Dhara Vikas). The undulation of the beds, trellis drainage pattern, land subsidence, and recurring earthquakes reckon towards the role of tectonics in governing the regional structural setting of the study area. We used Dhara-Vikas to revive drying water sources. Of the total 93 critical springs identified, around 60% have been recorded with higher discharge rates during the dry seasons. Aquifer-centric approaches are successful examples to maintain water sustainability and improve agroecosystem productivity. Support for the establishment of water harvesting structures and livelihood diversification are options to bring about economic welfare to farming communities in the region.

Keywords: Geohydrology, geolithology, climate change adaptation, aquifer-centric approaches, d*hara Vikas*

The ReLive Project

Osborne B.[1], M.I. Khalil[1,2], K. Klumpp[3], B. Kruijt[4], P. Gottschalk[5], G. Moreno[6], O. Valta[7,] A. Walkiewicz[8], L. Hallik[9], J. Herron[10], T. van der Weerden[11], J. Perez-Quezada[12], R. Kroebel[13]

[1]University College Dublin, Ireland, [2]Prudence College Dublin, Ireland, [3]INRAE, France, [4]Wageningen University, the Netherlands, [5]GFZ Potsdam, Germany, [6]Universidad de Extremadura, Spain, [7]Avoin Association, Finland, [8]Polish Academy of Sciences, Poland, [9]University of Tartu, Estonia, [10]Teagasc, Ireland, [10]AgResearch, New Zealand, [12]University of Chile, Chile, [13]Agriculture and Agri-Food Canada, Canada. Corresponding authors: bruce.osborne@ucd.ie; i.khalil@prudencecollege.ie

The widespread reintegration of crops and livestock could make a major contribution to the development of the wider EU circular (agricultural) economy and contribute to sustainable growth, through the more effective recycling of materials and resources, the minimization of waste, and a reduction in external supplies of feed and synthetic fertilizers, with potential biodiversity, environmental and soil health benefits. However, this comes with significant challenges, including the potential for enhanced methane emissions, from enteric fermentation, land degradation due to over grazing and water pollution as well as the need to substitute all/most inorganic fertilizers with

organic manures. Organic amendments applied to land could also result in enhanced nitrous oxide emissions, unless these are managed appropriately and the necessity to store large amounts of organic manures/wastes may also be problematic. Additional complications could arise due to associated modifications in land use, including a shift to a forage/alternative crop-based diets, and altered grazing practices. Another key issue is the economic consequences of reintroducing livestock and the appropriate incentives that are available to farmers. Whilst mixed farming systems were previously common and economically viable, new developments will require them to be matched with current production and market conditions and suitable value chains and business models to ensure their long-term viability. To address this, we have assembled a multi-actor inter-disciplinary research team, with wide ranging expertise in the whole animal-crop supply chain and its environmental and economic impacts, where we will take a holistic approach to the sustainable reintegration of livestock and cropping systems

Keywords: Livestock, crops, greenhouse gas mitigation, circularity, resilience

Theme 4: Decision Support Systems

Keynote presentation

Decision support in the digital agriculture era

Janssen S.*

*Wageningen University & Research, the Netherlands. *Corresponding author: sander.janssen@wur.nl*

Digital technologies, such as artificial intelligence, sensors, data analytics and big data, are developing rapidly and are also being used more frequently across sectors, with different speeds of uptake and development. The application and integration of these technologies in agriculture is often called digital agriculture, or digitization of agriculture. These technologies contribute all in their own way to the digitization of agricultural systems, in which management decisions can become more and more supported by data or insights from data. It is not such that one of these technologies will lead to the digital transformation, but their integration will gradually change how decision making by actors in agriculture is happening and which tools they are using. Traditionally decision support systems in agriculture have provided such functionality to support decision making, and through user interfaces offered functionality in accessing model results, data analysis and scenario tools. Thereby these decision support systems offered opportunities to deliver science to decisions. With the advance of digital technologies, it is timely to re-think the position and development of decision support systems. Such decision support systems could greatly benefit from having more data available and having more advanced algorithms and analytics integrated. However, this will only happen if the decision support systems themselves also evolve in the role they play in the wider actor network, how they are accessed, and when they are accessed. This contribution will explore some of the trends occurring behind this new role for decision support systems and provide some practical examples from the Netherlands of what sort of analysis will become possible and might be meaningful into the future.

Keywords: Digital agriculture, Data analytics, management decisions, decision support systems

Session IV: Oral presentations

Lowering the carbon footprint of milk production: a life cycle assessment of European dairy farms

Sorley M.[1,2], I. Casey[2], D. Styles[3], P. Merino[4], H. Trindade[5], M. Mulholland[6], C. Resch Zafra[7], R. Keatinge[8], A. Le Gall[9] and J. Humphreys[1]

*[1]Teagasc Moorepark, Ireland, [2]Waterford Institute of Technology, Ireland, [3]University of Limerick, Ireland, [4]Basque Institute for Agricultural Research and Development, Spain, [5]Universidade de Trás-os-Montes e Alto Douro, Portugal, [6]College of Agriculture, Food and Rural Enterprise, UK, [7]Instituto Galego de Calidade Alimentaria, Spain, [8]Agriculture and Horticulture Development Board, UK, [9]Institut de l'Elevage, Monvoisin, France. *Corresponding author: marion.sorley@teagasc.ie*

The objective of this study was to compare carbon footprints (CF) of European dairy farms using life cycle assessment (LCA). Data was collected on a monthly basis over two years from 71 commercial dairy farms in Ireland, Northern Ireland, England, Spain (Galicia and Basque Country), France and Northern Portugal. The emissions up to the point of sale of milk from the farm were

calculated within a global boundary. The functional units were: (i) per kg fat and protein corrected milk (FPCM); (ii) per hectare of the farm exporting milk; (iii) per hectare of global land use. Farms were categorized based on the proportion of time that cows spent grazing and mean carbon footprints were 1.13, 1.23 and 1.49 kg CO_2-eq./kg FPCM for grazing (>60% grazing; n = 16), mixed (15 to 60% grazing; n = 17) and confinement systems (0% grazing; n = 38), respectively. Although the grazing group of farms had the lowest mean CF, the confinement group had the largest range; between 0.92 and 2.49 kg CO_2-eq./kg FPCM and included the farm with the overall lowest CF. The confinement group had the highest mean CF: 43.13 t CO_2-eq. per hectare of the farm exporting milk, followed by mixed (15.11 t/ha) and grazing (11.62 t/ha). There was the same ranking per ha of global land for confinement (14.81 t/ha), mixed (9.78 t/ha) and grazing (9.25 t/ha). There was large variation in the CFs of these farms indicating considerable potential to identify best practices for lowering emissions in terms of both product and area-based functional units.

Keywords: Life cycle assessment, carbon footprint, dairy production

Key performance indicators to foster grass-based business innovation in European rural areas (GO-GRASS)

Mosquera-Losada M.R.[1]*, J.J. Santiago-Freijanes[1], N. Ferreiro-Domínguez[1], T.I. Franco-Grandas[1], V. Álvarez-López[1], R. Orozco[2], M.E. Adamseged[2], P. Grundmann[2] and F.J. Rodríguez-Rigueiro[1]

*[1]University of Santiago de Compostela, Spain [2]Leibniz Institute for Agricultural Engineering and Bioeconomy, Germany *Corresponding author: mrosa.mosquera.losada@usc.es*

The European Commission acknowledges the capital role of rural areas in the bioeconomy and climate change mitigation and adaptation through the EU Green Deal and Common Agricultural Policy, becoming potential spots for circular economy development, biodiversity protection and renewable energy sourcing (EC 2019). The GO-GRASS project aims at creating new business opportunities in rural areas based on grassland and green fodder, considering the replication potential of studied demonstration sites. Concretely, this study aimed to develop a list of common Key Performance Indicators (KPIs) for the successful implementation of grassland business models. To obtain the KPIs, a four-step approach was performed including (i) value chain description of 15 successful grass-based businesses (ii) survey seeking farmers' contribution as grass suppliers of the case studies (iii) desktop study comparing relevant KPI systems - SAFA, GRI and RUBIZMO – and, finally, (iv) expert's input for scoring each indicator considering rural EU environment/strategies. As a result, a set of 24 KPIs was obtained including eight economic, ten environmental and seven social indicators. Both economic and environmental KPIs coming from SAFA/GRI indicators were considered adequate while the social ones were found not so relevant since social rights contemplated are broadly established in Europe. Two economic indicators were found relevant for investment (net income and cost of production), three linked to vulnerability (product diversification, procurement channels and stability of supplier relationships), two for product quality and information (product labelling and certified production) and one for local economy (local procurement). As social indicators the following stand out: wage level, capacity development, fair pricing and transparent contracts, rights for suppliers, youth employment and job creation. Finally, environmental indicators were related to atmosphere (GHG reduction target and GHG mitigation practices), water (wastewater quality and soil improvement practices), land (net loss/gain of productive land and ecosystem enhancing practices), biodiversity (land use and land cover change), materials and energy (material consumption practices, renewable energy use target and energy-saving practices).

References

EC (2019) Communication from the commission to the European Parliament, the European Council, the Council, The European Economic and Social Committee of the Regions. The European Green Deal. Brussels.

Keywords: Bioeconomy, circular economy, SAFA, GRI, green deal.

Quantifying negative radiative forcing of non-permanent and permanent soil carbon sinks

Leifeld J., [1],* and S.G. Keel[1]

*[1]Agroscope, Climate and Agriculture Group, Zurich, Switzerland. *Corresponding author: jens.leifeld@agroscope.admin.ch*

Reversibility of soil carbon sinks is a major obstacle in assigning soil carbon sequestration as negative emission technology and it is still unclear how a non-permanent CO_2 removal shall be accounted for. In this study, we combine various scenarios of reversible and non-reversible soil carbon sinks with atmospheric CO_2 impulse response functions and calculations of the resulting radiative forcing. A time horizon of up to 500 years was considered. Results show that any soil carbon sink generates negative radiative forcing (i.e., cooling) when aggregated over longer time scales. Whereas also non-permanent CO_2 removals from the atmosphere provide negative average radiative forcing, their effect is substantially smaller than that of permanent removals of the same magnitude. We show that the average annual soil organic carbon balance over the integrated time window largely determines the average radiative forcing independently of rates of carbon gain or loss and longevity of the sink. This basic principle allows an unbiased assessment, comparison, and rating of mitigation measures that take advantage of soil carbon. The suggested approach is based on quantitative and relatively simple metrics and may therefore support guidance to climate policies and soil carbon markets.

Keywords: Soil carbon sequestration, impulse response function, carbon market, mitigation, CO_2

LIFE AGROGESTOR, a digital platform ecosystem for on-farm best crop decision in fertilization, irrigation, GHG and economic assessment, with sustainability objectives

Unamunzaga O.[1*] O. del Hierro[1]; A. Aizpurua[1], A.P. Armesto[2], M. Goñi[2], M.P. González-Dugo[3], H. López[4], A. Olivas[4], F. Jara[4], J. Doltra[5], A. Del Rey[7] and R. Romero[6]

*[1]NEIKER, Spain; [2]INTIA, Spain; [3]IFAPA, Spain; [4]ITAP, Spain; [5]IRTA, Spain; [6]AEMET, Spain; [7]PRODEVELOP, Spain. *Corresponding author: ounamunzaga @neiker.eus*

The European Green Deal is the EU's climate policy and growth strategy for Europe to become the first climate-neutral continent by 2050. In this new framework, the LIFE AGROgestor project has developed digital advisory tools and promoted good practices, through collective information management, aligning with the EU's Farm to Fork strategy. The LIFE AGROgestor project has developed an innovative Digital Platform Ecosystem based on the digital integration of information introduced by farmers using the AGROasesor platform and connected to the AGROgestor platform that allows collective management of defined management areas. These platforms use realistic and measurable environmental, economic and technical indicators, and promote multi-actor advisory ecosystems that integrate farmers as the source of knowledge and digital data of their farms. AGROgestor provides tools for optimal on-farm decision management in terms of fertilization, irrigation, and crop management, considering environmental and economic objectives. For that, 31 realistic and measurable environmental, economic and technical indicators have been developed. LIFE AGROgestor demonstrated the feasibility of using INDICATORS in 3 environmental pilots with a total of 266 Spanish farms comprising around 11.000 ha/year during 2018, 2019 and 2020. The irrigation water use efficiency, and the quality of water masses were

evaluated using digital technologies and earth observation data. Environmental benefits of the proposed management practices were assessed through these key indicators: water consumption and carbon footprint for each product. Thus, a 22% improvement in water consumption per tonne and a 25% improvement in CO_2 eq emissions per tonne produced were measured. In addition, in the pilot areas both N and P surpluses were lower at the end of the project and improved the EUROSTAT indicators for Europe and Spain, therefore clearly reducing the risk of nitrate leaching. The use of environmental indicators in expert advisory platforms represented a clear tool for improving input use, resulting in greater farm sustainability.

Keywords: DST model, GHG emissions, FaST, nutrient balance, water balance, crop monitoring, remote sensing.

Assessing greenhouse gas predictions with accessible tools for on-demand model-data synthesis: The Predictive Ecosystem Analyzer (PEcAn)

Cowdery E.[1*], D. Cameron[2], P. Smith[3], M. Aitkenhead[1], D. Donnelly[1] and J. Yeluripati[1]

[1]The James Hutton Institute, UK, [2]Centre for Ecology and Hydrology, UK, [3]University of Aberdeen, UK. Corresponding author: elizabeth.cowdery@hutton.ac.uk

Ecosystem models play a critical role in understanding the terrestrial biosphere and forecasting greenhouse gas (GHG) emissions, however current forecasts have considerable uncertainty. The amount of scientific data being collected and produced is increasing on a daily basis, but only a fraction of this data is being used to constrain models. Until we can improve the problems of model accessibility and model–data communication, none of these resources can be used to their full potential. The Predictive Ecosystem Analyzer (PEcAn) is an ecoinformatics toolbox and a set of workflows that wrap around an ecosystem model and facilitate the flow of information in and out of regional-scale ecosystem models. Here we present the modules developed in PEcAn that manage the processing of model initialization/parameterization data and meteorological drivers. In addition, we showcase modules used to bring model output and data together for validation and benchmarking. These PEcAn workflows have been coupled with the James Hutton Institute RETINA Project. We synthesise sensor driven measurements of soil and climate data from our Monitoring, Reporting and Verification (MRV) system implemented at the farm level to quantify changes in soil carbon change and GHG emissions as well as landowner/farmer management information from the RETINA app with three biogeochemical models DNDC, ECOSSE and BASGRA to produce dynamic and iterative crop yield forecasting. By running multiple models with alternative land management scenarios we are able to 1) quantify across-model predictive variability and 2) predict the effects of land management decisions. These results will inform the

RETINA decision support system which will provide novel solutions for farmers and policy makers in support of net zero GHG emissions for Scotland (2045) and the wider UK (2050).

Keywords: Soil carbon, monitoring reporting and verification, modelling GHG emissions, real time monitoring, climate change, netzero

Canada's whole-farm model Holos, the national GHG inventory applied to the farm-level

Kröbel, R.*, S.J. Pogue, A. McPherson and P. Mantle

[1]Agri-Food Canada, Canada, Corresponding author: roland.kroebel@agr.gc.ca

The Holos model is Agriculture and Agri-Food Canada's attempt to provide Canadian farmers with a software application that permits the investigation of the effect of management practice choices on farm greenhouse gas (GHG) budgets. For that purpose, the model aligns with and is built upon the assessment methods of the Canadian National GHG inventory. The model accounts for all field crops and livestock grown in Canada and provides regionally representative input defaults. The interface is designed to request data that are readily available on farms (rather than requiring laboratory analyses), but also offers a level of complexity and adjustability for more in-depth simulations.

Keywords: Canadian agriculture, whole-farm analysis, farm GHG budget, model development, stakeholder involvement

Terrain-AI: Platform for the estimation of the crop growth, water and CO_2 fluxes from Irish Croplands

Upreti D.*, T. McCarthy and R. Fealy

*[1]Maynooth University Kildare, Ireland. *Corresponding author: deepak.upreti@mu.ie*

Terrain-AI (T-AI) is a collaborative research project which is focussed on improving our knowledge and understanding of land use activity - as this relates to climate change. To optimise sustainable land use, it is essential that we develop tools and information services that can inform more effective and sustainable management practices. The objective of this research is to integrate a national network of benchmark sites and a digital data platform capable of integrating, analysing and visualising large volumes of Earth observation data-streams, including data from satellites, drones and on-site measurements and integrating these datasets into appropriate modelling approaches to simulate greenhouse gas fluxes, sources and sinks. The overall aim of T-AI is to increase our understanding of how management practices can influence carbon emissions arising from the landscape. As part of T-AI, we are using a range of model-based approaches, including empirical and dynamical models, to generate estimates of the energy, water and CO_2 fluxes over croplands. Building on the SAFY-CO_2 model framework proposed by Pique *et al.* (2020), we employ a light use efficiency-based modelling approach with modules for soil water balance and carbon fluxes. Observations from Sentinel-2 are ingested into the model in the sequential based data assimilation framework. ERA-5 Land Reanalysis data was processed for use as weather inputs. The model is subsequently evaluated at a selection of benchmark sites using eddy covariance flux tower data. In general, improvements on the simulated data could be observed. Due to cloud cover all over the year, limited remote sensing data was available and may have hindered the performance of the assimilation. The results of the data processing need to be further investigated with other sites.

Keywords: SAFY model, GAI, biomass, yield, CO_2 fluxes, evapotranspiration

Evaluating GHG simulation performance of DNDC in a boreal grassland setting

Forster[1]* D., J Deng[2], M Harrison[3], N Shurpali[1]

*[1]Natural Resources Institute Finland (Luke), Finland, [2]Princeton University, USA, [3]University of Tasmania, Australia. *Corresponding author: daniel.forster@luke.fi*

Food production in boreal regions is tending to expand into areas previously considered unproductive as a result of climate change. With increasing human populations and uncertainty regarding existing supply chains as well as the long-term viability of traditional bread-basket regions, northern countries are increasingly looking to their own under-exploited resources to increase food security. This is not without its risks, and mismanagement can cause stable carbon sinks to become sources due to land-use change. Agroecological models are an important tool for assessing the long-term effects of management, yet in boreal regions their use has so far been limited and model evaluations have only been carried out in a handful of instances. One reason for this is the limited availability of measured data against which to effectively compare simulated data. To overcome these obstacles, we used existing eddy-covariance measurements to evaluate the ability of the process based DNDC model to simulate GHG emissions from a timothy/red clover grassland in eastern Finland over a 4-year period. These initial results suggest that DNDC is able to simulate gross primary production (GPP) R^2 = 0.68, MAE = 14.4, RMSE = 26.6 and rBIAS = -30.8%, net ecosystem exchange (NEE) R^2 = 0.54, MAE = 12.7, RMSE = 20.2 and rBIAS = 16.4%, and ecosystem respiration (Reco) R^2 = 0.74, MAE = 11.35, RMSE = 15.43 and rBIAS = -41.2%. We then used an assessment criterion scoring method, where “poor” = 1, “fair” = 2, “good” = 3, and “excellent” = 4 for each evaluation method. Using this method, we determined that GPP and NEE simulations were “fair” whereas Reco was “good”. These results indicate that DNDC can satisfactorily simulate GHG fluxes in a boreal grassland setting but further work is needed to refine model calibration and evaluation methods.

Keywords: Ecophysiological modelling, boreal agriculture, greenhouse gases, model evaluation, DNDC

Potential of acoustic indices to assess biodiversity levels and predict endangered species habitat suitability

Parisi A.[1*], Moran J.[1], Carey J.[2], O’Brien J.[1]

[1]Galway-Mayo Institute of Technology, Ireland, [2]National Parks & Wildlife Service, Ireland. Corresponding author: andrea.parisi@research.gmit.ie

Bioacoustics is a long-term and unbiased monitoring tool to assess biodiversity. Acoustic indices can rapidly estimate the complexity and diversity in the soundscape that reflects the status of the ecosystem, and algorithms can be used to detect and count vocal species. Biodiversity monitoring is particularly relevant for conservation projects of species of conservation concern, such as the corncrake (*Crex crex),* locally endangered as Western European populations are declining. The Corncrake LIFE project works with farmers to improve meadow management, delay mowing, and create early and late cover (ELC) plots as habitats for breeding corncrakes and other species. Farmers are paid on a result-based system, meaning the field ecological quality scores determine their payment. Long-term, large-scale monitoring is required to complement the visual ecological assessments to ensure they reflect the improved population status of target species. We deployed sound recorders and tested the variation of five acoustic indices in (i) fields managed for the corncrake, (ii) with an ELC plot, and (iii) with calling corncrakes. Analysing one thousand hours of recordings, we found higher mean values of indices in fields with positive interventions and calling corncrakes (NDSI=0.18, ADI=0.60, BI=75.90) than in fields where features and corncrakes were

missing (NDSI=0.11, ADI=0.26, BI=53.46). High values of these indices correspond to mean low anthropogenic disturbance, high acoustic diversity and occurrence of biological sounds. We found that the average number of bird species detected was higher in sites with positive interventions (25) and calling corncrakes (27), compared to sites where positive interventions (21) and corncrakes (18) were missing. These preliminary results suggest that fields managed for the corncrake and areas with ELC plots are more acoustically diverse and biologically active. Acoustic indices and automated species detection may be effective tools to assess biodiversity associated with the corncrakes and other species of conservation concern in Ireland.

Keywords: Biodiversity assessment, soundscape ecology, acoustic indices, species conservation

Simulating N_2O emissions from cattle urine patches using the 'ecosys' ecosystem model

Kuntu-Blankson K.[1,2*], L. Barczyk[1,2], C. Ammann[1], J. Six[2], S. Mezbahuddin[3], R.F. Grant[3] and P. Calanca[1]

*[1]Agroscope, Switzerland, [2]ETH Zürich, Switzerland, [3]University of Alberta, Canada. *Corresponding author: kate.kuntu-blankson@agroscope.admin.ch*

Excreta return from livestock grazing is a major contributor to nitrous oxide (N_2O) emissions from grasslands. Cattle urine-patches have high nitrogen (N) amounts making them hotspots for N_2O emissions. The grazing related (excreta return) emission factor (EF_3) defined by the IPCC Tier 1 guidelines is a worldwide default of 2%. However, given the multitude of local environmental factors (soil, climate and management type) that control the microbial processes of N_2O production and consumption, more specific EF are nowadays recommended for N_2O emission reporting. The adoption of ecosystem models for investigating and simulating the complex interactions of soil processes is widespread and well documented. In this work, we use ecosys, a comprehensive, process-based, hourly time step ecosystem model to simulate N_2O emissions from cattle urine patches on grazed grasslands as a step towards inferring Swiss country-specific EF_3 values. In a first-step, we set up ecosys to represent urine-N as a fast hydrolysis urea fertilizer option with an added amount of water via irrigation. We tested this urine-setup against an artificial urine-patch field experiment conducted in the summer of 2020 in Eastern Switzerland. A urine-N input of 200 g N m^{-2} and 20 mm of water was applied after a vegetation cut event. The modelled output shows a total of 2.5 g N m^{-2} N_2O emitted over two months. The corresponding modelled EF of 1.3% is in close agreement with the measured value of 1.2%, both of which suggest a revision to the use of the Tier 1 default of 2%. Further sensitivity tests on the responses of urine-patch N_2O emissions to changes in management and environmental conditions (climate and soil) provide a starting point for discussing variations in urine-N N_2O EF across Switzerland and ways to improve the country-specific emission factor.

Keywords: N_2O emissions, N_2O modelling, urine Patches, grazed Grasslands

Mathematical modelling of a full-scale biogas plant co-digesting cattle slurry and grass silage

Tisocco S.[1,2], P. Crosson[1] and X. Zhan[2, 3]

*[1]Teagasc, Ireland; [2]National University of Ireland, Galway; [3]SFI MaREI Research Centre, Galway. *Corresponding authors: s.tisocco1@nuigalway.ie; xinmin.zhan@nuigalway.ie*

Livestock farming generates a large amount of animal slurry which gives rise to emissions of greenhouse gases (GHG), predominantly in the form of methane. Anaerobic digestion (AD) of

slurry is an effective way to reduce GHG emissions by producing biogas, which is a renewable energy source. Biogas plants convert various agricultural by-products and wastes into biogas. In Ireland, cattle slurry and grass silage are two of the main organic substrates available for AD. However, there is little information about the biogas production from cattle slurry and grass silage when co-digested on a large scale. In this regard, mathematical modelling is a powerful tool to evaluate the process and predict the dynamic behaviour of the system. The Anaerobic Digestion Model No. 1 (ADM1) is a widely used model which describes the biochemical and physicochemical processes involved in AD. However, an extensive characterisation of the substrates and numerous parameters are required for model implementation. Hence, the objective of this study was to refine ADM1 by simplifying the biochemical processes of acidogenesis and acetogenesis, and to apply the model to improve the understanding of the co-digestion of slurry and grass silage in an operating biogas plant. In the simplified model, polymers in the substrates were assumed to be hydrolyzed to acetic acid, which is finally transformed into biogas (composed of carbon dioxide and biomethane). Thus, the number of processes, parameters and model components was reduced by half. For model calibration, three months of daily operational data for a 650 m^3 reactor co-digesting 20 m^3 d^{-1} of cattle slurry and 3-4 tonnes d^{-1} of grass silage was simulated. The Nash-Sutcliffe efficiency coefficient (NSE) was implemented to evaluate the model efficiency. The values obtained were 0.70 and 0.68 for biogas and biomethane production, respectively. These results suggest that the model is adequate to characterise the process.

Acknowledgement: This research is funded by Teagasc Walsh Scholarship Programme (Ref: 2021010).

Keywords: ADM1, anaerobic co-digestion, agricultural feedstocks, full-scale, modelling.

Posters

Facilitating the decision-making required to minimize the climatic change impact on a semi-arid zone: results of the AMDRY-C4 LIFE PROJECT.

Martínez-Sánchez M.J., S. Martínez-López, L.B. Martínez-Martínez, M.C. Gómez-Martínez, M. Hernández-Cordoba, E. Jordan and C. Pérez. Sirvent*

*[1]Universityof Murcia, Spain.*Corresponding author: melita@um.es*

Mediterranean rainfed soils, which are subject to climatic stress, constitute a suitable scenario for the use of a methodology that uses an indicator of the ecosystem services provided by these soils. This indicator will in turn be used to calculate a climate adaptation indicator and provide a very useful monitoring tool for decision-making and the incorporation of mitigation measures. Different indicators are used for this purpose: a) indicator of the desertification of the territory, obtained from the environmental indicators of the chemical degradation of soils (salinity, alkalinity, macronutrient fertility, micronutrient fertility, phytotoxicity) and erosion, b) biodiversity indicator (vegetation indices, Shannon-Weaver, Simpson indices, etc.) and c) organic carbon indicator. The sum of these indicators makes it possible to calculate the soil ecosystem services indicator (SEI). To obtain the Climate Adaptation Indicator (CAI), SEI is summed with a transformational indicator called Mitigation Indicator (MI), calculated on the basis of the increase of organic C in the soil over a predetermined period of time. Within the LIFE AMDRYC4 project, work has been carried out on four plots and with a number of sampling points varying between 40 and 90 points per plot, providing organic matter from different origins. The use of drones equipped with multispectral cameras allows soil reflectance data to be collected in different wavelength bands and compared with soil organic carbon values obtained manually in the field. The correlation with transmittance values in the near infrared (NIR) allows a model to be obtained that can be applied to other areas

with similar characteristics. The first results show correlation coefficients ranging from 0.4 to 0.7, but there are still some uncertainties that make it advisable to carry out a fourth sampling to confirm the definitive model.

Keywords: Environmental indicators, ecosystem services, near infrared, soil organic carbon, remote sensing.

Irish Farmers' position on Greenhouse Gas Emissions: An insight into representation, perceived trust and worry

Sinnott Ú.[1,2]*, James Breen[1] and Dominka Krol[2]

[1]University College Dublin, Ireland, [2]Teagasc, Ireland. *Corresponding author: una.sinnott@ucdconnect.ie

This research brings unique questions to the fore and analyses the influences behind an Irish farmer's level of climate action. With a particular focus on emotive factors, this work allows for a cross sector analysis in Ireland and highlights the role of differing farming motivations for the uptake of low-carbon practices. Therefore, this work is crucial to the future uptake and continuing progress which agriculture across Europe is making towards low emission food production. Discussions which specifically relate to trust among society, level of personal worry and the feeling of being represented/understood draw the most valuable conclusions of all. This research showcases matters such as trust, representation, level of worry and climate awareness among Irish farmers. The research shares valuable insight into the differences observed between farmer demographic, farmer characteristics, farm size, farm type and regional location. The key findings from this work are of particular interest to policy makers, agricultural economists, agricultural advisors, extension services and fellow researchers.

Keywords: Greenhouse Gas Emissions, Irish Agriculture, Agricultural Extension Services, Low Emission Food Production, Behavioural Economics

Estimation of plant nutrient status based on hyperspectral data and machine learning

Siedliska A.*, Baranowski P. , Krzyszczak J. , Supryn G.

*Institute of Agrophysics of Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin, Poland, *Corresponding author: a.siedliska@ipan.lublin.pl*

Potassium (K) is a macronutrient that is crucial for plant growth and development. It plays a key role in many physiological and biochemical processes, such as photosynthesis, osmoregulation, transport of metabolites, synthesis of enzymes, proteins, starches and cellulose and plant stress alleviation. The monitoring of potassium content in plants and soil as well as efficient application of mineral nutrients are crucial for ensuring crop yield and for minimizing the negative environmental impact of fertilization. Conventional laboratory methods for quantifying and monitoring essential nutrients in plants are time consuming, expensive and require sample destruction, and thus cannot be used on a large scale. The hyperspectral imaging technique, which integrates conventional imaging and reflectance spectroscopy to obtain both spatial and spectral information from an object, provides the opportunity to monitor the nutrient status of plants. The main objective of this study was to investigate the potential of the hyperspectral imaging method for discriminating potassium concentrations in plant leaves. The leaf spectral reflectance, leaf potassium content and photosynthesis parameters were taken from an experiment that included a combination of four K treatments applied to sugar beet and celery plant leaves. The hyperspectral images of the leaves belonging to two plant species were captured using a hyperspectral camera

in the range of 400-2500 nm. Spectral data were extracted from the region of interest, followed by the second derivative to reduce background noise. Twelve wavelengths were automatically selected using a correlation-based feature selection method as the most appropriate for determination of potassium content in plant leaves. We found that the Random Forest algorithm performed well for estimation of potassium content in plant leaves, with an overall accuracy of more than 80%. These results suggest that hyperspectral imaging combined with machine learning methods have a remarkable ability to accurately predict the leaf nutrient content.

Keywords: hyperspectral imaging, machine learning, plant nutrition, potassium concentration

Whole farm modelling for quantification of greenhouse gases and mitigation-related land use planning decisions

Khalil M.I.[1,2,*] and B.A. Osborne[1,2]

*[1]University College Dublin, Ireland; [2]Prudence College Dublin, Ireland. *Corresponding author: i.khalil@prudencecollege.ie*

Agriculture contributes about 12% of greenhouse gas (GHG) emissions globally, although the magnitude of this at the regional or farm scale will depend on soils, climate and management practices, where GHG accounting and land use planning decisions for mitigation and/or offsetting could play a pivotal role. We evaluated a Canadian Whole Farm Model 'HOLOS', which is able to provide reasonable estimates of the overall GHG balance/budget at a land parcel to farm scale by using predefined emission factors (EFs) for N_2O (direct and indirect), CH_4 (enteric and manure) and CO_2 (biomass and soil C) and including energy usage. We used Irish data based on a 45-ha farm consisting of 2/3rd pasture and 1/3rd silage with 176 livestock units. The response of GHG emissions to soil variables depended on the ratio functions. The major drivers were N fertilizer and temperature, which when reduced by 30% decreased the total on-farm GHG emissions by 9% and 18%, respectively. The major contribution to the total 865 Mg CO_2-equivalent emissions was from enteric-CH_4 (51%), direct-N_2O emissions (22%) and manure-CH_4 (17%). Among the combination of land uses assessed, a reduction in dairy cattle by 10-20% decreased the emissions by 10-20% and by 86-90% when combined with silage, which showed the highest C sink, and arable (±forestry) showed lower emissions over pasture or pasture and silage with 100% dairy cattle (837-845 Mg CO_2-equivalent). The HOLOS model, with improvement possibilities through replacement of country-specific algorithms and EFs, can be useful for national GHG reporting and land use planning. The results imply that shifting from a single land use to a mixed farming system could have considerable potential for mitigating and offsetting on-farm GHG emissions. For achieving carbon-neutrality, a reduction in livestock units and the use of inorganic fertilizers, combined with more afforestation would be required.

Keywords: Whole Farm Modelling, greenhouse gases, mitigation, land use planning decisions

Theme 5: Novel Farming Systems

Keynote presentation

Novel farming systems and food value-chains: home-grown legumes as a multifunctional solution for wicked problems.

Iannetta P.P.M.*, G.S. Begg, C. Duffy[1], C. Hawes, E.K. James, A. Karley and T. Ndlovu

[1]*The James Hutton Institute, UK. *Corresponding author: pete.iannetta@hutton.ac.uk*

Achieving climate-resilient agri-food, and feed systems demands greater focus and resolution on the agri-environment and human-wellbeing. The infrastructures of modern value chains, plus the various policies which impact these, need to be harmonised to address the '*climate change-biodiversity loss-nutrition nexus*'. Purely 'productionist' and 'either-or' approaches that demand ever-greater yields at the expense of enhanced system functions, including long-term profitability, must be avoided. Instead, prioritisation of '*agroecological intensification*' via '*diversified cropped systems and short value chains*', catalysed by '*innovation stacking*', needs to be allied to an '*ecosystem function monitoring*' approach. In this context, cropped systems in the industrialised north are characterised by several key features that resist change, including the '*legume paradox*'. Across Europe, feed and food value chains already rely heavily on imported legume grains, even-though these could be readily home-grown, *i.e.*, within the country, or region, in which they are consumed. Most of these grains are routed to animal-feed use, and only infrequently adopted for human food. Put simply, legume-supported systems for food production are therefore novel across Europe. Legumes include grain-crops such as peas, and beans which are used for feed, or food, and also forage-crops such as clover or vetch which serve as feed, and/or green-manures. Whatever their form, legume crops are characterised by their capacity for biological nitrogen fixation and their non-dependency on mineral-nitrogen fertilisers. However, the provisions made by the sustainable cultivation of legume crops to the environment are complex and multifunctional, including utilising biodiversity for regulating ecosystem processes, and these benefits are forfeited by the very low levels of home-growing. From these perspectives, research carried out by the James Hutton Institute's Agroecology Group, in the UK and internationally, to improve legume growing and consumption is highlighted, and with respect to Scottish socio-economic paradigm, the ECs Green Deal and component strategies such as for 'Farm-to-Fork', 'Food Sustainability', and 'Biodiversity'.

Keywords: Resilience; food security; feed security; legumes; home-grown.

Session V: Oral presentations

Evidence of critical climate stress moments and climate-resilient practices along the Teesta River Basin of the Himalayas

Sharma, G.*

*The Mountain Institute India. *Corresponding author: banstolag@gmail.com*

Critical climate-stress moments (CCM) are situations when households, communities, and their livelihoods are vulnerable to climate-related risks and hazards. This study conducted during 2012-2019 examines CCM due to climatic and biophysical causes in the Teesta River Basin (TRB) of the eastern Himalayas. CCM can serve as a tool for communicating the vulnerabilities of communities and the challenges to sustainable lives and livelihoods and to link vulnerability assessments with adaptation policy and action. TRB (50–6000 m.a.s.l.) has fragile geology, complex climate, and ecosystem and socio-economic diversity. This study divided TRB into three sections: high-altitudes (>2000-5000 m.a.s.l.); mid-hills (1000–2000 m.a.s.l.); and floodplains (<50–500 m.a.s.l.). The study used qualitative/quantitative survey methods, focus group discussions, case studies, key informant interviews, and household surveys (490) conducted with a structured questionnaire using a mobile/tablet-based application called 'Akvo-flow'. The CCM in the high-altitudes were low temperature, frost- bite, pests/diseases in farms, new diseases in humans/animals, and unpredictable and heavy snowfall during winters leading to deaths of yaks and sheep. Thunderstorms, hailstorms, unpredictable/erratic rainfall patterns, water scarcity, crop loss, disease/pest emergence are CCM in mid-hills. Waterlogging, riverbank erosion, flooding, displacement of communities, health hazards, and loss of farmlands are CCM in the floodplains. Insufficient water for irrigation due to drying up of springs/rivers/rivulets is a major stressor along with other climatic stresses e.g., hailstorms, windstorms, cold-waves, avalanches, landslides, prolonged droughts, human-wildlife conflict, forest fire, and too-little water, and too-much water availability. Nonetheless, geohydrology study-based catchment area treatment for spring revival, ecosystem reconstruction in degraded farmlands by afforestation reviving traditional agroforestry systems, diversification of farmland-use types, reintroduction of traditional landraces/folk varieties, highland-lowland seed exchange, farm-labor sharing, and nomadic rotational- pastoralism in Indo-Tibetan plateaus are climate-resilient adaptation strategies. Upscaling of present practices with critical scientific and policy review is required for improving the lives/livelihoods of farming communities.

***Keywords*:** Teesta River basin, eastern Himalayas, critical climate stress moments

Drought legacy on microbiomes influences maize traits

Carter K.R.[1*], L.T. Dickman[1], A.C. Nachtsheim[1], E.R. Moore[1], J.P. Heneghan[1], A.J. Sabella[1], C.R. Steadman[1], M.B.N. Albright[1], C.M. Anderson-Cook[2], L.H. Comas[1], J.M. Heikoop[1], N.E. Lubbers[1], D. Musa[1], S. Negi[1], B.D. Newman[1], S. Twary[1], C.M. Yeager[1], J.M. Dunbar[1] and S. Sevanto[1]

*[1]Los Alamos National Laboratory, USA, United States Department of Agriculture, USA.*Corresponding author: kcarter@lanl.gov*

Beneficial plant-microbe interactions can improve plant performance under drought; however, we know less about how rapid drought-induced shifts in microbial communities will affect plant traits. To quantify how quickly microbiomes can shift to influence key plant drought resistance traits, we grew two generations of *Zea mays* inoculated with soil microbiomes originating from contrasting

environments under two irrigation treatments (full or limited water; 65% and 45% relative water content, respectively) in a greenhouse using an artificial soil. For the first generation, we inoculated plants using both watering treatments with either a microbiome from historically droughted agricultural soil or from pine forest soils. After the first generation, we used the microbiome from each pot to inoculate our second-generation pots. Here, we either maintained or switched the watering treatment to investigate whether water treatment legacies are carried forward through the microbiome to alter plants in the subsequent generation. We found that the microbiome legacy had a clear effect on plant growth, with some effects on plant function that were dependent on watering treatments and/or original microbiome source. Plants grown in the soil microbiome with a history of water limitation produced water conservative physical traits, including thinner stems and longer roots, regardless of the prevailing water treatment. Microbiome legacy effects on plant functional traits were more nuanced. Plants growing under a full water treated microbiome for two generations had higher rates of photosynthesis and stomatal conductance, but only in the plants with a microbiome that originated from the pine forest. These results suggest that plant-associated microbiomes can develop toward a state that alters plant performance under drought after just one generation of plant growth. These results further validate the concept that microbial consortiums can be manipulated to help solve global issues in ensuring productive, sustainable agriculture.

Keywords: Crop traits, drought, microbiome legacy effects, root traits, *Zea mays*

Does vertical farming offer a sustainable alternative to traditional crop production?

Sandison F.*, J. Yeluripati and D. Steward

*[1]The James Hutton Institute, Scotland. *Corresponding author: frances.Sandison@hutton.ac.uk.*

Fresh food production has increasingly seen a move toward contained agriculture concepts like controlled environment agriculture (CEA). This project aimed to explore the environmental impacts of vertical farming (VF) in Scotland, to determine if it offers a viable alternative to open field agriculture. VF was seen to show a range of carbon footprint values in the literature, connected to general efficiencies in production. Of this 90% was attributed to electricity use. While under the current electricity mix, VF does not offer a viable competition to traditional agriculture, under a 100% renewable energy scenario it proved to be on par (0.338 tCO_2 eq/t).

Keywords*:* Vertical farming, life cycle assessment, carbon footprint, sustainability, environmental impact

An assessment of potential pesticide transmission, considering the impact of soil texture and pesticide properties

McGinley J.[1],* J.H. O'Driscoll[2], M.G. Healy[1], P.C. Ryan[2], P.-E. Mellander[3], L. Morrison[4], O. Callery[1] and A. Siggins[1,3]

*[1]National University of Ireland Galway, Ireland; [2]University College Cork, Ireland; [3]Teagasc, Ireland; [4]National University of Ireland Galway, Ireland. *Corresponding author. j.mcginley8@nuigalway.ie*

Pesticides are widely employed as a cost-effective means of reducing the impacts of undesirable plants and undesirable organisms. The aim of this paper is to develop a risk ranking of transmission of key pesticides through soil to waterways, taking into account physicochemical properties of the pesticides (soil half-life, and water solubility), soil permeability, and the relationship between adsorption of pesticides and soil texture. This may be used as a screening tool for land managers, as it allows assessment of the potential transmission risks associated with the use of specified

pesticides across a spectrum of soil textures. The twenty-eight pesticides examined were differentiated into three groups: herbicides, fungicides and insecticides. The potential transmission risk can be quantified either on the basis of soil texture or pesticide type, with the highest score in each case being the most transmissible. Considering the herbicide chlorotoluron, for example, the potential risk ranking varied from 36 in sand to 17 in clay. Therefore, the soil textures most likely to transmit chlorotoluron may be identified. Within sandy loam soils, for example, MCPA, Mecoprop-P, Bentazone, Metamitron and Metribuzin are some of the highest risk herbicides. As Pendimethalin, also used for the removal of broad-leaved weeds from cereals, has a much lower transmission ranking value in sandy loam soils, it might be more appropriate when applying to this soil texture. The highest risk of pesticide transmission through soils to waterways is associated with soils containing <20% clay or >45% sand. The data generated in this paper may also be used in the identification of critical area sources, which have a high likelihood of pesticide transmission to waterways. Furthermore, they have the potential to be applied to GIS mapping, where the potential transmission risk values of the pesticides can be layered directly onto various soil textures.

***Keywords*:** Adsorption; freundlich; half-life; pesticides; soil texture.

Towards agricultural soil carbon monitoring, reporting and verification through real-time carbon and GHG predictions

Yeluripati J.[1]*, P. Smith[2], D. Camerond[3], E. Cowdery[1], M. Aitkenhead[1] and D. Donnelly[1]

[1]The James Hutton Institute, United Kingdom, [2]University of Aberdeen, United Kingdom, [3]Centre for Ecology and Hydrology, United Kingdom. Corresponding author: jagadeesh.yeluripati@hutton.ac.uk

Carbon sequestration in soil is one of the promising biological negative emissions (BNE) technologies to mitigate climate change. Soil carbon sequestration relies on the adoption of best management practices to increase the amount of carbon stored in soil. An advantage of soil carbon sequestration in agriculture is that carbon stocks are most depleted in cropland systems, so there is great potential to capture atmospheric carbon without land use conversion and competition for land resources. The successful implementation of land based negative emission technologies will require continuous monitoring, reporting and verification of soil storage changes and greenhouse gas (GHG) emissions to estimate net carbon sequestration in soils. Currently, a lack of cost effective, robust, consistent, transparent, and accurate methods limits large-scale implementation of these technologies. There is a need to combine information from diverse sensor networks in different environments and to accurately model soil carbon changes and GHG emissions from various management practices by combining information from novel cost-effective technological developments in field-based sensors, remote sensing, and/or smartphone apps and integration of models on cloud platforms to confirm management practice effectiveness. This setup allows near real-time simulations on carbon changes and GHG emissions on the cloud without the need for individual user inputs. We established two demonstrator sites and deployed soil sensors. A novel sampling strategy has been developed using topography (elevation, slope, aspect) and aerial photography from GetMapping to identify optimal sensor deployment locations and soil carbon sampling within land parcels. Three ecosystem models DNDC, ECOSSE and BASGRA have been coupled to PEcAn by creating model specific wrappers around each model. The RETINA Android app has been developed. This decision support system will provide novel solutions for farmers' and policy makers' information needs in support of net zero GHG emissions for Scotland (2045) and the wider UK (2050).

Keywords: Soil carbon, monitoring reporting and verification, modelling GHG emissions, real time monitoring, Climate change, netzero

Monitoring agricultural land biodiversity with multispectral aerial imagery

Papadopoulos A.V.*, S. Kosmidis, G. Tsitselis, C. Kolovos, G. Zagklis, S. Kavasilis and M.K. Doula

*Benaki Phytopathological Institute, Greece. *Corresponding author: a.papadopoulos@bpi.gr*

The fifteenth Sustainable Development Goal (SDG), among others, refers to halting biodiversity loss on land. According to the Food and Agriculture Organization of the United Nations (FAO), agricultural land occupies 38 percent of the global land surface, making its biodiversity a crucial proportion of flora and fauna biodiversity worldwide. Agricultural biodiversity conservation can only be instigated and further realized by means of reliable procedures for identifying plant and animal habitats. The advent of remote sensing technologies in the field of Unmanned Aerial Systems (UAS) has promoted mature solutions for monitoring agricultural land biodiversity. The main objective of this study was to record and map plant species in agricultural landscapes on the island of Kefalonia (Ionian Sea), with the use of UAS and Geographical Information Systems (GIS). The flight equipment used in the study consisted of a fixed-wing unmanned aerial vehicle (UAV) Real Time Kinematic (RTK) enabled, a multispectral camera, a GPS base receiver and the ground station hardware and software. Site selection for carrying out the flights was carefully implemented based on criteria like land cover and use, terrain slope, flight restricted areas and environmentally sensitive regions. Two campaigns were launched on the island of Kefalonia during which 48 flight missions were fulfilled, monitoring approximately 2500 ha of agricultural land. Via photogrammetry software, numerous orthomosaics, vegetation indices maps, segmented and classified aerial images were produced in order to identify plant species in agricultural areas. The results so far have revealed that variable biodiversity conditions exist in the island's cultivated land. The causes of this variability should be carefully examined, in order to deduce useful conclusions about the current biodiversity status under the influence of climate change on Kefalonia island and broadly in Mediterranean agricultural habitats.

Keywords: Unmanned aerial system, Remote sensing, Biodiversity, Geographical information systems, Image classification

Grazing multispecies swards: the annual and seasonal dry matter production of four sward types under co-grazing of cattle and sheep

Shackleton J.[1,2*], J. Kennedy[1], C. Grace[1], G. Beaucarne[1,2], B. Lynch[2,4], T. Boland[2], O. Schmidt[2], E. Hoffland[3] and H. Sheridan[2]

*[1]Devenish Nutrition, Ireland; [2]University College Dublin, Ireland; [3]Wagenigen University and Research, The Netherlands; [4]Teagasc, Ireland. *Corresponding author: jane.shackleton@devenish.com*

The four sward types investigated were: permanent pasture receiving 135 kg N $ha^{-1}yr^{-1}$ (PP), perennial ryegrass receiving 170kg N $ha^{-1}yr^{-1}$ (PRG), six species sward (6S) (PRG, timothy (*Phleum pratense*), white clover (*Trifolium repens*), red clover (*T. pratense*), chicory (*Cichorium intybus*) and ribwort plantain (*Plantago lanceolata*) and a twelve species sward (12S) (6S plus cocksfoot (*Dactyls glomerata*), greater birdsfoot trefoil (*Lotus pedunculatus*), yarrow (*Achillea millefoilum*), sainfoin (*Onobryclis vicifolia*), salad burnet (*Sanguissorba officinales*), sheep's parsley (*Petroselinum sativum*) both receiving 70 kg N $ha^{-1}yr^{-1}$. Farmlets were co-grazed with cattle and sheep in 2020 and 2021. Pre-grazing herbage mass targets were 1500 kg DM/ha for PRG and PP swards and 2500 kg DM/ha for 6S and 12S. Post-grazing residual targets were 4cm for PRG, PP and 6cm for 6S,12S. Data was analysed using the MIXED procedure of SAS. Permanent pasture had lower annual DM production compared to all other sward types ($P<0.05$). Annual DM

production from PRG did not differ from 12S but was lower than the 6S (P<0.05). Annual DM production from 6S and 12S did not differ (P>0.05). DM production from PP was significantly lower in early season compared to other sward types (P<0.05). Mid- season DM production was similar from PP, PRG and 12S. Mid-season DM production from 6S was similar to 12S but higher than PP and PRG (P<0.05). In conclusion, MSS under reduced N applications produced higher DM than PRG and PP swards treated with higher levels of N.

***Keywords*:** multispecies swards, dry matter production, co-grazing, permanent pasture

Multispecies swards improve the growth performance of lambs co-grazed with heifers

Beaucarne G.[1,2*], J. Shackleton[1,2], C. Grace[2], J. Kennedy[2], H. Sheridan[1] and T. Boland[1]

*[1]University College Dublin, Belfield, Ireland, [2]Devenish research and innovation company, Ireland. *Corresponding author: gaspard.beaucarne@ucdconnect.ie*

Irish grazing systems are facing environmental and economic challenges. It was hypothesized that grazing multispecies swards (MSS) receiving 70 kg N/ha/y (a six species sward (6SP) with 2 grasses, 2 legumes and 2 herbs and a 12 species sward (12SP) with 3 grasses, 4 legumes and 5 herbs) compared to a perennial ryegrass sward (PRG) receiving 170 kg N/ha/y and a permanent pasture sward (PP) receiving 135 kg N/ha/y, would improve the growth performance of lambs co-grazed with heifers. Each sward treatment was rotationally grazed from April to November 2020 and 2021 by ewes plus lambs (n=22 ewes /treatment/year, mean litter size of 1.65) and heifers (n= 20/treatment/year). Heifers were weighed monthly and drafted for slaughter when their estimated fat class on the EUROP grid scale reached 3-. Lambs were weighed fortnightly and drafted for slaughter at 42 kg (turnout to weaning at 16 weeks of age), 44 kg (weaning to September) and 46 kg (after September 1st) to obtain a target carcass weight of 21 kg. From turnout to slaughter, heifers grazing the 6SP sward had an average daily gain (ADG) of 1.09 kg/day compared to 0.99 kg/day for the 12SP and 0.92 kg/day for both the PRG and PP swards. Lamb weaning weight was higher for the lambs grazing the MSS (≈44 kg) compared to the PRG (40.2 kg) and the PP swards (39.6 kg; P<0.001). ADG from turnout to slaughter of lambs grazing the 6SP (390 g/day) and 12SP (360 g/day) were greater than the PP (300 g/day) or PRG swards (290 g/day; P<0.001). Lambs grazing the 6SP and 12SP swards had reduced number of days from turnout to slaughter (82 and 93 days respectively) compared to lambs grazing the PP (127) and PRG swards (132; P<0.01). Overall, grazing MSS improved lamb performance when co-grazed with heifers.

Keywords: Multispecies swards, co-grazing, sheep production, lamb performance

Life Cycle Assessment of novel grass-based products

Álvarez-López V.[1]* , K. Lorentzon[2], S. Ahlgren[2], A. Baky[2] and R. Mosquera-Losada[1]

*[1]University of Santiago de Compostela, Spain; [2]RISE Research Institutes of Sweden, Sweden. *Corresponding author: vanessa.alvarez.lopez@usc.es*

Although grassland covers an important part of the total EU surface area (around 20%), nowadays, this resource is highly underused (mainly in northern European countries). The project GOGRASS has been examining ways for using this unexploited potential. Within this project, four different pilot experiences (DEMOs) have been established in Sweden, Denmark, The Netherlands, and Germany aimed at the development of grass biobased products, as an alternative to existing options that are highly dependent on fossil fuels (such as fertilisers, animal bedding, paper, animal feeding, and/or energy production). Within this work, the products from the DEMO in Denmark

(aimed at developing a small-scale bio-refining technology to extract protein concentrates from grassland in nitrate sensitive areas) and the DEMO in Sweden (aimed at establishing briquetting technology at local and small-scale to produce heat treated animal bedding using reed canary grass) are being analysed for their environmental impact according to their Life Cycle Assessment (LCA). The aim of this study is to identify potential hotspots of negative environmental impacts in the product value chains. Moreover, special attention will be paid to examine potentially beneficial environmental issues related to grasslands, such as their potential soil carbon sequestration. LCA analysis is currently taking place and results of the LCAs will help to guide the design of improved value chains in further steps of the GO-GRASS project. Results and recommendations will be presented at the ISCRAES Conference.

Keywords: Grasslands, bioproducts, life cycle assessment, environment, value chains

Feasibility analysis of electrodialysis technology for nutrient recovery as fertiliser from digestate in Ireland

Meng J.[1,2*], R. Li [1], S. Lin[3], S. Wang[1,2] and X. Zhan[1,2*]

*[1]National University of Ireland Galway, Ireland, [2]SFI MaREI Research Centre, Galway, Ireland, [3]University of Science and Technology, China. *Corresponding author: j.meng1@nuigalway.ie*

Livestock manure management is an important topic for sustainable agriculture development. Anaerobic digestion is an effective method for livestock manure treatment, which can produce biogas for heating, electricity or biomethane. The produced digestate can be regarded as an organic fertilizer that can be applied on adjacent farmlands. However, large livestock farms can generate manure digestate exceeding the crop uptake threshold of the adjacent farmlands, and over-fertilization using digestate can pose significant environmental pollution via nutrient leaching and runoff. Thus, nutrient recovery from the surplus digestate is a wise way for digestate management, and the recovered high concentration nutrients can be used as a marketable fertilizer. Electrodialysis (ED), an electric driven technology, has offered potential to recover the nutrient from manure digestate as it can avoid severe membrane fouling. With the application of electric power, the nutrient ions (ammonia ions and phosphate ions) can be recovered into the product solution with a high concentration (i.e., >10 g/L NH_4^+-N). However, the economic feasibility of ED application in nutrient recovery from digestate is unclear. This study modelled the energy consumption of ED systems and assessed the economic feasibility of ED application in nutrient recovery from digestate in the context of Ireland. The results indicated that the energy consumption of the ED system for nutrient recovery from pig manure digestate was 9.27 kWh/m^3. Based on the annual production of pig manure digestate of 16,539 m^3 in a typical farm, the annual electricity cost was estimated at €23,105, accounting for 86% of the total operation cost. With the application of ED, 1836 kg K and 4284 kg N can be recovered as fertilizer annually, whose marketable value can cover the electricity cost.

Acknowledgement: this research is funded by Gas Networks Ireland and SFI through MaREI research centre (200819)

Keywords: Manure digestate, anaerobic digestion, nutrient recovery, electrodialysis, energy consumption, economic analysis.

Can plant-microbiome interactions be harnessed to support food security and carbon sequestration?

Sevanto S.[1]*, K.R. Carter[1], E.R. Moore[1], A.C. Nachtsheim[1], A. Kim[1], J.M. Mitchell[1], L.T. Dickman[1], J.P. Heneghan[1], A.J. Sabella[1], C.M. Anderson-Cook[1], J.M. Heikoop[1], N.E. Lubbers[1], D. Musa[1], S.Negi[1], B.D. Newman[1], S. Twary[1], C.M. Yeager[1], L.H. Comas[2], C.R. Steadman[1], M.B.N. Albright[1] and J.M. Dunbar[1]

*[1]Los Alamos National Laboratory, USA, [2]United States Department of Agriculture, USA. *Corresponding author: sanna@lanl.gov*

Microbiome optimization could be a solution to improve the performance of biological systems. Yet, owing to challenges in finding and cultivating microbiomes that maintain their function under field conditions, the use of microbes to improve plant productivity, crop stress tolerance or ecosystem carbon sequestration has not become widespread despite years of trials. Based on the strong interactions and interdependency of rhizosphere microbes and plants, directed plant-microbiome evolution has been suggested as a means for developing microbiomes for these purposes. Here, this directed evolution approach was used to test whether microbiomes that improve plant water use efficiency (WUE) and stomatal closure point (SCP) could be produced as potential plant traits that could be optimized. SCP, defined as the water potential at which the plant closes stomata under drought, is a metric that determines plant carbon sequestration capacity under drought conditions. Pushing SCP towards lower values would allow increased carbon sequestration under drought conditions. We cultivated *Zea mays* from seed in an artificial soil inoculated with microbiomes originating from a pine forest or a historically-droughted maize field. In the initial generation, WUE and SCP were measured once the plants grew 10 leaves. The microbiomes of three plants demonstrating the best or worst WUE or SCP values for each microbiome source were selected for propagation to the next generation, and the process was repeated for two additional generations. After three generations of directed evolution, the microbiome originating from the forest soil was able to consistently influence the SCP of the plants, while the microbiome from the agricultural field had no significant effect on SCP or WUE. No single microbial strain was responsible for these effects, but consortia of bacteria related to the plant traits were identified using a dimensionality reduction method called Latent Dirichlet Allocation (LDA). The forest microbiome contained more bacteria related to the nitrogen cycle than the agricultural microbiome, suggesting that rejuvenation of agricultural soils might be critical for improved plant performance and carbon sequestration. Hypotheses on the mechanisms that improve plant drought tolerance, the reproducibility of the results as well as the use of these microbiomes under field conditions will be discussed.

Keywords: Directed evolution, microbiome optimization, plant stress tolerance, machine Learning

Posters

A Novel Hybrid Coagulation-Intermittent Sand Filter for the Treatment of Dairy Soiled Water

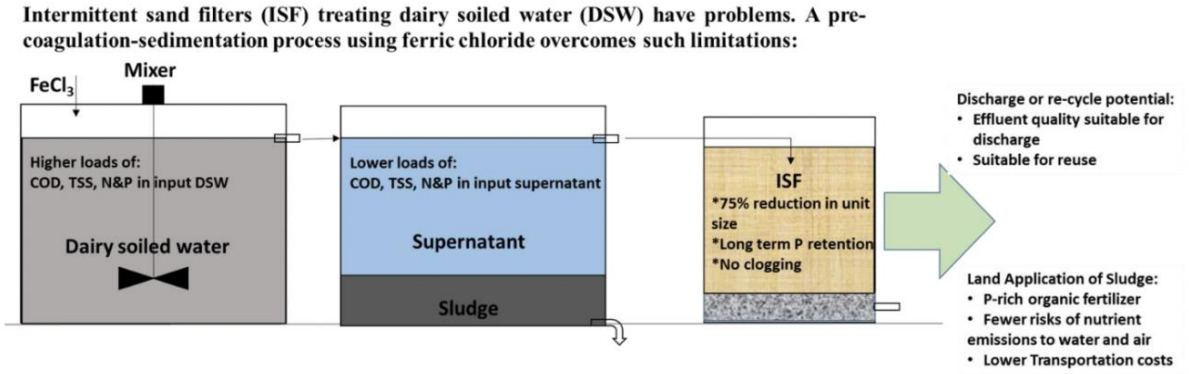
Mohamed A.Y.A.[1, 2],*, A. Siggins[2], M.G. Healy[2], O. Fenton[1], D. Ó hUallacháin[1] and P. Tuohy[1]

*[1]Teagasc, Ireland. [2]NUI Galway, Ireland. *Corresponding author: ahmed.mohamed@teagasc.ie*

An intermittent sand filter (ISF) is a simple and cost-effective treatment method that may be adopted on farms to treat dairy soiled water (DSW). However, the use of ISFs has been limited

due to the large area required for treatment, and the risk of filter clogging and phosphorus (P) breakthrough, which decrease the operational lifetime. To overcome these limitations, this study uses a novel, pilot-scale coagulation-sedimentation process prior to loading ISFs with DSW. The performance and operational lifetime of this new hybrid coagulation-ISF system was compared to a conventional ISF system in a replicated outdoor pilot-scale experiment over a 43-wk study duration (covering an entire milking season on a farm in Ireland). The hybrid system was able to operate effectively at a higher hydraulic loading rate than conventional ISF systems. The effluent quality from the conventional ISF deteriorated over the timeframe of the study until clogging occurred, while the hybrid system continued to perform effectively without any evidence of clogging or P breakthrough. The hybrid system obtained removal efficiencies ≥ 99 % for all measured water quality parameters (chemical oxygen demand, total suspended solids, total P, ammonium and turbidity), and complied with EU directives concerning urban wastewater treatment. Overall, the hybrid coagulation-ISF is a promising technology that requires a small area (75% reduction in footprint in comparison to a conventional ISF) and minimal operator input, and produces high effluent quality that can be recycled to wash farmyards to save water.

Graphical abstract:



Keywords: Dairy soiled water, intermittent sand filter, wastewater coagulation, filter clogging, biofilm growth.

Evaluation of Regenerative Farming Practices for Enhancing Crop Productivity and Reducing the Environmental Footprint

Mishra A.K[1]*, S. Sharma[1] and A. Mateen[2]

[1]*International Rice Research Institute, India.* [2]*Grassroots Energy Technologies (I) Pvt Ltd, India. Corresponding author: a.k.mishra@irri.org*

Strategic and adaptive research was introduced in Kharif in 2020 aimed at identifying low-cost nature-based solutions to develop better soil management options for improving overall soil health, crop productivity and reducing emissions in Eastern UP, India. One on-station strategic experiment was initiated to determine the impact of different easily transportable organic inputs in rice-based cropping systems (rice-wheat and rice-wheat-mungbean). More than 100 adaptive demonstrations were established in farmers' fields to evaluate the impact of Samvardhak application vis-à-vis farmers' fertilizer practices. The experiment was initiated in Kharif 2020 in main plots (Conventional Farming (CF-rice-wheat; no residues) and Regenerative Farming (RF-rice-wheat-mungbean; 50% rice crop residue)) and sub-plot (State Fertilizer Recommendation (SRF) and Site-Specific Nutrient Management (SSNM)). The SSNM recommendation was generated by Rice-Wheat Crop Manager (RWCM) developed for Eastern UP in collaboration with BHU and several other partners. The subplot was further divided into with and without Samvardhak. The trial was replicated four times

in a split-plot design. In Kharif the Moti rice variety and in Rabi the PBW 343 wheat variety and in Jayad the Virat mungbean variety were used for the experiments. In the Samvardhak plot, we reduced NPK by 25% to assess the impact of its application on yield and other attributes. During Rabi 2020-21, 15% and 21% yield increment was observed by the application of Samvardhak in SFR and SSNM, respectively in conventional farming. Whereas an 18% and 26% increase in yield was recorded by the application of Samvardhak in SFR and SSNM, respectively in regenerative farming. Such increases might be due to the creation of a conducive rhizosphere micro-climate for nutrient uptake and mobility. Reduced GHG emissions were observed in the regenerative farming practices as compared to conventional farming. In a nutshell, regenerative farming practices might be the game-changer in developing sustainable production systems with the provisioning of improved livelihood and scalable technologies.

***Keywords*:** Nature-based solutions, residue recycling, reduced tillage, carbon farming, Precision Agriculture

Patterns of soil microbial biomass and diversity across Mediterranean agroecosystems in areas under desertification risk

Quatrini P.[1]*, V. Catania[1], S. Castaldi[2], E. Grilli[2],T. La Mantia[1], F.A. Rutigliano[1] and R.S. Bueno[1]

[1]Università degli Studi di Palermo, Italy; [2]Università degli Studi della Campania Luigi Vanvitelli, Italy.
**Corresponding author: paola.quatrini@unipa.it*

The EU biodiversity strategy set ambitious targets and commitments for 2030, and soil health plays a central role. Degraded soils fail to support the ecosystem services required for a productive agriculture, hamper ecological restoration and increase climate change effects and desertification. Soil microorganisms i.e. bacteria and fungi are the backbone of soil health, although these are often ignored in public policies and constantly suppressed by conventional agricultural practices. As the soil microbiota directly and indirectly regulates the flux of organic carbon between soil and the atmosphere and determines plant health and growth, its correct management is the best nature based solution for sustainable agriculture. However, the drivers of belowground diversity are still largely unknown and it is still unclear whether soil physico-chemical features (e.g. soil organic matter, pH, nitrogen) are potential drivers of microbial diversity or are regulated by it. Within the LIFE Desert-Adapt project we are investigating the relationship between soil microbial biomass (SMB) and bacterial diversity with soil physical-chemical indicators across diverse types of land use in soils under high desertification risk in Italy, Spain and Portugal. SMB is estimated as total extracted dsDNA while soil bacterial diversity is obtained with Automated Ribosomal Intergenic Spacer Analysis (ARISA) and metagenomics 16S gene sequencing. So far we have found that SMB significantly varied across countries and land uses, with soil organic carbon (SOC) and nitrogen (N) the most relevant predictors. Bacterial diversity was strongly related to pH and soil use but, surprisingly, not to SOC. Our results unravel the patterns of bacterial biomass and richness in Mediterranean soils under desertification and we further discuss pathways for future research linking soil microbiota, agroecosystem management and correlated ecosystem services.

Keywords: Climate change, ecosystem services, desertification, Mediterranean, soil microbiota

Theme 6: Carbon Farming and Nature-based Solutions

Keynote presentation

Carbon farming and results-based solutions, an innovative scheme for boosting carbon initiatives and developing sustainable agriculture

Dollé J.B.* and C. Brocas.

*IDELE, French Livestock Institute, France. *Corresponding author: jean-baptiste.dolle@idele.fr*

The European objective of carbon neutrality aims to balance greenhouse gas emissions and absorption, by reducing emissions and increasing carbon removals. Regarding these objectives, there is a need to develop a Carbon Farming scheme which manages carbon pools and greenhouse gas emissions at farm level in a common way among countries and stakeholders. This can be done by improving the methods for measuring, reporting and verifying (MRV) mitigation actions, and by providing payments for the delivery of climate mitigation benefits. In France, the French Government adopted the Label Bas Carbone, a framework for a voluntary carbon reduction project. Complying with this standard, CARBON AGRI, a MRV process, has been certified by the French government. To capture emissions reductions and soil carbon sequestration, CARBON AGRI measures progress from a range of 40 mitigation practices. Based on the national life cycle assessment farm tool CAP'2ER® , the reductions are assessed against a baseline level of GHG emissions before the project starts. Each participating farm uses its own figures to calculate its baseline and its mitigation action plan. For the five-year credit period, carbon reductions between the baseline and the project scenario represents from 300 to 500 tons of CO_2. These result-based emissions reductions are traded for payment from an external party voluntarily offsetting their emissions or contributing to the project implementation. Thanks to environmental co-benefits (water, biodiversity benefits etc.), farmers are selling the avoided CO_2 for prices of 30-40 €/t CO_2 which represent 9 000 to 20 000 € per farm. Other sources of funding have to be explored, but this carbon farming scheme is playing a strategic role in catalysing carbon transition, providing financial resources and providing a rigorous framework to monitor mitigation efforts. This is the first step for an ambitious and common carbon certification framework at European scale, that the commission is working on.

Keywords: MRV, agriculture, mitigation, carbon

Session VI: Oral presentations

Role of soil carbon sequestration in sheep farming systems: A life cycle assessment case study

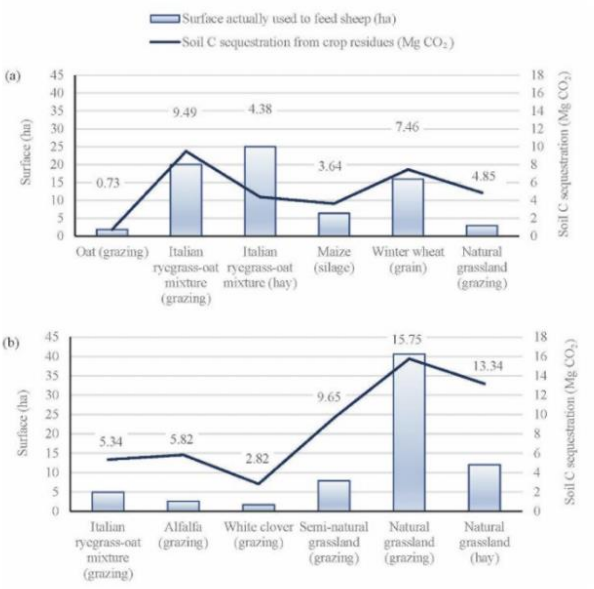
Arca P.[1*], E. Vagnoni[2], P. Duce[2] and A. Franca[1]

*[1]CNR-ISPAAM, National Research Council of Italy, Italy; [2]CNR-IBE, National Research Council of Italy, Italy. *Corresponding author: pasquale.arca@ibe.cnr.it*

The Mediterranean sheep sector represents an interesting case study for testing strategies aimed at achieving a sustainable livestock supply chain and to explore the role of ecosystem services provided in carbon farming systems. The main aim of this work was to evaluate the environmental

implications of a Sardinian (Italy) dairy sheep farming system, before and after the transition from a semi-intensive (SI) to a semi-extensive (SE) production system, through an LCA study, including the contribution of soil C sequestration (soil C_{seq}) and using both mass and area-based Functional Units (FUs). We observed that the extensification of the production system underlied contrasting environmental effects when using different FUs accounting for soil C_{seq}. Including soil C_{seq} and using kg FPCM as FU, the emission intensity decreased slightly by 0.3 (from 3.4 to 3.1) kg CO_2 equivalents (CO_2-eq) in the SI production system and largely decreased by 0.6 (from 3.5 to 2.9) kg CO_2-eq in the SE production system. Using the utilized agricultural area (UAA) as FU and including soil C_{seq}, the emission intensity decreased by 464 (from 6257 to 5793) kg CO_2-eq and by 731 (from 4020 to 3299) kg CO2-eq in SI and SE, respectively. In the SE production system, soil C_{seq} was favoured by larger areas covered by permanent grasslands destined for grazing. The improvement of the soil organic C stock associated with the permanent grasslands would contribute effectively to mitigate GHG emissions in Mediterranean dairy sheep farms, highlighting the positive role of ecosystem services provided by extensive farming systems. These results indicate that the emission intensity from semi-extensive Mediterranean dairy sheep farms can be considerably reduced through soil C_{seq}. However, consideration must also be given to the uncertainty inherent in C_{seq} modelling. Further investigations based on direct field measurements are recommended in order to improve both data quality and the reliability of the results.

Fig 1. Land use and soil C sequestration. Surface actually used to feed sheep (ha) and soil C sequestration (Mg CO_2 per total surface occupied) deriving from crop residues, based on grassland type and use destination of the biomass, in the semi-intensive (a) and semi-extensive (b) system. The label values indicate the C sequestered (Mg) per whole surface of each grassland.



Tab 1. Process contributions for the Climate Change impact category. Emission and contribution of the processes to the total greenhouse gas emissions of semi-intensive (SI) and semi-extensive (SE) production systems, calculated including and excluding soil C sequestration (soil Cseq), for both 1 kg of fat and protein corrected milk (FPCM) and 1 ha of utilised agricultural area (UAA) functional units.

Climate Change	**Soil C_{seq} excluded**		**Soil C_{seq} included**	
	SI	**SE**	**SI**	**SE**
kg CO_2-eq per kg FPCM	3.37	3.54	3.12	2.90
kg CO_2-eq per ha UAA	6,257	4,030	5,793	3,299
Process contribution (%)				
Animal emissions	56	65	61	
Purchased feeds	12	18	13	22
On-farm feeds	15	1	16	1
Power supply	6	3	7	4
Transport (lorry and/or transoceanic freight ship)	3	4	3	5
Infrastructures	1	0	1	0
Tractor and agricultural machinery production	0	3	0	3
Soil C sequestration	0	0	-8	-22
Remaining processes (1)	7	6	7	7

Keywords: Sheep farming; life cycle assessment; greenhouse gas emissions; carbon sequestration.

Evaluation of benefits and limitations of a Desertification Adaptation Model framework for sustainable land management in areas under desertification risk

Castaldi S.*, M. Bijl[2], R.S. Bueno[3]* , E. Coppola[1], E. Grilli[1], T. La Mantia[3], M. Mastrocicco[1], F. Pulido[4], O. Quatrini[3], F.A. Rutigliano[1] and F. Silva[5]

*[1]Università degli Studi della Campania Luigi Vanvitelli, Italy; [2]Forest Service Group, Netherlands; [3]Università degli Studi di Palermo, Italy; [4]Universidad de Extremadura, Spain; 5Associação de defesa do património de Mértola, Portugal. *Corresponding author: rafael.dasilveirabueno@unipa.it*

The LIFE project Desert-Adapt (LIFE16 CCA/IT/000011) has designed a Desertification Adaptation Model (DAM) framework of land management to respond to two of the most critical problems experienced by farmers, public land and communities of the Mediterranean Basin, given the need to adapt to current Climate Change and reduce or counteract the increasing phenomenon of land degradation and desertification risk. These two issues are interrelated, as land degradation often characterizes fragile areas where the co-occurrence of climatically unfavourable conditions, mostly prolonged aridity and high temperatures, and inappropriate land management, leads to loss of ecosystem quality, biodiversity, productivity, agronomic activity abandonment, economic impoverishment and social crisis. The key concept behind the DAM approach is that successful long-term economic self-sufficiency and social balance, in areas under climatic and degradation risk, can only be achieved with land management strategies tailored to maintaining and enhancing the land resource base, i.e the natural capital associated with land resources and ecosystem services. The model is being tested in 9 areas under desertification risk covering almost 1000h belonging to municipalities or private farmers in southern Portugal, Spain and Italy. Ecological, economic and social functions, as well as adaptation measures are being tested to evaluate the feasibility of the proposed solutions, their benefits and immediate or long-term impacts and current limitations to the wider application of the proposed strategy.

Keywords: land degradation, climate change, Mediterranean, adaptation, LIFE.

Effect of mineral soil cover on CO_2 and N_2O emissions from agricultural drained peatland

Wang Y[1,2]*, S. Paul[1], M. Jocher[1], C. Alewell[2] and J. Leifeld[1,2]

*[1]Agroscope, Switzerland, [2]University of Basel, Switzerland. *Corresponding author: yuqiao.wang@agroscope.admin.ch*

Agricultural drained peatlands emit large amounts of greenhouse gases (GHGs), summing up to c. 5 % of all anthropogenic GHGs. In order to improve the sustainability of peatland management in agriculture, and to counteract soil subsidence, mineral soil coverage is becoming an increasingly used practice. This management may change the GHG balance from the corresponding organic soil. To explore this, we established a field experiment in the Swiss Rhine Valley and measured soil–borne carbon dioxide (CO_2, $^{14}CO_2$) and nitrous oxide (N_2O) fluxes from two adjacent sites: drained peatland with (Cov) and without mineral soil cover (Ref). Both sites were intensively managed permanent meadows with identical farming practices. Mineral soil material was applied 13 years ago with a thickness of ~ 40 cm. In 2019, soil surface CO_2 and $^{14}CO_2$ emissions were measured with static chambers in triplicate per site and date. N_2O emissions were monitored continuously over two years (2019-2021) by automatic time– integrating chambers. The result showed that heterotrophic soil respiration was similar at both sites. However, higher $^{14}CO_2$ values were observed from Cov, indicating a different origin of CO_2. Regarding N_2O, emissions from the Ref site were at the upper end of previously measured fluxes. In contrast, N_2O emissions from Cov

were reduced by a factor of nine over two years. In conclusion, mineral soil coverage seems not to affect the size of heterotrophic soil respiration, but to shift the source of decomposition of soil organic carbon from a higher share of old peat towards a higher share of younger material. This may move the system towards a reduced peat loss in the future. The substantial and persistent reduction in N_2O emissions is an exceptional finding, suggesting that mineral soil coverage seems to be a promising mitigation strategy for intensively used drained peatlands when a potential restoration is not possible.

Keywords: Organic soil, greenhouse gas, peatland management, radiocarbon.

LIFE15 ENV/IT/000392 LIFE VITISOM: sustainable management of vineyard organic fertilization to reduce GHG emissions

Ghiglieno I.[1,a], I. Minardi[2,b], L. Tezza[3], A. Pitacco[3], L. Coppo[2], F. Amari[1] and L. Valenti[1]

*[1]University of Milan, Italy; [2]West Systems, Italy; [3]University of Padova, Italy; [a]University of Brescia, Italy; [b]Ecol Studio S.p.A, Italy * Corresponding author: i.ghiglieno@unibs.it*

In the viticulture sector the main non-CO_2 GHG produced is N_2O as these emissions are directly related to N inputs applied in the field as fertilizers, released through nitrification and denitrification processes, or immediate volatilization. The reduction of N_2O emissions through better N management practices represent an important opportunity of mitigation in the viticultural sector. The LIFE15 ENV/IT/000392 LIFE VITISOM project was funded in 2015 as part of the European Life Programme. One of its main objectives was to evaluate the GHG emissions resulting from different organic fertilization managements in the vineyard. The investigation was carried out by implementing a spatial and continuous monitoring of GHG from vineyard soil. The spatial monitoring was carried out during 2017-2019 in five vineyards belonging to five Italian wine growing companies involved in the project. Continuous monitoring was done in the period October 2016-October 2019 in one winegrowing company located in the Veneto Region, comparing different soil management practices, including tillage and organic fertilised treatments. We focus on results obtained by these monitoring actions in terms of nitrous oxide emissions. From the spatial monitoring an increase of emission factor can be observed in the tilled treatment; however, a non-negligible variability is observed between sites. Continuous monitoring allowed us to highlight a strong relationship between meteorology and N_2O emissions. An emissions peak was observed, both in the treated and untreated sites, corresponding with heavy rain events through the entire year. The maximum N_2O fluxes were found in the fertilized plots, where high emissions occurred during the first 6-7 days after treatment followed by a decrease in the fluxes. This study allowed us to increase our knowledge about N_2O emissions related to vineyard soil management although the variability of results obtained in different contexts suggests the need to investigate more deeply the possible interactions between the meteorological and pedological conditions of each site.

Keywords: Vineyard, greenhouse gas emissions, nitrous oxide fluxes, organic fertilization, soil tillage

Co-benefits for biodiversity and hydrological integrity from a results-based agri-environment scheme, the Pearl Mussel Project

Overy P.[1], Byrne D.[1], Moran J[2], Lucy F.[1] and Crushell P.[3]

*[1]Institute of Technology Sligo, Ireland; [2]Galway-Mayo Institute of Technology, Ireland; [3]Pearl Mussel Project, Ireland. *Corresponding author: poppy.overy@mail.itsligo.ie*

Under the weight of a global biodiversity crisis, described as the earth's 6th mass extinction event, major efforts are needed to change the relationship between humans and the natural world. Taking a step towards change is the Pearl Mussel Project (PMP), a European Innovation Partnership where farmers, researchers and agricultural advisors are working together for the benefit of the endangered Freshwater Pearl Mussel (FPM). A results-based payment system is being used within eight priority FPM catchments to reward farmers for taking an environmental approach to land management with the main aim of improving water quality. The PMP uses a ten-point indicator scoring system to assess plot-based habitat quality. Using vegetation and management practices as indicators the scoring system assesses habitat threats combined with ecological and hydrological integrity. While the PMP focus is the improvement of catchment water quality the results-based approach can potentially have wider ecosystem benefits. Hence, this study explored the co-benefits of this novel approach for both biodiversity and hydrology of terrestrial habitats. Carabid beetles and wider plant diversity were sampled across the range of peatland and grassland habitat scores in three Mayo/Galway FPM catchments. To gather a deeper understanding of the relationship between biodiversity and the PMP scores the species traits and community composition of carabid beetles was explored. Composition changed for each score category in both grassland and peatland habitats and was strongly driven by land management and hydrology. Species traits were also used in connecting the PMP scores and hydrology. Both vegetation and carabid species have specific moisture preferences which were used as a proxy for habitat wetness. Results showed a positive connection between hygrophilous species and high habitat quality scores. The links seen between PMP scores, biodiversity and hydrology indicate the positive opportunities for results-based programmes to co-benefit both biodiversity and hydrological integrity.

Keywords: Results-based agri-environment scheme, Biodiversity, Carabid beetles, Indicators, Farmland.

Challenges and opportunities for upscaling and out-scaling locally adapted results based agri-environmental payments systems in Ireland.

Moran J.*

Galway-Mayo Institute of Technology, Ireland; Corresponding author: james.moran@gmit.ie

High Nature Value farmland (HNVf) covers approximately 33% of the agricultural land and 50% of the designated Natura 2000 area of Ireland. Designing effective policy supports to underpin the future socio-ecological and financial viability of these areas across the EU is challenging. A locally adapted, hybrid resulted-based agri-environment payments (RBPS) approach has emerged in recent decades as a potential mechanism to recognise the value from the broad range of ecosystem services from these areas. The success of the approach has been demonstrated in the Burren programme and successor pilot initiatives funded under various EU LIFE and European Innovation Partnership (EIP) operational group projects. This has led to the proposed roll out to approximately 20,000 farmers in Ireland's Common Agricultural Policy Strategic Plan (CSP) from 2023-2027. This will involve the set up of eight local cooperation projects in high priority

geographical areas (HNVf and High-Status Water bodies), which have significant capacity to meet the growing demand for a wide range of ecosystem services from farmland. This paper describes the two-decade development pathway of the approach in Ireland. The roll out of the approach requires upscaling of the system within discrete geographical areas where pilot programmes exist (up-scaling) and replicating the system across other geographical areas with diverse biophysical characteristics (out-scaling). The BurrenLIFE programme and the successor Burren Programme provides an example of upscaling. This is complemented by a description of the out-scaling of the approach informed by the EU RBPS pilot (2014-2018) and various EIP and EU LIFE projects (2017-2022). Partnership formation, trust and capacity building between dedicated community champions, innovation brokers/advisors, researchers and policy makers are key to its success. Lessons learnt have the potential to inform replication of this process across diverse agricultural landscapes and it provides a national case study of the co-creation of nature-based solutions.

Keywords: Agri-environment; nature-based solutions; European innovation partnerships; ecosystem services; results-based payments

LIFE Agromitiga: Development of climate change mitigation strategies through carbon-smart agriculture

Veroz-González O.[1]*, R. Ordóñez-Fernández[2], J.A. Gil-Ribes[3], G. Basch[4], J.F. Robles del Salto[5], M. Rodríguez-Surian[6], R. Carbonell-Bojollo[2], M.R. Gómez-Ariza[1], G. Blanco-Roldán[3], F. Márquez-García[3], J. Román-Vázquez[4], F.M. Sánchez Ruiz[1], R. Gómez-Ariza[1], E.J. González-Sánchez[3,1,4]

*[1]Asociación Española Agricultura de Conservación. Spain, [2]Área de Producción Ecológica y Recursos Naturales, Spain, [3]Universidad de Córdoba, Spain, [4]European Conservation Agriculture Federation. Belgium, [5]Asociación Agraria Jóvenes Agricultores ASAJA Sevilla. Spain, [6]Consejería de Agricultura, Spain. *Corresponding author: overoz@agriculturadeconservacion.org*

In agricultural systems, one of the most relevant natural resources for fighting climate change is soil, thanks to its potential to capture CO2 from the atmosphere. Proof of this is that soil, with three times more carbon than the atmosphere, is recognized as the second largest stock of Carbon (C) on the planet after the oceans, in addition to constituting one of the most important components of the biosphere, for its provision of ecosystem functions and services. Some agricultural practices, such as Conservation Agriculture, can increase carbon sequestration in soils. In that sense, this practice is considered by the 4per1000 initiative as one of the most effective practices to combat climate change. On this basis, LIFE Agromitiga, a European project financed by the EU LIFE Program, promotes a low-carbon agricultural system to battle climate change from the agricultural sector, through the use of Conservation Agriculture (CA), providing validated results applicable to EU commitments on global climate alliances. To do so, LIFE Agromitiga is carrying out the implementation of CA practices at 3 scales (pilot, regional and transnational scale). Therefore, a Network of Demonstrative Farms has been established, which includes 36 farms in Andalusia (Spain) in which techniques such as no tillage and different groundcovers are being monitored, as well as the amount of carbon that each practice would produce. To date, higher Organic Carbon (OC) contents have been observed in soils managed by CA techniques than in soils managed by conventional agriculture management practices, with values that are up to 40% higher in herbaceous crops and 35% higher in woody crops.

The LIFE Agromitiga project has received funding from the LIFE Programme of the European Union.

Keywords : Conservation agriculture, no-till, groundcovers, carbon sequestration.

Soil organic carbon stocks for afforested soils In Ireland

Jarmain C.[1,2*], T. Cummins[3], A.J. Jovani-Sancho[4,5], T. Nairn[6], A. Premrov[7,8], B. Reidy[9], F. Renou-Wilson[3], B. Tobin[3], K. Walz[1], D. Wilson[10] and K.A. Byrne[1*]

*[1]University of Limerick, Ireland, [2]University of Stellenbosch, South Africa, [3]University College Dublin, Ireland, [4]UK Centre for Ecology and Hydrology, United Kingdom, [5]University of Nottingham, United Kingdom, [6]SWS Forestry, Ireland, [7]Trinity College Dublin, Ireland, [8]Maynooth University, Ireland, [9]National Parks & Wildlife Service, Ireland,[10]Earthy Matters Environmental Consultants, Ireland. *Corresponding author: ken.byrne@ul.ie*

Forest ecosystems are recognised as Natural Climate Solutions (NCS). Forest soils are important carbon (C) stores, containing almost half of the total soil organic C of terrestrial ecosystems. Protecting, managing, and restoring forest ecosystems are important: they work to keep soil C in the ground, avoid new emissions, allow the potential for further accumulation and make a net contribution to the C sink. There is a continued interest in accurately quantifying soil C stocks (SCS) and understanding the drivers of change. SCS are not measured routinely in forest inventories, despite soil potentially being a large C pool and SCS is the most uncertain component in the forest C budget. SCS within a forest ecosystem are affected by factors related to soil, climate, forest type and management practices. National Inventories on Greenhouse Gas Emissions (GHG) report on the emissions (by sources) and removals (by sinks), resulting from Land Use, Land Use Change and Forestry activities. They are submitted annually to the United Nations Framework Convention on Climate Change and, as part of the Kyoto Protocol, afforestation, reforestation, deforestation and forest management are reported, with estimates of forest C pools. Here we present preliminary results of a synthesis of soil C and forest floor C stocks for afforested soils in the Republic of Ireland. Preliminary results characterizing the data by soil group and depth show a large variation in SCS with substantial SCS contained in Histosols and the surface layers of certain mineral soils. It presents supporting evidence that SCS need to be protected and appropriately managed to avoid GHG emissions. The large range in soil and litter C stocks stresses the importance of adequately accounting for soil differences when GHG inventories are compiled. The synthesised dataset should contribute to improved SCS estimations for afforested lands in Ireland.

Keywords: Soil carbon stocks, afforested soils, forest floor litter.

From fundamental science to application: how to motivate farmers into carbon farming

Vanrespaille, H.E.* and A. Elsen

*[1]Soil Service of Belgium, Belgium, *Corresponding author: hvanrespaille@bdb.be*

Soil quality and soil carbon are key for sustainable agriculture. Both society and farmers benefit from optimal carbon contents in the soil. Sequestering CO2 in the soil as organic carbon mitigates climate changes. In addition, more carbon in the soil leads to more resilience towards changing climates. However, despite the interest of farmers, the carbon levels in Belgian soils have been declining since 1990 and remain at a suboptimal level. How can it be? Constraints in the short-term, such as socioeconomic costs or strict legislation, cause burdens for farmers, as building soil carbon requires a long-term approach. By offering a framework for carbon payments, we want to motivate farmers to start working on carbon today. There is already knowledge about practices with a positive effect on carbon sequestration, like sowing green cover crops, using compost or solid manure and introducing crops like alfalfa, etc. The next question is how to make it happen? There already exists a market for carbon crediting where enterprises and institutions can compensate for their CO2-emissions by supporting carbon sequestration projects. The carbon

market offers opportunities for farmers as they can receive carbon payments and get the opportunity to show their efforts to the wider public. More than the economic balance, the emotional reward for efforts motivates farmers. However, carbon markets also contain risks, like the risk of greenwashing. The goal is not to give a license to pollute, but to motivate both parties to reduce emissions and improve sequestration. Therefore, the demands for additionality, permanence and transparency should be met. Different disciplines like soil sciences, economics and social sciences have to be combined to construct a sound and motivating framework for carbon sequestration.

Keywords: Soil carbon, carbon farming, carbon credits, sequestration, carbon markets

Planting hedgerows in England as a Nature-based Farming Solution for climate, biodiversity, and hydrology

Sofia Biffi[1]* , P. J. Chapman[1], R. Grayson[1], and G. Ziv[1]

*[1]University of Leeds, United Kingdom. *Corresponding author: s.biffi@leeds.ac.uk*

Strong emphasis has been put on the role of agriculture for climate change mitigation goals, as well as on the multi-functional delivery of ecosystem services by hedgerows. While, historically, their role was related to crop protection and livestock enclosure, hedgerows have been shown to provide other significant benefits within farmed environments, such as aboveground biodiversity, nutrient interception and protection of surface water quality, flood and drought mitigation. In the UK, where hedgerows are a defining feature of agricultural landscapes, the Climate Change Committee has proposed a 40% increase in hedgerow length as a key contribution to reaching net-zero targets. However, the role of hedgerows for the delivery of ecosystem services on farmland remains largely unclear. In our study, thirty-two hedgerows in Cumbria, England, were classified into four age categories and their associated carbon stocks, bird and bat activity, soil nutrients, and hydrological properties were quantified, and paired with adjacent grassland fields. Our results indicate an important contribution of hedgerows to ecosystem service provision in agricultural landscapes if their planting is widely encouraged and supported. However, we also show that at the current rates of planting in agri environment schemes it will take over 200 years to reach the Climate Change Committee target. In contrast, upscaling the planting rates, as shown by a private-supply chain initiative, indicates that the 40% increase in hedgerow length could be achieved in 16 years.

Keywords: Hedgerows, field boundary, climate change mitigation, agroforestry, soil organic carbon, biodiversity, hydrology

Posters

The application of carbon farming in a group of mountain dairy farms on the Emilian Apennines. First results of LIFE18/CCM/IT/001093 agriCOlture

Pacchioli M.T. [1,*], E. Bortolazzo[1], R. Davolio[1], L. Filippi[2], D. Galli[2], S. Raimondi[2]

*[1]Centro Ricerche Produzioni Animali – CRPA spa, Italy; [2]Consorzio di Bonifica dell'Emilia Centrale, Italy. *Corresponding author: m.t.pacchioli@crpa.it*

LIFE agrCOlture has been implementing carbon farming (CF) applications directed at carbon removal (sequestration and permanent storage of carbon in soils and biomass), avoided emissions

(preventing the loss of already stored carbon), and emissions reductions, in a network of 15 farms of the Emilian Apennines. This area is exposed to landslide and erosion, so the measures introduced in farms boost the conservation of carbon stocks. A characterisation of soil conditions, biology, and productivity as forage was carried out to address best practices for CF introduced for each farm. Three soil and biomass samples from 3 plots were collected per farm in a field representative of the farm's altitude, slope and cropping system. Parameters evaluated for soil are: textural classification, water-stability of aggregates, pH, conductivity, porosity, total limestone, total nitrogen, assimilable phosphorus, exchangeable potassium, FAO World Reference Base classification, land capability, biological quality index (QBS-ar). Organic carbon, organic matter, total extractable carbon and carbon stock were evaluated both for the 0-15 and 15-30 cm soil layers. For topsoil, information was collected about agronomic use (arable, pastures, permanent meadow), year from last plowing, and animal waste use. The biomass used for phytocoenosis evaluation were classified per % of Fabacae, Poaccae, and other species. Cluster analysis of data (IBM SPSS Statistics 27) groups the 15 fields in 5 clusters from higher sheep and goats dairy farms (DFs), higher cow DFs, cow DF with an efficient forage system (FS), cow DFs with poor FS, and no use of animal waste. Principal component analysis identified three main components that were able to explain 63.93% of the variance between the 5 clusters. Component 1 (42,89% of variance) segregates for phytocoenosis, Fabacae and other species vs Poacae, porosity, water-stability of aggregates, carbon stock and total nitrogen content. Component 2 segregates for altitude, land capability, agronomic use, textural classification. Component 3 for stability of the aggregates, total limestone, altitude.

Keywords: Carbon farming, soil protection, carbon stock, LIFE18/CCM/IT/001093

The carbon footprint of three olive orchards under different agricultural practices in the Mediterranean Region

Zagklis G.*, S. Kavasilis, M.K. Doula, C. Kolovos, A.V. Papadopoulos and G. Tsitselis

*Benaki Phytopathological Institute, Greece.*Corresponding author: g.zagklis@bpi.gr*

Agriculture produces considerable quantities of Greenhouse Gases (GHG), due to emissions related to specific agricultural practices applied by the farmers, such as the use of nitrogen fertilizers, the management of organic materials (e.g., manure, slurries), the use of fuel for agricultural machinery, electricity, land-use change and others. In this study, three olive orchards located in south, central and northern Greece were studied in terms of unsustainable practices, implemented by the farmers, and are considered GHG sources. The orchard in south Greece is under organic cultivation, combined with livestock farming, while the two other orchards are under conventional agriculture (mineral fertilization, pesticides, etc.). The IPCC guidelines (2006, 2019) were applied for the estimation of the carbon footprint of the orchards for three consecutive years, 2018, 2019, and 2020 by collecting field data and estimating CO_2, CH_4 and N_2O emissions from all possible sources, including LULUCF. Results show that organic agriculture combined with livestock farming, apart from other benefits, such as increased soil organic matter, caused less GHG emissions in comparison to the fields under conventional practices. Practices that were found as major contributors to the emissions are machinery use (i.e., fuels), nitrogen fertilizers, and burning of agricultural residues. Motivating farmers to implement sustainable practices will lead to a reduction of GHGs emissions from agriculture but also to the conservation of natural resources, avoiding energy overuse, and protecting the agricultural environment.

Keywords: Carbon footprint, agricultural practices, GHG´s emissions, Mediterranean Region.

Voluntary Guidelines for sustainable soil management: an Italian experience

Iavazzo P.[1]*, F. Altobelli[2], A. Benedetti[2], A. Martelli.[2], M.G. Piazza[2], L. Verdelli[1] and S. Brenna[1]

*[1]ERSAF - Ente Regionale per i Servizi all'Agricoltura e alle Foreste Italy; [2]CREA - Consiglio per la Ricerca in agricoltura e l'analisi dell'economia agrarian, Italy. *Corresponding author: pietro.iavazzo@ersaf.lombardia.it*

Increasing citizens' knowledge of soil protection and raising awareness among national and EU institutions of the need to adopt adequate regulations to stop soil loss and prevent its degradation is the main objective of European policies on Soil. Within this context, the Soil4Life project aimed to promote sustainable use of the soil as a strategic, limited and non- renewable resource in line with the commitment signed by the European countries at the United Nations table, through adherence to the Sustainable Development Goals. Soil4Life therefore pursued the application of the Voluntary Guidelines for sustainable soil management promoted by FAO, adapting them to national, regional and local contexts, and provided information and support to territorial planning involving the agricultural and professional sectors. The application of sustainable cultivation models enhancing the functionality of soils can have a key role for environmental and territorial rebalancing. One of the main objectives of sustainable management of agricultural soils is the ability to promote the maintenance, and possibly stimulate the increase, of the organic matter content, thus contributing to the mitigation of climate change and better adaptation to its effects. This objective can be achieved through the interaction between different best practices such as crop rotations and diversification, the use of quality organic matrices as fertilizers, the adoption of conservative soil management practices and continuous vegetation cover. A Pilot within the Lombard agricultural context, characterized by extremely intensive management, was developed highlighting the benefits of the application of best practices in terms of ecosystemic services. Specifically, some of the most widespread techniques for the management of organic matrices of zootechnical and extra- agricultural origin were assessed in terms of conservation/increase of soil organic matter. The study allowed the arrangement of a conceptual model of soil management based on the integration of best practices leading to effective and long-term results.

Keywords: Sustainable soil management, soil organic carbon, best practices, soil ecosystemic services

Validating NBFS contributions to agrobiodiversity values through a multi-scale floristic, vegetational and landscape monitoring approach

Chiaffarelli G. and I. **Vagge***

*University of Milan, Italy. *Corresponding author: ilda.vagge@unimi.it*

Nature Based Farming Solutions (NBFS), here considered as landscape management features, such as agroforestry and agroecological crop management, are practices directed at restoring, within agricultural systems, the often undermined ecosystem functions. These approaches still strongly demand further context specific scientific validation for their viable deployment at a local scale. Applied ecological sciences, like landscape ecology and phytosociology, are focused on the need for scientific applied knowledge building related to an understanding of the ecological patterns and trends underlying these practices, allowing for the accounting of their overall contribution to the enhancement of environmental stability and the ecological functionality of agro-ecosystems. In this context, our project is focused on the testing, calibration and validation of a

monitoring scheme for accounting for the contributions of NBFS practices on the agrobiodiversity values. Floristic, vegetational and landscape ecology analyses are the main focus of the assessment, which are then integrated and correlated with other matrices (soil, fauna, climate, agronomic data). Analyses are carried out among specific pedo-climatic contexts, on different spatial and time scales, among four pilot organic farms belonging to the *Polycolturae* network, located in the Po Plain context, applying diversified sets of agroecological practices (including crop diversification, cover crops and intensive crop residues mulching, landscape features and agroforestry management of rice productive systems). Nearby conventional farms are also under assessment, for data comparison. We here present the preliminary results obtained on one of the pilot farms. Floristic and vegetational data were collected at single patch scale. Landscape ecology indicators were calculated at the landscape and farm scale. Diversity indexes were also calculated. Chorology, auto-ecology, sin-ecology and dynamic traits of the spontaneous cenosis were studied, allowing us to map their degree of adaptation and balance in relation to the environmental context. These results are intended to be integrated with further data, then correlated with other matrices, in order to calibrate and validate the environmental monitoring indicator system. In parallel, these results are intended to converge into a qualitative and quantitative Ecosystem Services assessment.

Keywords: NBFS, agrobiodiversity, phytosociology, landscape ecology, multi-scale indicators

Biochar's impact on soil carbon sequestration and sustainability of crop residue harvesting for bioenergy

Laird D.*

*Iowa State University, USA.*Corresponding author: dalaird@iastate.edu*

The Pyrolysis-Biochar-Bioenergy Platform (PBBP) is a candidate system for the production of carbon negative biofuels. The enabling technology, autothermal fast pyrolysis, converts biomass into biochar and various bioenergy co-products. The bioenergy co-products address a critical societal need for drop-in liquid transportation fuels that offset fossil fuels, and the biochar co-product addresses the equally critical need for carbon sequestration. However, the harvesting of crop and forest residues inherently removes plant nutrients from soils, accelerates soil acidification, and expropriates organic residues that are needed to build new soil organic matter. Here we consider whether the biochar co-product is effective for making the harvesting of biomass for PBBP systems sustainable. The biochar co-product contains most of the nutrients harvested with the biomass; hence applying biochar to soils recycles nutrients (~50% of N and S and >95% of P, K, Ca, Mg, Zn and most micronutrients). Most biochar's are liming agents, which are effective for offsetting the acidifying effects of biomass harvesting. However, some pyrolysis processes produce acidic biochars. Soil applications of acidic biochars would necessitate compensating lime applications to maintain soils in the optimum pH range for plant growth. Biochars are typically 50 to 70% C by mass and are dominated by condensed aromatic C, which is recalcitrant to microbial degradation. Numerous studies indicate that biochar amendments are highly effective for increasing total soil organic C content. Furthermore, recent research indicates that biochar amendments increase the carbon saturation level of soils by providing surfaces that adsorb dissolved organic compounds facilitating their transformation into stabilized biogenic humic materials (aka, negative priming). Thus, biochar amendments have the capacity to compensate for most of the negative effects of biomass harvesting on soils. Biochar amendments, however, do not protect soils from erosion, hence enough residues should be left on soils surfaces to prevent erosion.

Keywords: soil carbon sequestration, crop residues, biochar, bioenergy, sustainability

Biodiversity and resilience of agro-ecosystem functions for environmental sustainability

Gleadow R.

Monash University, Clayton Melbourne, Australia.

Humans are connected to nature and to each other through rising CO_2 and global heating, habitat destruction and pollution, many of which are the direct result of outdated 20th Century agricultural systems. Yet those systems have been very effective in increasing global food supplies. Clearly, new approaches are needed. Plants around the world are being driven to extinction. How can we maintain biodiversity in a world that is under increasing pressure? Sustainability is not only

important; it is essential. Ecosystems need to be conserved, not just because they have a right to be preserved for their own sakes, but for the health and well-being of the human population. At the most basic level, we may be losing plants with unique chemicals that could be used to cure diseases, unique genotypes of crop wild relatives that could be a source of traits to improve agricultural productivity etc. Plant scientists around the world are working to document diversity, collect seeds for storage in seed banks, develop more efficient crops that use less fertilizer and water and are resistant to pests and diseases without the need for the application of large volumes of agrichemicals. What will it take to translate this science into action? The aim of the Global Plant Council, a coalition of plant science institutions and research organisations from around the world, is to facilitate the development of plant science for global challenges, foster international collaborations, and enable the effective use of knowledge and resources. We provide an independent and inclusive forum to bring together all those involved in plant and crop research, education and training. This talk will present some strategies that can be implemented to help communicate the how and why of addressing issues of sustainability, biodiversity decline, ecosystem resilience and food security with a view to enabling real change.

Keywords: Science communication, international collaboration, food security

Integration of livestock with various land uses for reducing the carbon-footprint

Mottet A.*

*Food & Agriculture Organizations of the UN, Italy. *Corresponding author: anne.mottet@fao.org*

Livestock, like any other agricultural sub-sector, have a role to play in climate change mitigation. The potential of applying best practices in livestock to reduce GHG emissions is estimated at about 30% of baseline GHG emissions at global level. This potential ranges from 14% to 41% according to species, system, and region. Pastures and rangeland soils are estimated to contain globally about 343 Gt of carbon, 50% more than in forests. Improving grazing management can also contribute to climate change mitigation through increased soil carbon sequestration. FAO (2017) identifies three main strategies for climate change mitigation of livestock, which cover all types of production systems: (i) Improving efficiency and productivity, (ii) Better integrating ruminants in the circular bioeconomy by enhancing the use of by-products and crop residues as feed, which also reduces feed/food competition, and recycling energy and nutrients from manure (see the next subsection on circularity) and (iii) Increasing soil organic carbon content, particularly in pastures (see previous subsection on soils). Direct mitigation strategies, such as feed supplementation or manure treatment or application also have a potential to reduce emissions. Such practices are however more adapted to production systems where animals are fed indoors, and manures are collected regularly. They also usually come at higher costs than measures targeting efficiency. The role of livestock in climate change mitigation and adaptation is well recognized by policy makers. 92 developing countries have included livestock in their nationally determined contributions (NDCs) under the Paris Climate Agreement. These commitments are however often conditioned to accessing finance and capacity development, in addition to data availability.

Keywords: Livestock, grazing systems, carbon-foot printing, climate change mitigation

Policy strategies and challenges for climate change mitigation in the agriculture and AFOLU sector

Henderson B.*

Trade and Agriculture Directorate, OECD, France. Corresponding author: b*en.henderson@oecd.org;*

There is ample scope for agriculture to reduce both its direct and indirect GHG emissions and contribute to sector-wide efforts to achieve net-zero emissions. The sector also offers nature-based options to remove CO2 from the atmosphere through carbon sequestration in biomass and soils, which can also contribute to productivity and resilience. OECD research shows that with a comprehensive policy package combining global emissions taxes and carbon sequestration subsidies agriculture, forestry and other land use (AFOLU), as a whole, could mitigate 8 Gt CO_2eq/year in 2050, representing 12% of total global anthropogenic GHG emissions. Direct (agriculture) emission reductions would represent 29% of this total, soil carbon sequestration 9%, and other land use changes 62%. Despite this potential, agriculture lags behind other sectors in terms of climate change commitments and actions. By mid-2022, only 16 countries of OECD and key major emerging economies had set emissions reduction targets specific to the agricultural sector. Agriculture is often exempt from mitigation policies such as carbon pricing or equivalent regulatory measures. While agriculture receives considerable policy support, very little of this is aligned with climate objectives. In particular, the share of support directed to general services-including agricultural knowledge and innovation systems and infrastructure) has declined over the past two decades from 16% to 13%, which constrains the transition to more resilient and sustainable production. Fulfilling the agriculture sector's mitigation potential is a complex task, as mitigation needs to be achieved while facilitating adaptation to harsher conditions in order to minimise adverse effects on food security and nutrition, safeguard livelihoods and protect the environment. However, there is still considerable scope for action through reforming agricultural support policies, providing direct incentives for adaptation and mitigation, and using social safety net policies to facilitate an inclusive transition.

Keywords: Emissions policy support, sustainable production, food security

Carbon farming and nature-based solutions for GHG offsetting

Rasse D.*

Norwegian Institute of Bioeconomy Research, Norway. Corresponding author: Daniel.Rasse@nibio.no

Carbon farming aims at managing agroecosystems in order to increase C sequestration in soils, while enhancing soil health for sustainable food production. Carbon farming covers an ensemble of methods, which can provide efficient and low-cost solutions for climate mitigation in order to reach the 55% net reduction in GHG emissions by 2030. The key principle behind C farming is increasing the flux of photosynthetic C to soil and fostering its stabilisation in the form of soil organic matter. Some methods like cover crops increase the year-round fixation of C, others like pyrolysis and composting improve the stabilisation of C, while others like deeper rooting crops and improved grazing potentially do both. In choosing a method, one must consider the expected C sequestration potential, the certainty to reach the expected effect, the maturity of the technology, and the ease of implementation by farmers. In answering these points, one must also consider that responses are often ecosystem specific, and data obtained in one region might not apply to another. For example, no-till solutions appear to increase soil C sequestration in dryer and warmer climates, while effects in colder and wetter climates are not as clear. Cover crops are currently being investigated in multiple carbon-farming projects as they are an attractive solution based on available and easy-to-implement technology. Other methods like enhanced root systems might

have a great potential but are still under development. Multiple methods are likely to be phased in progressively as more data become available and our understanding progresses. Whether combining these methods into regenerative agricultural systems will become the prevalent solution is too early to tell, and it will certainly largely depend on the magnitude of the synergistic effects and on our capacity to implement these solutions efficiently.

Keywords: Photosynthetic C, cover crops, deep rooting, no-tillage, carbon farming, nature-based solutions

Towards a carbon-neutral and climate-resilient rice cropping systems

Ibáñez C.*

*Climate Resilience Centre, Eurecat, Catalonia, Spain. *Corresponding author: carles.ibanez@eurecat.org*

The cultivation of rice is very important as it is the staple of food for a third of the world's population. However, present rice cropping systems show a low resilience against climate impacts such as drought and at the same time contribute to global warming due to significant greenhouse gas emissions, since they contribute to circa 10% of the global methane emissions. Rice fields occupy about 9% of the world's cropland and their soils play an important role in the carbon cycle. The high productivity of rice and the flooding conditions of the crop promote carbon storage in the soil, but they can also produce greenhouse gases, such as carbon dioxide, methane, and nitrous oxide. The introduction of more sustainable practices is of paramount importance to make the crop more climate-resilient and contribute to climate mitigation. Practices such as alternate wetting and drying can achieve significant water savings and reduce by up to 90% the methane emissions during the growing season. However, in temperate rice fields it has been shown that most of the methane emissions may occur in the post-harvest period, and in this case the management of water and straw is very important to reduce the global warming potential of the crop. At the same time, the change in farming practices can be the base for developing carbon farming and agri-environmental schemes to economically support rice farmers to carry out the transition towards a climate-resilient rice production.

Keywords: Sustainable practices, carbon farming, greenhouse gas mitigation, rice paddies

Agricultural measures and policies for climate change mitigation

Brennan, L.*

*Department of Agriculture, Food and the Marine, Ireland. *Corresponding author: liam.brennan@agriculture.gov.ie*

The Irish Government is committed to delivering on the climate targets for the agricultural sector as set out in Ireland’s Climate Action Plan 2021. The Climate Action Plan 2021 sets out in detail the decisive action to achieve a 51% reduction in overall greenhouse gas emissions by 2030 and setting Ireland on a path to reach net-zero emissions by no later than 2050. It will put Ireland on a more sustainable path, cut emissions, create a cleaner, greener economy and society; and protect us from the devastating consequences of climate change. The Plan lists the actions needed to deliver on our climate targets and sets indicative ranges of emissions reductions for each sector of the economy. It will be updated annually, including in 2022, to ensure alignment with our legally binding economy-wide carbon budgets and sectoral ceilings. This Plan makes Ireland one of the

most ambitious countries in the world on climate. The high proportion of national emissions represented by agriculture in Ireland means that for Ireland to meet its overall emissions reduction targets, along with all other sectors, the agriculture sector must make a positive contribution to combating climate change and supporting the transition to a climate resilient, biodiversity rich and climate neutral economy and society no later than 2050. Irish agriculture is dominated by livestock grazing outdoors, a pasture-based food system, which compares favourably to systems where animals are housed on intensive grain-based production systems. The sector has a reputation for high quality and sustainably produced food, and it is important that we maintain that reputation, in a world with increasing consumer demands for credible evidence that food and ingredients are produced sustainably. The Climate Action Plan 2021 commits the agricultural sector in Ireland to reducing its Greenhouse Gas emissions by 22-30%, to reach 16-18 MtCO2eq. by 2030. The plan sets out in detail mitigation measures to deliver these reductions, with a focus on reducing chemical nitrogen usage, improved animal breeding and feeding, reducing the finishing age of beef cattle and increasing the area of organically farmed land in Ireland.

Keywords: Irish Climate Action plan, emissions reductions, climate neutral economy

A farmer's perspective on how to make agriculture carbon neutral

Cullinan T.*

*Irish Farmers Association, Ireland. *Corresponding author: president@ifa.ie*

Farmers are committed to playing their part to make agriculture carbon neutral. Achieving net zero in agriculture will be extremely challenging, there is no magic bullet or one-size-fits-all approach, a multitude of different options are needed to both reduce emissions and capture or store carbon in soils and woodlands. Carbon neutral agriculture refers to the net zero balance of emissions and sinks of all the greenhouse gases on farms in terms of their CO2 equivalents, resulting in climate neutral systems. The first step in reducing emissions from agriculture is to produce food as efficiently as possible—that is, to change how we farm. Targeting waste and inefficiencies in the system can help bring emissions down. Farmers need to be supported to overcome the capital and knowledge constraints in order to be able to access new technologies and adopt new practices to reduce their emissions at farm level. Science-based options and new technologies will have a huge role to play, these include genetic selection and breeding programmes, menthane inhibiting feed additives or vaccines, as well as technologies that improve production efficiencies. There needs to be further investment in research and development as well in the deployment of these innovative solutions at scale. This represents a significant challenge and will be exacerbated for farmers with smaller holdings. While land use change will play a critical role in land-based mitigation - forests, peatland restoration and improved grassland management can improve carbon stores. Supporting farmers to improve carbon sequestration and storage through carbon farming can contribute significantly in the efforts to tackle climate change, bringing other co-benefits, such as increased biodiversity and preservation of ecosystems. There are also opportunities for farmers to diversify to produce renewable energy be it solar, wind or anaerobic digestion. Capturing and using methane through anaerobic digesters can significantly reduce emissions from livestock. There is significant scope for expanded generation of biogas, which can be used on the farm or sold back to the grid.

Keywords: Net zero agriculture, science-based options, carbon farming

Mitigation options for greenhouse gases from Latin American grazing systems

Alfaro M.* and F. Salazar

*Instituto de Investigaciones Agropecuarias (INIA), Chile. *Corresponding author: malfaro@inia.cl*

The increase of global temperature due to greenhouse gas (GHG) accumulation in the atmosphere has significantly affected agriculture and food security and are likely to be exacerbated in the future years. During the last decade, Central and South America have suffered extreme weather events that have contributed to an increase in the vulnerability of resources. Decreasing trends of precipitation have been reported, together with an increase in air temperature of 2-4°C, whose overall effect can reduce fodder yield. The major impacts of climate change have been reported over forage crops and grazing systems, including effects on plant growth, pasture composition, quality of forage, dry matter yield and nitrogen leaching. Livestock production makes a major contribution to human livelihoods, especially for smallholder farming systems, particularly in Latin-American countries, and the current global trend of increased consumption of livestock products is expected to continue, thereby emphasizing the importance of developing effective emission-reduction options for livestock production. Thus, several mitigation strategies have been discussed but more importantly, the pursuit of mitigation together with adaptation measures has emerged, both of which could benefit from synergistic effects to overcome the effects of climate change. Strategies and advances made in Latin-American grazing systems will be presented, including feeding strategies, the development of novel nitrogen fertilizers and the effect of replacing grassland monocultures by mixed legume-grass pastures.

Keywords: Grazing systems, smallholder farmers, mitigation and adaptation

Is it possible to reduce GHG emissions from cultivated peat soils while maintaining productivity?

Berglund Ö.*

*Swedish University of Agricultural Sciences, Sweden. *Corresponding author: orjan.berglund@slu.se*

Peat soils are mainly found in areas where water limits organic matter decay. In Europe, the proportion of peat soils is particularly high in some regions such as Northern Finland or the Northern and Western coast of Norway, where they constitute up to 60 % of the soils and a significant portion of the arable land. Drained peatlands are important contributors to the global cycling of atmospheric gases. When peatlands are drained, aerobic activity becomes possible in deeper layers, and the increased decomposition of the peat increases the fluxes of CO_2 to the atmosphere. Peatlands dominate the emissions of CO_2 from agricultural land in many countries. For example, the estimated combined total emissions of CO_2 and N_2O from agricultural peat soils in Sweden in 2003 corresponded to approximately 6-8% of total emissions of all greenhouse gases reported by Sweden, and in Finland, 8% and 25% of total national anthropogenic CO_2 and N_2O emissions, respectively. Where paludiculture is possible, and there is a market for the product, that might be a viable option. Still, it is not suitable everywhere due to legal, climatic and management constraints. Other options to reduce greenhouse gas emissions from peat soil evaluated in field trials over the last 20 years include: Water table management, different crops, different cultivation intensities, sand addition, copper fertilisation and soil compaction. So far, the most promising method is sand addition, where a 20% reduction of CO_2 over three years could be observed.

***Keywords**:* Cultivated peat soil, greenhouse gas emissions, field trials, water table

ACKNOWLEDGEMENTS

We would like to thank all of the organisations that support ISCRAES 2022.

Platinum Sponsors

The OECD Co-operative Research Programme: Sustainable Agricultural and Food Systems

OECD
BETTER POLICIES FOR BETTER LIVES

Back to the Future: Reintegrating Land and Livestock for Greenhouse Gas Mitigation and Circularity

ReLive

Gold Sponsors

epa Research

Fáilte Ireland
National Tourism Development Authority

Silver Sponsors

eagasc
Agriculture and Food Development Authority

VAN WALT
IRELAND

agronomy
an Open Access Journal by MDPI

UCD Earth Institute
UCD Institiúid an Domhain

Bronze Sponsors

International Union of Soil Sciences

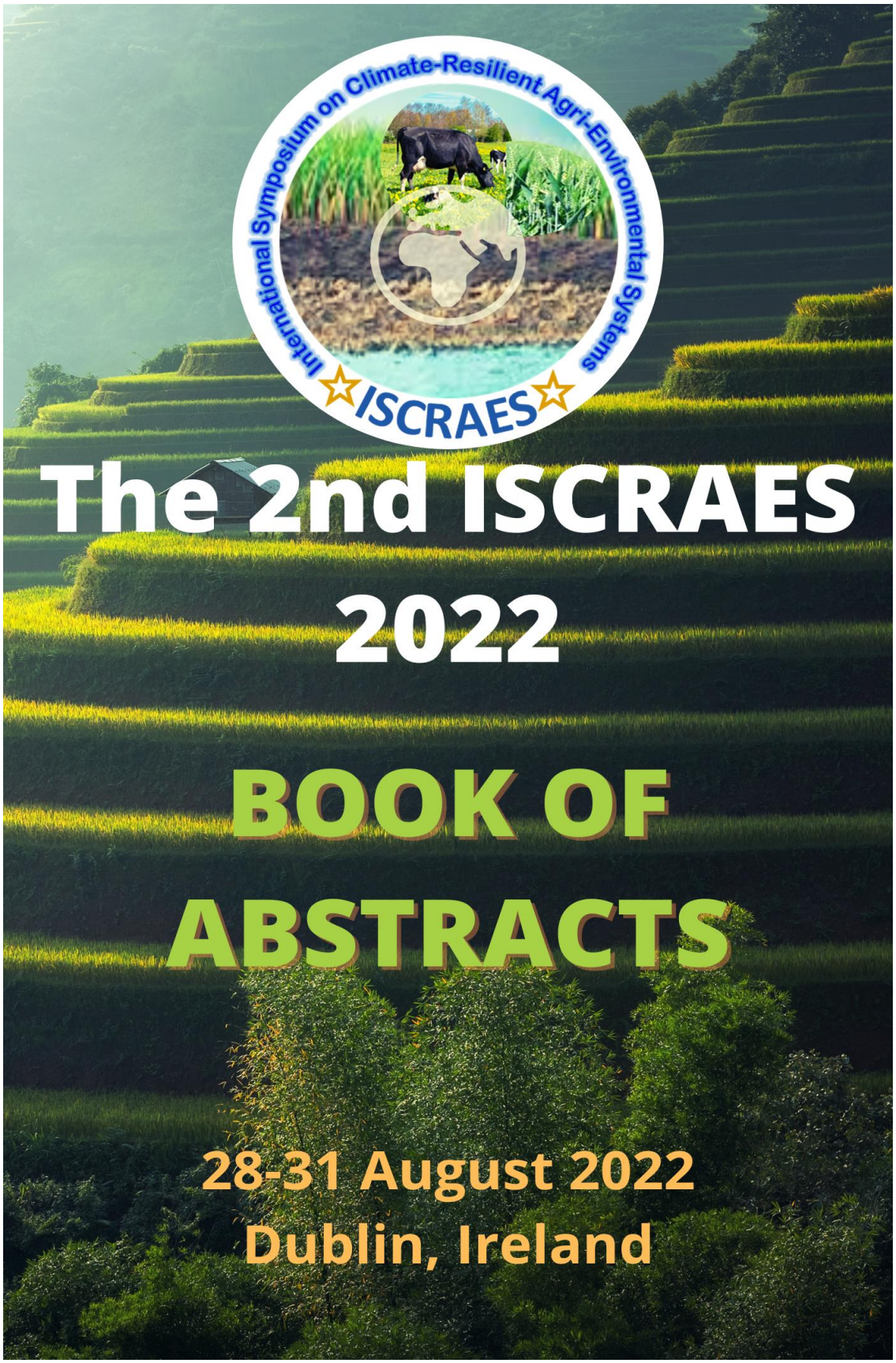
The GLOBAL PLANT COUNCIL

PRUDENCE COLLEGE DUBLIN

i-VOL
THE NATIONAL VOLUNTEERING DATABASE

- Dún Laoghaire Rathdown Volunteer Centre
- South Dublin County Volunteer Centre

Edited by M.I. Khalil, B. Osborne and A. Wingler; ISCRAES Book of Abstract Series 2; Published in 2022 by the ISCRAES 2022 Organising Committee in collaboration with Prudence College Dublin.



Edited by M.I. Khalil, B. Osborne and A. Wingler; ISCRAES Book of Abstract Series 2; Published in 2022 by the ISCRAES 2022 Organising Committee in collaboration with Prudence College Dublin.