CGIAR

ASSOCIATION OF APPLIED BIOLOGISTS
CROPPING AND THE ENVIRONMENT

USDA

President: **Professor Mike Gooding**

Long Term Experiments: Meeting future challenges

Three-day Hybrid event hosted online and at *Rothamsted Research, West Common, Harpenden, UK*

20th-22nd June 2023

Association of Applied Biologists, Warwick Enterprise Park, Wellesbourne, Warwick CV35 9EF, UK
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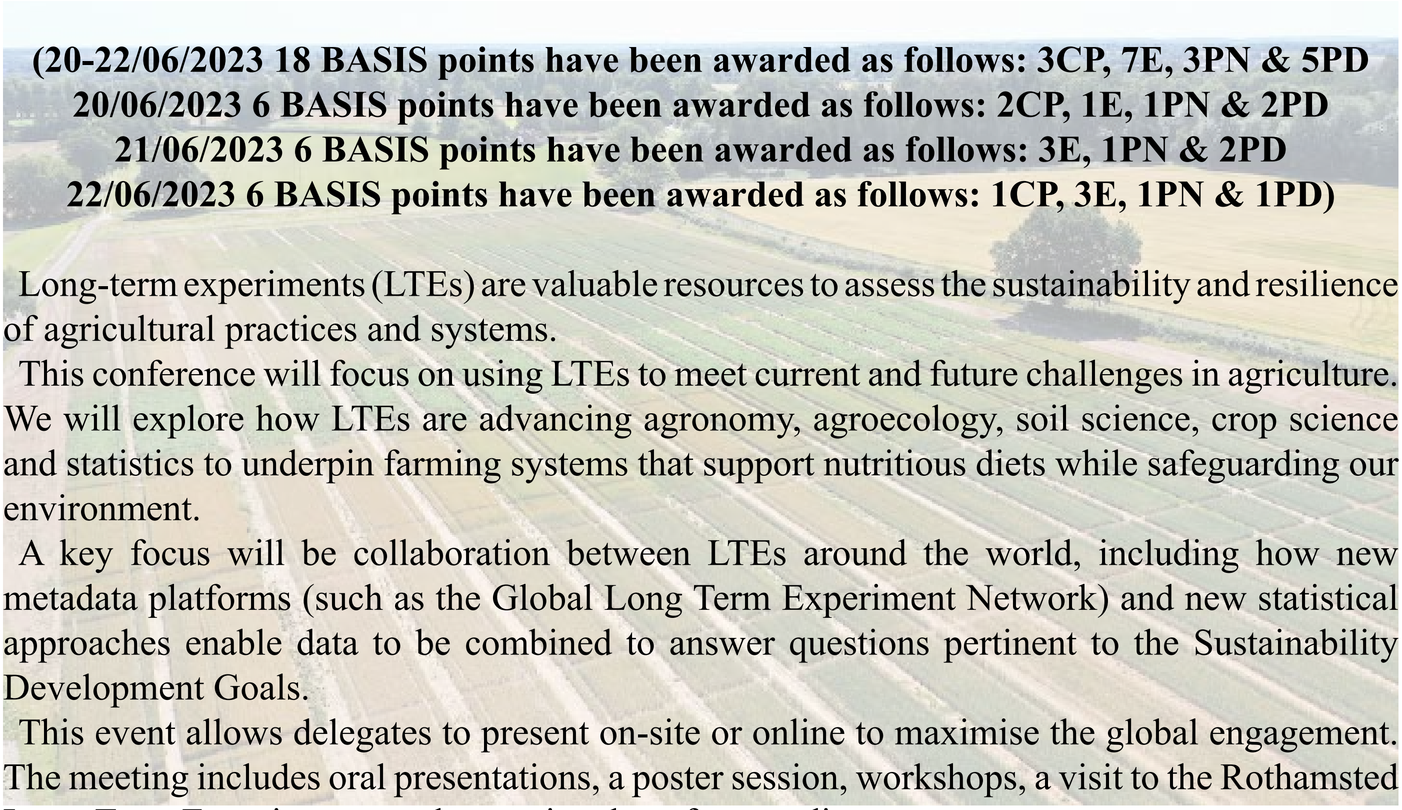


(20-22/06/2023 18 BASIS points have been awarded as follows: 3CP, 7E, 3PN & 5PD
20/06/2023 6 BASIS points have been awarded as follows: 2CP, 1E, 1PN & 2PD
21/06/2023 6 BASIS points have been awarded as follows: 3E, 1PN & 2PD
22/06/2023 6 BASIS points have been awarded as follows: 1CP, 3E, 1PN & 1PD)

Long-term experiments (LTEs) are valuable resources to assess the sustainability and resilience of agricultural practices and systems.

This conference will focus on using LTEs to meet current and future challenges in agriculture. We will explore how LTEs are advancing agronomy, agroecology, soil science, crop science and statistics to underpin farming systems that support nutritious diets while safeguarding our environment.

A key focus will be collaboration between LTEs around the world, including how new metadata platforms (such as the Global Long Term Experiment Network) and new statistical approaches enable data to be combined to answer questions pertinent to the Sustainability Development Goals.

This event allows delegates to present on-site or online to maximise the global engagement. The meeting includes oral presentations, a poster session, workshops, a visit to the Rothamsted Long-Term Experiments, and an optional conference dinner.

The conference will celebrate the 180th anniversary of the Broadbalk Winter Wheat experiment. Broadbalk is the world's oldest field experiment, and was established in 1843 to investigate the relative importance of different plant nutrients. Today, it helps to answer questions about how farming practices, inputs, and weather patterns affect crop production.

PROGRAMME

Tuesday 20th June

09:00-09:50 **REGISTRATION with COFFEE**

10:00 **WELCOME and INTRODUCTION (Auditorium)**

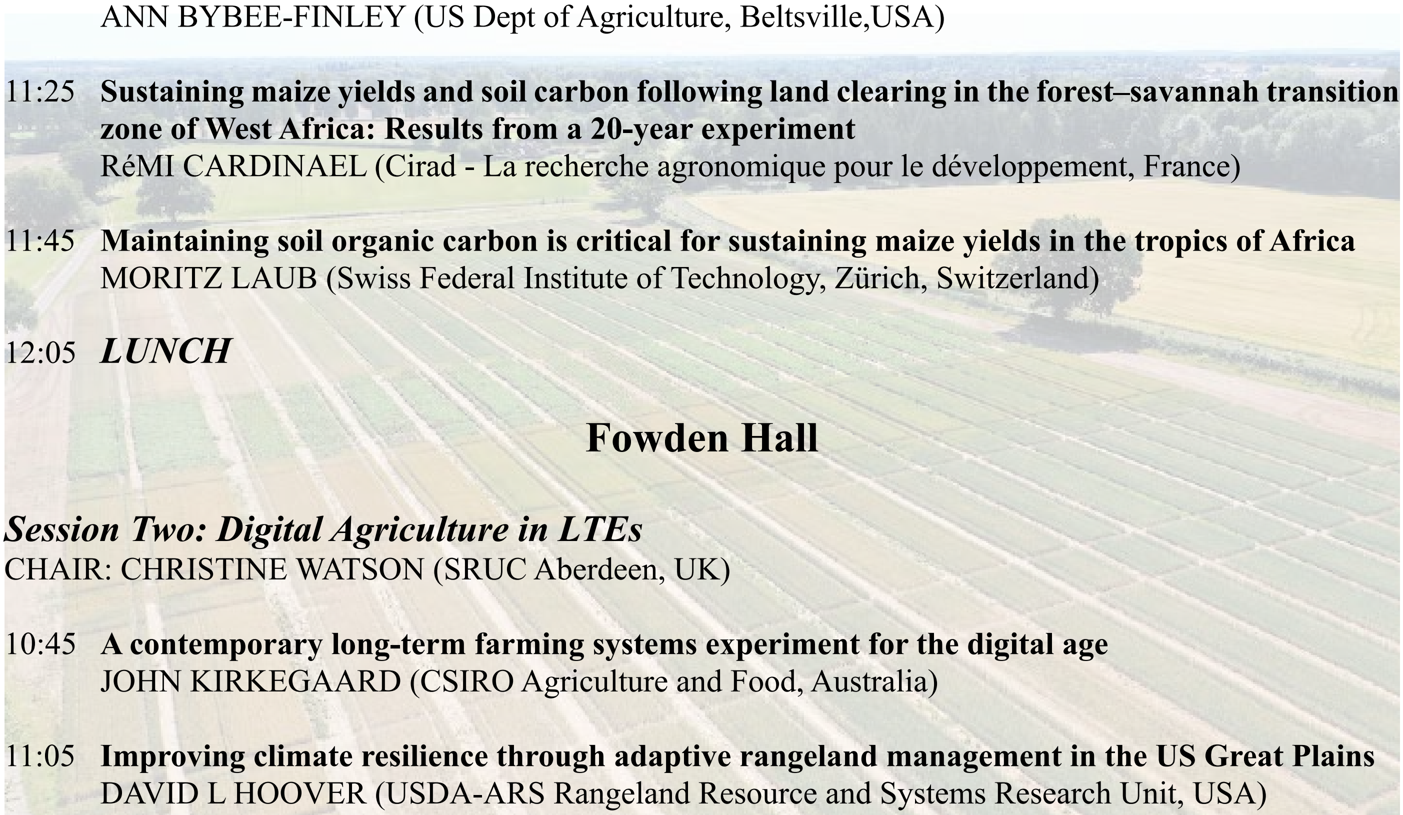
10:10 ***Keynote speaker***
Conservation Agriculture Research in Southern Africa – the role of Long-term experiments
CHRISTIAN THIERFELDER (CIMMYT, Zimbabwe)

Auditorium

Session One: Sustaining Cropping Systems
CHAIR: CAIRISTIONA F E TOPP (Scotland's Rural College (SRUC), Edinburgh, UK)

10:45 **The integration of cover crops and soil tillage to build resilience in farming systems in a long running UK field experiment**
NATHAN MORRIS (NIAB, Cambridge UK)

11:05 **Yield and yield stability within a rotational complexity gradient derived from a network of long-term cropping systems experiments**
ANN BYBEE-FINLEY (US Dept of Agriculture, Beltsville,USA)



11:25 **Sustaining maize yields and soil carbon following land clearing in the forest–savannah transition zone of West Africa: Results from a 20-year experiment**
RéMI CARDINAEL (Cirad - La recherche agronomique pour le développement, France)

11:45 **Maintaining soil organic carbon is critical for sustaining maize yields in the tropics of Africa**
MORITZ LAUB (Swiss Federal Institute of Technology, Zürich, Switzerland)

12:05 ***LUNCH***

Fowden Hall

Session Two: Digital Agriculture in LTEs
CHAIR: CHRISTINE WATSON (SRUC Aberdeen, UK)

10:45 **A contemporary long-term farming systems experiment for the digital age**
JOHN KIRKEGAARD (CSIRO Agriculture and Food, Australia)

11:05 **Improving climate resilience through adaptive rangeland management in the US Great Plains**
DAVID L HOOVER (USDA-ARS Rangeland Resource and Systems Research Unit, USA)

11:25 **Combining randomized field experiments with observational satellite data to asses the benefits of crop rotations on yields**
DAN KLUGER (Stanford University, USA)

11:45 **Spatial temporal variability in yield and nutrient use e□ciency across a long-term farming systems experiment**
DAVID CLARKE (NIAB, Morley St Botolph, Norfolk, UK)

12:05 ***LUNCH***

Auditorium

13:00-14:30 **Workshop 1: Generating research questions for LTE networks**
ORGANISER: ANN BYBEE-FINLEY (US Dept of Agriculture, Beltsville,USA)

Fowden Hall

13:00-14:30 **Workshop 2: Data management for LTEs**
ORGANISER: RICHARD OSTLER (Rothamsted Research, Harpenden, UK)

14:30 ***TEA BREAK***

Auditorium

Session Three: (Re)Designing LTEs for the Future
CHAIR: CHLOE MACLAREN (Swedish University of Agricultural Sciences, Uppsala, Sweden)

15:00 ***Keynote speaker***
Looking back to look forward – the role of LTEs in predicting the impact of future land use policy
CHRISTINE WATSON (SRUC Aberdeen, UK)

15:30 **Never change a running system? Balancing systems approach and comparability when adapting LTEs**
EVA GOLDMANN (Research Institute of Organic Agriculture (FiBL), Switzerland)

15:50 **Re-designing Long-Term Rotations**
CAIRISTIONA TOPP (Scotland's Rural College (SRUC), Edinburgh, UK)

16:10 **Designing farms of the future using LTEs**
MARIE WESSELINK (Wageningen University & Research, The Netherlands)

16:30 **Reflections on the design and management of a new Long Term Experiment**
JONATHAN STORKEY (Rothamsted Research, Harpenden, UK)

Fowden Hall

16:50-17:00 ***Put up Posters***

17:00-20:00 ***Poster Session and Drinks Reception***

18:30-20:00: ***Hot Buffet Served***

Wednesday 21th June

08:00-09:00 **REGISTRATION with COFFEE**

Auditorium

Session Four: Soil Carbon
CHAIR: CHRISTIAN THIERFELDER (CIMMYT, Zimbabwe)

09:00 **Soil organic carbon stocks and greenhouse gas emissions in two long-term conservation agriculture experiments in sub-humid Zimbabwe**
ARMWELL SHUMBA (University of Zimbabwe, South Africa)

09:20 **Leveraging long-term experiments to assess the carbon sequestration potential of diverse agroecosystems on Mollisols of the North Central US**
GREGG SANFORD (University of Wisconsin-Madison, USA)

09:40 **Rotation with forage crop and fertilization slowed down soil carbon loss from Swedish long-term field experiments**
RONG LANG (Swedish University of Agricultural Sciences, Sweden)

10:00 **Soil organic carbon and nitrogen dynamics under long-term conservation agriculture systems in Cambodia**
VIRA LENG (Cambodian Conservation Agriculture Research for Development Center, Cambodia)

10:20 **Soil organic matter stocks decrease despite increasing plant productivity - Insights from 14C analyses of an 80-years-old field experiment**
SABINA BRAUN (Swedish University of Agricultural Sciences, Sweden)

10:40-11:10 ***COFFEE BREAK***

Brenchley Suite

Session Five: Innovative Methods
CHAIR: JORGEN EIVIND OLESEN (Aarhus University, Denmark)

09:00 **Challenges and approaches in data management of LTE trials in tropical field sites: Experiences from two trials in India and Bolivia**
CHIGUSA KELLER (Research Institute of Organic Agriculture FiBL, Switzerland)

09:20 **Application of Bayesian Regression to data from long-term field experiments**
JOHN ADDY (Rothamsted Research, Harpenden, UK)

09:40 **From Long Term Experiment gross results to soil nutrient critical concentration: Which adjustment method can be used with best robustness and precision? Case study of P**
LIONEL JORDAN-MEILLE (Bordeaux Sciences Agro et INRAE, France)

10:00 **A comparison of 16 soil-crop models using four term experiments in sub-Saharan Africa to guide improvement**
ANTOINE COUËDEL (AIDA, University Montpellier, CIRAD, Montpellier, France)

10:20 **The importance to consider analytical method changes for soil organic carbon in long-term experiments**
KATHRIN GRAHMANN (Leibniz Centre for Agricultural Landscape Research (ZALF), Germany)

10:40-11:10 ***COFFEE BREAK***

Auditorium

11:10-12:40 **Workshop 3: Statistical approaches for LTEs**
ORGANISER: ANDREW MEAD (Rothamsted Research, Harpenden, UK)

Brenchley Suite

11:10-12:40 **Workshop 4: Adapting LTEs to new challenges**
ORGANISERS: CHRISTIAN THIERFELDER (CIMMYT, Zimbabwe)
REGIS CHIKOWO (University of Zimbabwe, Zimbabwe)

12:40-13:40 ***LUNCH***

Auditorium

Session Six: Soil Health
CHAIR: ANDY GREGORY (Rothamsted Research, Harpenden, UK)

13:40 ***Keynote speaker***
Organic Carbon and Texture Dependent Emergent Soil Behaviour
ANDY NEAL (Rothamsted Research, Harpenden, UK)

14:10 **A bayesian belief network with which to infer soil quality and health**
KIRSTY L HASSALL (Rothamsted Research, Harpenden, UK)

14:30 **Bioprospecting for plant growth promoting microbes: Rich seams in long-term agricultural field experiments?**
OWEN THORNTON (Rothamsted Research, Harpenden, UK)

14:50 **Higher plant species diversity increases the estimated abundance of key genes involved in soil phosphorus turnover**
AARON FOX (Environment Research Centre, Teagasc, Ireland)

15:10 **From LTE data to the sustainable control of soil fertility**
THIBAUT PUTELAT (Rothamsted Research, Harpenden, UK)

15:30-16:00 ***TEA BREAK***

Fowden Hall

16:00-18:00 ***Informal Poster Session, Visit Broadbalk Experiment, Rothamsted Museum Tour***

18:30 ***Conference Dinner in Rothamsted Restaurant***

Thursday 22nd June

08:00-09:00 **REGISTRATION with COFFEE**

Auditorium

Session Seven: Responses to Weather and Climate Change
CHAIR: MICHEL CAVIGELLI (USDA-ARS, Beltsville Agricultural Research Center, USA)

09:00 ***Keynote speaker***
The role of LTEs for designing future cropping systems
JORGEN EIVIND OLESEN (Aarhus University, Denmark)

09:30 **Prediction of maize yields under conservation agriculture using crop and machine learning models in Eastern Southern Africa**
SIYABUSA MKUHLANI (International Institute for Tropical Agriculture (IITA), Kenya)

09:50 **The signature of the North Atlantic Oscillation on long-term aboveground primary production dynamics through 160 years of the Park Grass long-term experiment**
GONZALO IRISARRI (Rothamsted Research, North Wyke, UK)

10:10 **Climatic effect of no-tillage and mulch due to albedo change differs with soil type: A field study in Zimbabwe**
SOULEYMANE DIOP (Université Paris-Saclay, INRAE, AgroParisTech, UMR EcoSys, France)

10:30 **Mud, mud, glorious mud - impacts of modern farming and extreme weather on soil loss revealed by the North Wyke Farm Platform**
ADIE COLLINS (Rothamsted Research, Harpenden, UK)

10:50-11:20 ***COFFEE BREAK***

Auditorium

Session Eight: LTE Networks and Platforms

CHAIR: JONATHAN STORKEY (Rothamsted Research, Harpenden, UK)

11:20 ***Keynote speaker***
The First Decade of the USDA Long Term Agroecosystem Research (LTAR) Network: Successes and Strategy Moving Forward
LINDSEY WITTHAUS (Water Quality and Ecology Research Unit, Oxford, Mississippi, USA)

11:50 **USDA long term agricultural research: Carrying out multi-site research in the cropland common experiment**
LORI J ABENDROTH (USDA-ARS, University of Missouri, USA)

12:10 **Bringing metadata of European Long-Term Field Experiments through an open-access geospatial platform**
CENK DöNMEZ (Leibniz Center for Agricultural Landscape Research (ZALF), Germany)

12:30 **Current and future adaptation strategies to heat stress for global livestock production systems in the context of climate change**
M JORDANA RIVERO (Rothamsted Research, North Wyke, UK)

12:50 **GLTEN 5 years on**
RICHARD OSTLER (Rothamsted Research, Harpenden, UK)

13:10-14:10 ***LUNCH***

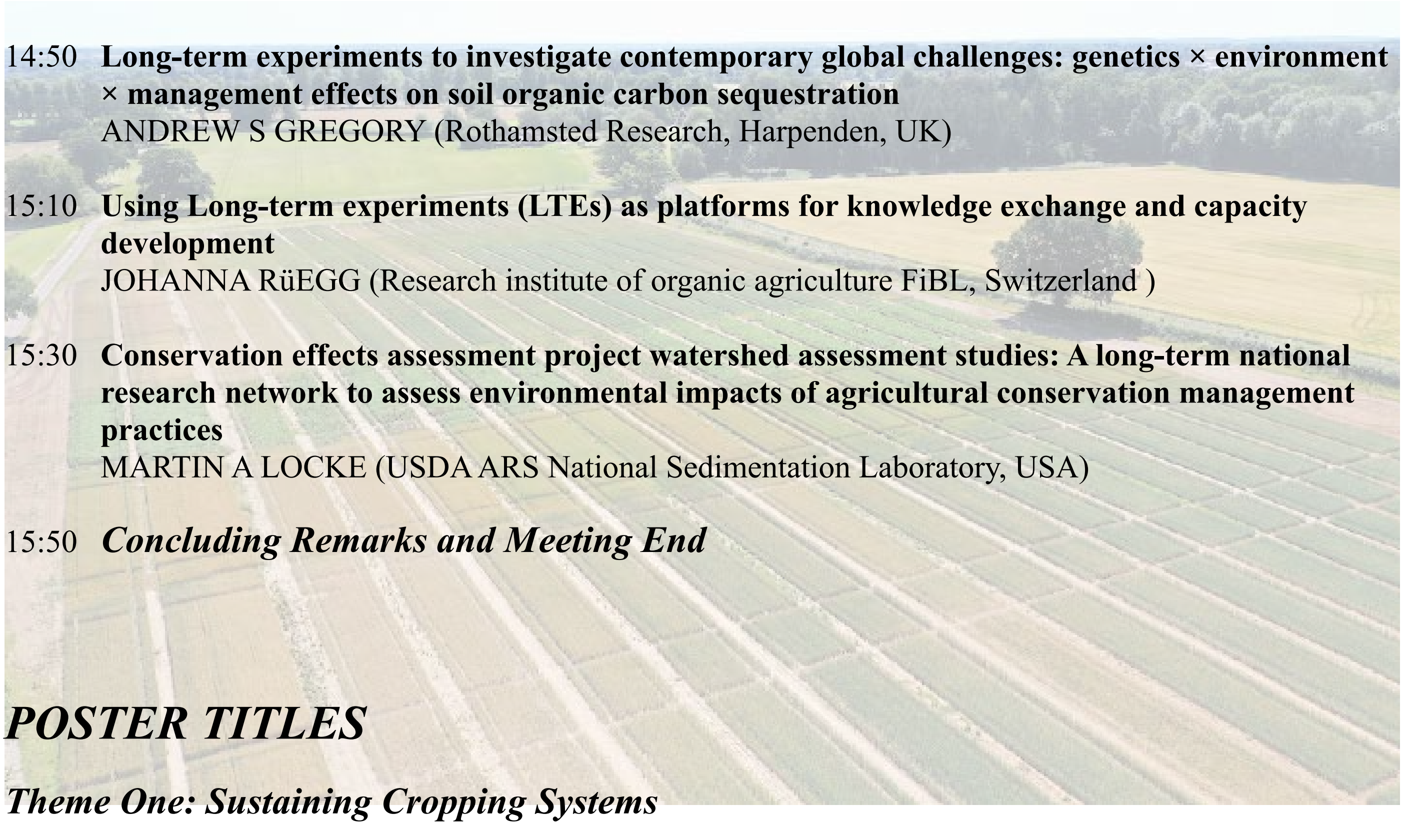
Auditorium

Session Nine: The Wider Impact of LTEs

CHAIR: RICHARD OSTLER (Rothamsted Research, Harpenden, UK)

14:10 **Crop response to soil potassium under diverse pedoclimatic conditions in multiple environments – implications for fertilization recommendations**
JULIANE HIRTE (Agroscope, Zürich, Switzerland)

14:30 **Long-term conservation agriculture effects of wheat production on the economy and environment**
JOHANN STRAUSS (Directorate Plant Sciences, South Africa)



14:50 **Long-term experiments to investigate contemporary global challenges: genetics × environment × management effects on soil organic carbon sequestration**
ANDREW S GREGORY (Rothamsted Research, Harpenden, UK)

15:10 **Using Long-term experiments (LTEs) as platforms for knowledge exchange and capacity development**
JOHANNA RüEGG (Research institute of organic agriculture FiBL, Switzerland)

15:30 **Conservation effects assessment project watershed assessment studies: A long-term national research network to assess environmental impacts of agricultural conservation management practices**
MARTIN A LOCKE (USDA ARS National Sedimentation Laboratory, USA)

15:50 ***Concluding Remarks and Meeting End***

POSTER TITLES

Theme One: Sustaining Cropping Systems

IN PERSON

P1

Ecological intensification can increase yields with lower inputs: Evidence from long-term experiments
CHLOE MACLAREN (Rothamsted Research, Harpenden, UK)

P2

Impact of pH on grass-white clover growth and nutritional quality in grassland soils: A long term experiment study in Scotland
ROSE BOYKO (SRUC, Edinburgh, UK)

P3

Yield dynamics of crop rotations response to farming type and tillage intensity in an organic agricultural long-term experiment over 24 years
FRANZ SCHULZ (Justus-Liebig University Giessen, Germany)

P4

Assessing sward management on biological nitrogen fixation from a white clover grass mixture
MIEKE VERBEECK (Rothamsted Research, North Wyke, UK)

P5

The Broadbalk Wheat Experiment, 1843–2023

PAUL R POULTON (Rothamsted Research, Harpenden, UK)

P6

Long-term effects of tillage on soil carbon and crop production within a diverse crop rotation

LOUIS DANEEL DU PREEZ (Stellenbosch University, South Africa)

P7

Root - and fine seeded crops in reduced tillage on a sandy loam soil

DERK VAN BALEN (Wageningen University & Research Field Crops, The Netherlands)

P8

Harvest index is reduced by high nitrogen application in monocropping paddy rice

JENYU CHANG (Taiwan Agricultural Research Institute, Taiwan)

P9

A multi-year evaluation of the effect of green manures in crop rotation systems

VIVIEN PÁL (University of Debrecen, Hungary)

P10

The long-term effect of crop rotation on wheat production and soil selected nutrients in the Mediterranean region of South Africa

ANNEMARIE VAN DER MERWE (Directorate Plant Science, Western Cape Department of Agriculture, South Africa)

P11

Organic cropping systems maintain yields but fail in yield levels and yield stability compared to conventional

JOCHEN MAYER (Agroscope, Switzerland)

P12

Long-term grassland experiments in Norway. Grassland yields and botanical succession at Fureneset

ÅSMUND M KVIFTE (Norwegian Institute of Bioeconomy Research, Grassland and Livestock, Norway)

P13

Park Grass over 160 years: Carrying capacity and nutritional composition are driven by fertilisation strategy

M JORDANA RIVERO (Rothamsted Research, North Wyke, UK)

P14

Ten years of YEN: Learnings for the future

EMILY GUEST (ADAS Boxworth, Cambridge, UK)

P15

Use e□ciency of di□erent nitrogen sources applied to wheat fields

ABDUL WAKEEL (University of Agriculture, Faisalabad, Pakistan)

P16

Nitrogen Use Efficiency of integrated crop livestock systems in 'Palo a Pique' long term experiment

FABIANA PEREYRA-GODAY (Instituto Nacional de Investigación Agropecuaria (INIA), Uruguay)

P17

Long-term experiments show conservation agriculture practices increase cereal yields in the (sub) tropics

NELE VERHULST (International Maize and Wheat Improvement Center (CIMMYT), Mexico)

P18

Nitrogen recovery and losses in a cereal- based cropping system using different organic fertilisers: FYM, compost, anaerobic digestate (AD) and straw

CATHY THOMAS (Rothamsted Research, Harpenden, UK)

ONLINE

P19

Fortification of micronutrient in pearl millet (*Pennisetum glaucum* (L.) R. Br.) hybrids using customized fertilizer in dryland condition of Rajasthan in India

MANOJ KUMAR (Agriculture University, Jodhpur (Rajasthan), India)

P20

Nutrient management through organic and inorganic sources in pearl millet in Western Rajasthan of India

MANOJ KUMAR (Agriculture University, Jodhpur (Rajasthan), India)

P21

Role of *Arabidopsis thaliana* Phosphoinositide specific Phospholipase C Isoform 5 gene in sensing heat stress and conferring thermotolerance in spring wheat

NAZISH ANNUM (Constituent College Pakistan Institute of Engineering and Applied Sciences, Pakistan)

P22

Integration of ridge and furrow rainwater harvesting systems and soil amendments improve crop yield under semi-arid conditions

ERASTUS MAK-MENSAH (Gansu Agricultural University, Lanzhou, China)

P23

No-tillage and liming long-term trial for sugarcane-soybean crop rotation system

DENIZART BOLONHEZI (Agronomic Institute of Campinas, São Paulo, Brazil)

P24

Impact of occasional tillage after 26 years in no-till on soybean yield and soil attributes changes

DENIZART BOLONHEZI (Agronomic Institute of Campinas, São Paulo, Brazil)

P25

Improving biodiversity within upland permanent pastures: Lessons form the brignant long-term plots

MARIECIA FRASER (Aberystwyth university, UK)

P26

Effects of tillage depth on winter wheat yield and soil properties: Results of 14 years of no- till in a long-term trial in western Switzerland

LUCA BRAGAZZA (Agroscope, Field-Crop Systems and Plant Nutrition, Switzerland)

P27

Yield stability and profitability: Perspectives from a long-term conservation agriculture trial in the tropical highlands of western Kenya

JOB M KIHARA (The Alliance of Bioversity International and CIAT, Italy)

Theme Two: Digital Agriculture in LTEs

IN PERSON

P28

LTEs and remote sensing to predict soil organic carbon variability at farm scale
CARMEN SEGURA QUIRANTE (Rothamsted Research, North Wyke, UK)

ONLINE

P29

Drone-based high-throughput techniques for monitoring long term experiments - building a digital archive
ANDREW B RICHE (Rothamsted Research, Harpenden, UK)

Theme Three: (Re)Designing LTEs for the Future

IN PERSON

P30

Stockless organic farming – the future of sustainable farming?
MORTEN MöLLER (University of Kassel, Germany)

P31

A new long-term experiment to explore the impact of rainfall extremes on the agronomic and environmental performances of cropping systems in the sub-humid tropics
RéMI CARDINAEL (AIDA, Univ. Montpellier, CIRAD, France)

P32

The long-term experiments of Livada
PATRICK URSAN (Research and Development Station Livada, Romania)

P33

The rise of the pHoenix: Relocation of a 60+ year old soil pH gradient trial
ROBIN WALKER (SRUC, Aberdeen , UK)

P34

Development of an agroforestry LTE in the Netherland Experimental design and monitoring choices
MARIA FRANCA DEKKERS (Wageningen UniversityThe Netherlands)

P35

Modelling the management decisions used for crop selection in a long-term sub-tropical farming systems experiment
JEREMY WHISH (CSIRO Agriculture and Food, Brisbane, Australia)

P36

A 20-Year retrospective on the Centre for Environmental Farming System large-scale field experiment in the Southeast USA
ALEX WOODLEY (North Carolina State University, USA)

P37

EcoServ: A long-term experiment to assess agroecosystem functions and services along a gradient of functional diversity and soil disturbance

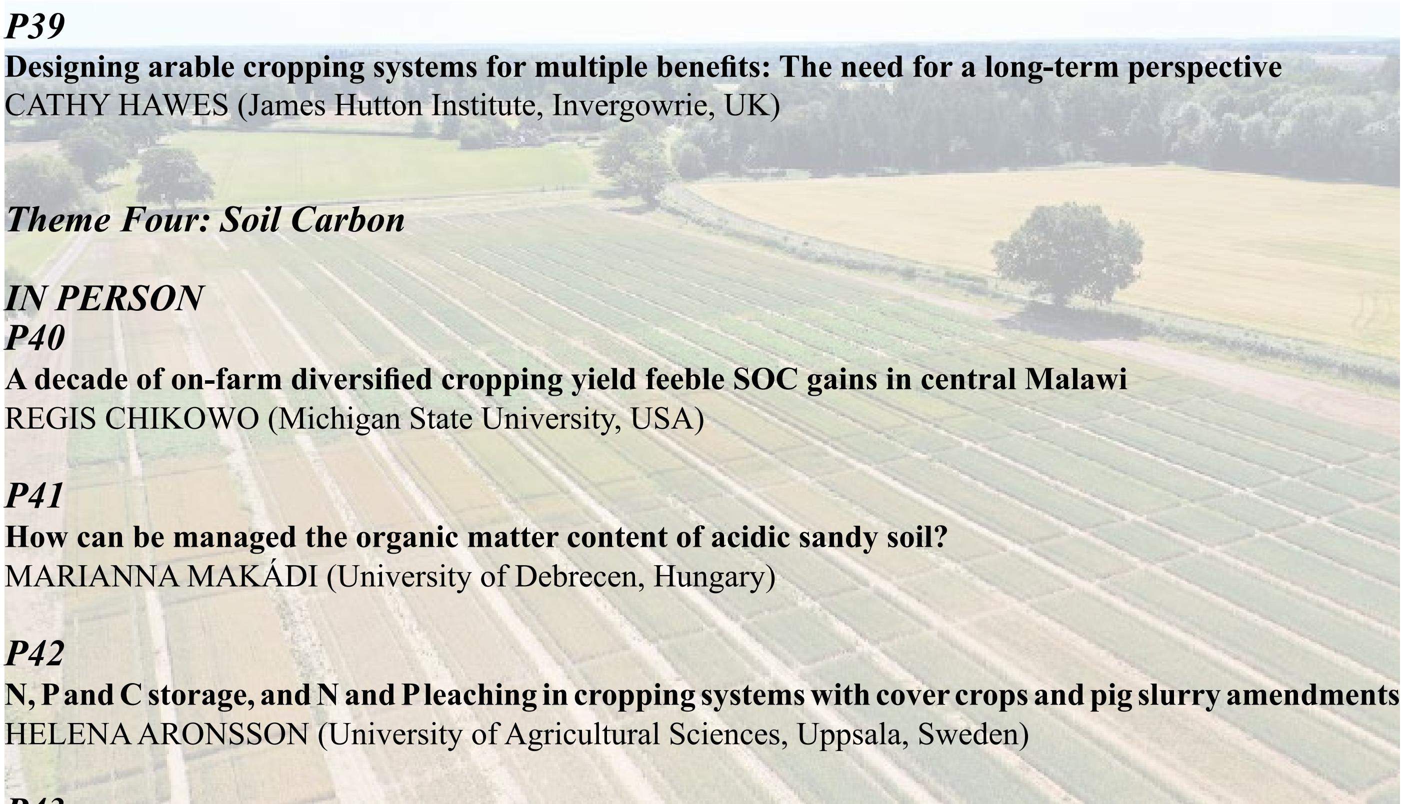
ALEXANDER MENEGAT (Swedish University of Agricultural Sciences, Sweden)

ONLINE

P38

Design of long-term experiments with perennial crops: Learnings and challenges of 15 years of research in a cacao agroforestry trial

JOHANNA RüEGG (Research institute of organic agriculture FiBL, Switzerland)



P39

Designing arable cropping systems for multiple benefits: The need for a long-term perspective

CATHY HAWES (James Hutton Institute, Invergowrie, UK)

Theme Four: Soil Carbon

IN PERSON

P40

A decade of on-farm diversified cropping yield feeble SOC gains in central Malawi

REGIS CHIKOWO (Michigan State University, USA)

P41

How can be managed the organic matter content of acidic sandy soil?

MARIANNA MAKÁDI (University of Debrecen, Hungary)

P42

N, P and C storage, and N and P leaching in cropping systems with cover crops and pig slurry amendments

HELENA ARONSSON (University of Agricultural Sciences, Uppsala, Sweden)

P43

Effect of plough on CO_2 fluxes from temperate grazed pastures on the North Wyke Farm Platform

LAURA M CARDENAS (Rothamsted Research, North Wyke, UK)

P44

Depletion of soil organic carbon and porosity after only two arable harvests decreased nitrogen use efficiency

CARMEN SEGURA QUIRANTE (Rothamsted Research, North Wyke, UK)

P45

Long-term effect of tillage practices on soil carbon in the Mediterranean area of South Africa

ANNEMARIE VAN DER MERWE (Directorate Plant Science, Western Cape Department of Agriculture, South Africa)

P46

Using LTE data to map soil carbon loss and gain on different land treatments and its implications for rewilding

FERGUS BLYTH (Rothamsted Research, Harpenden, UK)

P47

Soil organic carbon pools as early indicators for soil organic matter stock changes under different tillage practices in inland Pacific Northwest

STEPHEN MACHADO (Oregon State University, USA)

P48

Soil organic carbon and nitrogen cycling in an arable crop rotation in Flanders, Belgium, after 25 years of vegetable, fruit and garden waste compost application

MIEKE VERBEECK (Soil Service of Belgium, Belgium)

P49

Perennial cropping systems increased soil C and N stocks over annual systems – a nine-year field study

YIWEI SHANG (Aarhus University, Denmark)

ONLINE

P50

Soil response to eight different fertilisation schemes - results from a long term (55 years) field experiment

MICHAEL BLANKE (University of Bonn, Germany)

P51

Long-term changes in soil characteristics and ley yields on an organic dairy farm in Norway

TATIANA RITTL (Norwegian Centre for Organic Agriculture (NORSØK), Norway)

Theme Five: Innovative Methods

IN PERSON

P52

Can conservation agriculture principles mitigate greenhouse gas emissions? A scoping review and meta-analyses

MANZEKE-KANGARA (Rothamsted Research, Harpenden, UK)

P53

EJP soil CropGas project: The effect of conservation agriculture interventions on greenhouse gas emissions

ARANZAZU LOURO-LOPEZ (Rothamsted Research, North Wyke UK)

P54

Greenhouse gas emissions from the Large Scale Rotation Experiment: Metric options

ARANZAZU LOURO-LOPEZ (Rothamsted Research North Wyke, UK)

P55

Simulation of the effect of soil compaction on wheat, barley and winter bean yield using DSSAT

PRZEMEK DOLOWY (Harper Adams University, Newport, UK)

P56

The challenge of soil sampling in a long-term agricultural trial with permanent crops and agroforestry systems

ULF SCHNEIDEWIND (Georg-August University Göttingen, Germany)

Theme Six: Soil Health

IN PERSON

P57

Leveraging 132 years of Continuous Research at Sanborn Field to Understand Soil Health
TIM REINBOTT (University of Missouri-Columbia, USA)

P58

The role of cultivations and rotations in building resilient farming systems in a long running UK field experiment
NATHAN MORRIS (NIAB, Cambridge, UK)

P59

Long-term slurry inputs increase soil Cu concentrations and raise the risk of earthworm community decline in a Northern Irish grassland soil
JONATHAN HOLLAND (Agri-Food and Biosciences Institute (AFBI), Belfast, UK)

P60

Ecosystem Resilience: A variational approach applied to some of the Rothamsted Long-Term Experiments
ANDREW WHIMORE (Rothamsted Research, Harpenden, UK)

P61

Transforming green waste into precious biochar: An organic soil amendment source
MUMTAZ KHAN (Sultan Qaboos University, Sultanate of Oman)

P62

Effect of treated wastewater irrigation on heavy metals accumulation in fruit trees
AHMED AL-MASKRI (Sultan Qaboos University, Sultanate of Oman)

P63

Long-term field experiments in Water quality management, Sweden
LISBET NORBERG (University of Agricultural Sciences, Uppsala, Sweden)

P64

Extracellular enzymes as promising soil health indicators: Assessing response to different land uses using long-term experiments
MUNISATH KHANDOKER (Rothamsted Research, Harpenden, UK)

P65

Long-term organic fertilization and cropping systems have an uncertain effect on tea bag decomposition
MARCOS PARADELO PEREZ (University of Greenwich, Kent, UK)

P66

Phosphorus (P) budgets, P availability and P use efficiencies in conventional and organic cropping systems after four decades of continuous monitoring
KLAUS JAROSCH (Agroscope, Zurich, Switzerland)

P67

Chemical properties of an oxisol under mineral, organomineral, and biomass ash fertilization in the Brazilian Cerrado
LUANA APARECIDA MENEGAZ MENEGHETTI (Federal University of Rondonópolis, Brazil)

P68

Combination of organic and mineral fertilization on soil acidity parameters after *Panicum maximum* cultivation

LUANA APARECIDA MENEGAZ MENEGHETTI (Federal University of Rondonópolis, Brazil)

P69

Changes in soil chemical characteristics over 40 year period depending on the use of mineral fertilisers

LIVIJA ZARINA (Institute of Agricultural Resources and Economics, Priekuli, Latvia)

ONLINE

P70

The impact of long-term anaerobic digestion treated manure on soil organic matter, soil nutrients and ley yields in Norway

TATIANA F RITTL (Norwegian Centre for Organic Agriculture (NORSØK), Norway)

P71

Soil health and crop yields in the old rotation (Est. 1896): The world's oldest, continuous cotton experiment

AUDREY GAMBLE (Auburn University, USA)

P71a

Digging Deeper: Long-Term Experimentation Discloses the Influence of Tillage Systems on Soil Properties in Semiarid Rainfed Mediterranean Conditions

INÉS SANTÍN (INIA-CSIC, Madrid, Spain)

Theme Seven: Responses to Weather and Climate Change

IN PERSON

P72

Stabilising wheat yield and quality under variable climatic conditions

ERNST SMIT (Western Cape Department of Agriculture, South Africa)

P73

From controlled environment to field: Confounding factors in container trials

KARIN KOEHL (Max Planck Institute of Molecular Plant Physiology, Potsdam, Germany)

P74

Modelling wheat-climate interactions today to aid future development

JAKE BISHOP (University of Reading, UK)

P75

Fingerprinting the effects of global environmental change on agriculture using long-term experiments

CHLOE MACLAREN (Swedish University of Agricultural Sciences (SLU), Sweden)

ONLINE

P76

Sowing term as a pivotal limiting factor in winter wheat breeding strategy for climate change

BOHDANA MAKAOVA (Poltava state agrarian university, Ukraine)

Theme Eight: LTE Networks and Platforms

IN PERSON

P77

Rothamsted long-term experiments: Historic data for current and future challenges

SARAH A M PERRYMAN (Rothamsted Research, Harpenden, UK)

P78

Farmers and Rothamsted scientists working together on a new Long-Term Experiment: The Devon Silvopasture Network

CARMEN SEGURA QUIRANTE (Rothamsted Research, North Wyke, UK)

P79

Long-term experiments at the Swedish University of Agricultural Sciences

SABINA BRAUN (Swedish University of Agricultural Sciences, Sweden)

P80

An open-source metadataset of running European mid-term and long-term field experiments

TOMMY D'HOSE (Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Belgium)

P81

Network Strategies and Studies to Advance Science for Climate-Smart Agriculture in the LTAR Network

LINDSEY WITTHAUS (USDA-ARS National Sedimentation Laboratory, Oxford, USA)

Theme Nine: The Wider Impact of LTEs

IN PERSON

P82

Re-evaluating the nitrogen use efficiency of selected mineral and organic fertiliser categories based on the analysis of Swiss long-term field experiments

CAROLE ALICE EPPER (Agroscope, Research Division Agroecology and Environment, Switzerland)

P83 -> ONLINE POSTER

Costs and benefits of reduced tillage compared to ploughing in an organic long-term trial on Loess in Switzerland

MEIKE GROSSE (Research Institute of Organic Farming FiBL, Switzerland)

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Nutrient runoff in a long-term agricultural experiment in central-Southeast Norway

ISABELL EISCHEID (NIBIO Apelsvoll, Norway)

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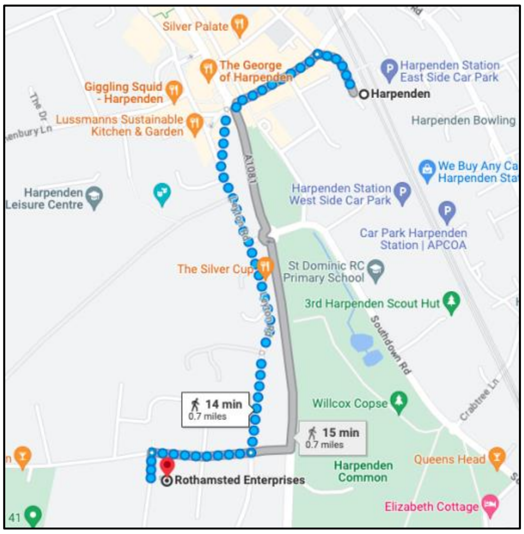
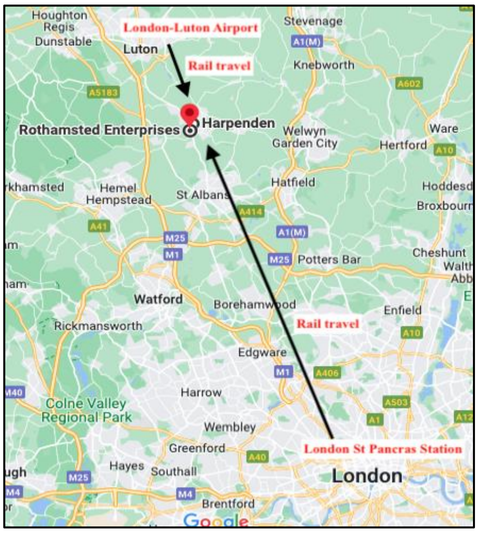
Delegate Instructions

Thanks for attending the AAB event on
'Long-Term Experiments: Meeting Future Challenges'.

The meeting venue is Rothamsted Conference Centre. Rothamsted Research, West Common, Harpenden, Hertfordshire, AL5 2JQ.
https://www.rothamstedenterprises.com/rothamsted-conference-centre/

Rothamsted Research is a 14minute walk from Harpenden Railway Station, which is 25minutes on the train from St Pancras International in central London. Therefore the event site is easily accessible from many places in central London.
UK train timetables can be found at Trainline.com
St Pancras International is the terminus for the Eurostar, which offers overland access to Continental Europe and we encourage delegates to travel overland if possible. London has a 5 international airports, the closest of which to Rothamsted is London-Luton, which is a 20minute taxi drive or 30minute train journey away from Rothamsted.





Registration will take place in the CC foyer. This is where all lunches, coffee-breaks and evening hot buffet (on June 20th) will take place. The optional Conference Dinner will also take place at the Conference Centre.

Free Wifi is available at the venue and a daily-password will be shared with delegates by event staff.

The meeting includes Keynote talks, plenary and concurrent sessions and Workshops. Unfortunately Workshop sessions will not be available to online delegates.

Main Auditorium: All Keynotes, most sessions and Workshop 1+3 will take place in this location.

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Fowden Hall: This will host Session 2 and Workshop 2 on the morning of June 20th. On the afternoon of June 20th we will set up the poster boards, which will be available for poster hanging later in the afternoon. The official Poster session will take place on the evening of June 20th but posters will be available for viewing for the entire meeting.

Brenchley Suite: This will host Session 5 and Workshop 4 on the morning of June 21st.

Early career in-person poster presenters are eligible for the £100/£50/£25 poster prizes which will be voted on by members of the organising committee and announced at the end of the meeting.

Prior to the meeting all delegates will be sent a '**Digital-Poster-Book**' which includes both in-person and online posters and we very much encourage all delegates to look at this document.

Online delegates can join the meeting using this link:

Auditorium Zoom Call:
https://us02web.zoom.us/j/87177938362?pwd=MHBQVVFkTVZTVjlveGtvYTM4dXBOUT09

Fowden Hall (Session 2)/ Brenchley Suite (Session 5) Zoom Call:
https://us02web.zoom.us/j/84826989955?pwd=L1lDNCtxb2Y1dTdCOGRwN1BOYlFCZz09

Online delegates are encouraged to ask questions in the text-box and time-allowing they will be relayed to the speaker by AAB staff members Dr Geraint Parry (Auditorium) or Dr John Andrews (Fowden Hall and Brenchley Suite).

We offer online poster presenters the opportunity to present their posters online during the in-person poster session. This will be from 5pm-6pm BST on June 20th. This will be hosted in the **Auditorium Zoom Call** and moderated by Dr Geraint Parry. This informal session will allow online poster presenters to present their poster in a short-talk.

We offer huge thanks to the CGIAR Excellence in Agronomy program and the USDA Agricultural Research Service for supporting this event.

https://www.cgiar.org/initiative/11-excellence-in-agronomy-eia-solutions-for-agricultural-transformation/

https://www.ars.usda.gov/

If you have any questions about the meeting please contact Geraint Parry
gerait@aab.org.uk

Wednesday June 21st Afternoon Schedule

From	To	Group 1	Group 2	Group 3	Group 4	Group 5
16:00	16:05	Tractor - CC to Manor	**Introduce to the Rothamsted e-RA**	**Visit the Rothamsted Museum**	**Visit the Sample Archive**	
16:05	16:10	Walk to Broadbalk	CC Auditorium			
16:10	16:15	**Visit Broadbalk Experiment**				**Introduce to the Rothamsted e-RA**
16:15	16:20					CC Auditorium
16:20	16:25		Tractor - CC to Manor			
16:25	16:30		Walk to Broadbalk	**Introduce to the Rothamsted e-RA**	**Visit the Rothamsted Museum**	**Visit the Sample Archive**
16:30	16:35	Walk to Manor	**Visit Broadbalk Experiment**	CC Auditorium	Old Sample House	
16:35	16:40	Tractor - Manor to CC				
16:40	16:45			Tractor - CC to Manor		
16:45	16:50	**Visit the Sample Archive**		Walk to Broadbalk		
16:50	16:55		Walk to Manor	**Visit Broadbalk Experiment**		
16:55	17:00		Tractor - Manor to CC			**Visit the Rothamsted Museum**
17:00	17:05				Tractor - CC to Manor	Old Sample House
17:05	17:10		**Visit the Sample Archive**		Walk to Broadbalk	
17:10	17:15			Walk to Manor	**Visit Broadbalk Experiment**	
17:15	17:20	**Visit the Rothamsted Museum**		Tractor - Manor to CC		
17:20	17:25	Old Sample House				Tractor - CC to Manor
17:25	17:30					Walk to Broadbalk
17:30	17:35		**Visit the Rothamsted Museum**	**Visit the Sample Archive**	Walk to Manor	**Visit Broadbalk Experiment**
17:35	17:40		Old Sample House		Tractor - Manor to CC	
17:40	17:45					
17:45	17:50	**Introduce to the Rothamsted e-RA**			**Introduce to the Rothamsted e-RA**	
17:50	17:55	CC Auditorium			CC Auditorium	Walk to Manor
17:55	18:00					Tractor - Manor to CC

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ENQUIRIES

Enquiries concerning the technical content of the Abstracts should be addressed directly to the authors; however, other matters should be directed to the Executive Officer, Dr Geraint Parry (geraint@aab.org.uk) at the AAB Office, Warwick Enterprise Park, Wellesbourne, Warwick CV35 9EF, UK

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Theme Two: Digital Agriculture in LTEs

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Theme Four: Soil Carbon

Theme Five: Innovative Methods

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Conservation Agriculture Research in Southern Africa – the role of Long-term experiments

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ABSTRACT

Southern Africa is heavily affected by climate change and soil fertility decline, and farmers will have to adapt their cropping systems to heat and drought stress while maintaining soil fertility over time. Since 2004, a series of long-term experiments have been established in six research stations of Malawi, Mozambique, Zambia and Zimbabwe to test whether conservation agriculture (CA) can help farmers to meet these challenges. CA, defined by its core principles of minimum soil disturbance, crop residue retention and crop rotation, amongst other good agriculture practices, increases water infiltration and available soil moisture which potentially leads to greater adaptation to climate stress. Crop productivity is usually higher under no-tillage as compared to conventional ploughed systems, and this becomes more prominent if diversified crop rotations are used. In particular, rotational legumes increase yields, highlighting that nitrogen is a major limiting factor in soils of southern Africa. Crop rotations also led to greater below- and above-ground biodiversity. Overall, long-term trends in crop productivity were more affected by declining and erratic rainfall than by soil fertility decline, indicating limits to agronomic adaptation if climate stress becomes too extreme. However, CA systems were more resilient to in-season dry spells, and in some cases increased yields in normal rainfall seasons. Long-term experiments in CA research provide a unique opportunity to assess these systems over time to help smallholders to adapt to a changing climate.

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Session One: Sustaining Cropping Systems

The integration of cover crops and soil tillage to build resilience in farming systems in a long running UK field experiment

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ABSTRACT

The NFS (New Farming Systems) project is a long-term study at Morley Farm, Morley, Norfolk, UK on an Ashley Series, sandy loam soil. Research is managed by NIAB and supported by The Morley Agricultural Foundation (TMAF). The aim of this long running experiment is to explore the interaction between cultivation and cover /companion crop use for sustainable arable production. This research uses a single rotation – based on winter cereals with winter and spring sown break crops – in a fully replicated experiment; as described by Stobart and Morris, 2013. This paper presents findings on the impact of soil tillage and rotational cover crop use over 12 years (2009-2020) and considers the impact on crop yield, financial returns and the implications of energy use efficiency (Warner *et al*. 2016) for producing combinable crop grains. Energy use per hectare (highest to lowest) was: plough > deep non- inversion > shallow non-inversion. When considered in combination with lower energy input per hectare, energy efficiency increased relative to the plough-only control.

Yield and yield stability within a rotational complexity gradient derived from a network of long-term cropping systems experiments

ANN BYBEE-FINLEY[1], KATHERINE MULLER[1], KATHYRN WHITE[2], TIM BOWLES[3], MICHEL CAVIGELLI[3], EUNJIN HAN[2], HARRY SCHOMBERG[2], SIEG SNAPP[4] and FREDERI VIENS[5]

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[2]*US Dept of Agriculture, Agricultural Research Service, Adaptive Cropping Systems Lab, Ithaca, NY 14853, USA*
[3]*University of California Berkeley, University of California, Berkeley, USA*
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ABSTRACT

The benefits and trade-offs of complex crop rotations in regards to yield and yield stability have not been well-quantified. ARS and university scientists amassed 460 site-years of yield data from 21 sites with 6 to 60 years per site for this analysis. Yield was converted to yield dollars for focal crops (corn, soybean, small grains, and perennial forages) to combine crops with differing yield potentials and calculate rotation-level yield dollars. We quantified rotational complexity using a diversity cover index (DCI) that accounted for species richness, species evenness, and bare soil. Using Bayesian analysis, we analyzed DCI across growing conditions quantified with an environmental index for each focal crop and entire rotations. Overall, greater rotational complexity had a positive effect on focal crop yields but a neutral effect at the rotation-level. The effect of DCI on rotation-level yield differed across growing conditions, and the yield gap between more and less-complex rotations reduced under poor conditions (10th percentile of environmental index). Future research will account for more complex management by considering opportunity costs.

Sustaining maize yields and soil carbon following land clearing in the forest–savannah transition zone of West Africa: Results from a 20-year experiment

RéMI CARDINAEL[1], HERVé GUIBERT[1], SOUMAïLA T KOUASSI BRéDOUMY[2], JACQUES GIGOU[1], KOUADIO EMMANUEL N'GORAN[3] and MARC CORBEELS[1]

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[2]*Université Nangui Anbrogoua, R8, Abidjan, Côte d'Ivoire, Ivory Coast*
[3]*Centre National de Recherche Agronomique de Cˆote d'Ivoire (CNRA), Adiopodoumé, Km 17, Route de Dabou, 01 BP 1740 Abidjan 01, Ivory Coast*

ABSTRACT

Sustainable alternatives to slash-and-burn shifting cultivation in the (sub)humid tropics often rely on the use of external nutrient inputs to address soil fertility decline. The objective of this study was to investigate whether maize productivity and SOC can be sustained under permanent cropping with sole and combined use of compost and mineral nitrogen (N) fertilizer. Here, we report results from a long-term experiment carried out in Gagnoa, Ivory Coast, from 1971 to 1990. The experiment followed a randomized block design comprising eight replicates of 12 treatments. The two studied factors were compost (0 or 10 t DM ha^{-1} yr^{-1}) and mineral N (0, 40, 80, 120, 160 or 200 kg N ha^{-1} yr^{-1}) additions. Average maize grain yields of the first cropping cycles were significantly lower without compost (5.05 ± 1.57 t ha^{-1}) than with compost addition (6.07 ± 1.31 t ha^{-1}). The annual yield variability as shown by the standard deviation of the mean was reduced by 20% with compost addition. Without compost, 53% of the initial SOC stock in the 0–20 cm soil layer was lost, resulting in a SOC loss rate of − 0.62 t C ha^{-1} yr^{-1} compared to 21% with compost (−0.27 t C ha^{-1} yr^{-1}). Compost addition therefore reduced SOC loss with an apparent SOC storage rate of 0.35 t C ha^{-1} yr^{-1}. The conversion rate of organic carbon (OC) inputs to SOC was about 12%. The Introductory Carbon Balance Model (ICBM) reproduced well SOC dynamics, especially without compost. Without mineral N and without compost, maize grain yield decreased with decreasing SOC concentration until the introduction of leguminous crops in the second cropping cycle. We conclude that combined application of compost with mineral N fertilizers was effective at maintaining maize productivity but inadequate to prevent the decline of SOC stocks, despite large additions.

Maintaining soil organic carbon is critical for sustaining maize yields in the tropics of Africa

MORITZ LAUB[1], MARC CORBEELS[2], SAMUEL MATHU NDUNGU[3], MONICAH WANJIKU MUCHERU-MUNA[4], DANIEL MUGENDI[5], MAGDALENA NECPALOVA[6], MARIJN VAN DE BROEK[1], WYCLIFFE WASWA[3], BERNARD VANLAUWE[3] and JOHAN SIX[1]

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ABSTRACT

Increasing and sustaining crop productivity are a challenge in large parts of sub-Saharan Africa (SSA), mainly due to low inherent soil fertility. Integrated soil fertility management, which includes the combined use of mineral and organic fertilizer, is believed to address this challenge by enhancing soil organic carbon (SOC). Yet, SOC and yield responses to fertilizer additions are expected to be site-specific, depending on pedo-climatic conditions.

We analyzed maize yield and SOC trends in four long-term (16–19 years) field experiments in Kenya with contrasting soil textures and different climates. Two sites were in humid western Kenya (Aludeka, Sidada, >1700 mm annual rainfall), two in sub-humid central Kenya (Embu, 1200 mm and Machanga, 800 mm). Treatments were different organic resource additions (1.2 and 4 t C ha^{-1} yr^{-1} including farmyard manure, high-quality *Tithonia diversifolia* residues and low-quality saw dust), combined with (+N) or without (-N) 120 kg^{-1} mineral N fertilizer ha^{-1} $season^{-1}$.

Across sites, the no-input control showed significant (P<0.05) yield decline over time. Farmyard manure +N maintained yields at both 1.2 and 4 t C ha^{-1} yr^{-1}. Annual SOC losses across sites ranged from 1.9% to 0.6% for the control and farmyard manure (at 4 t C ha^{-1} yr^{-1}), respectively. Yield and SOC trends were, however, site specific. In western Kenya, the long-term yield trends were significantly (P<0.01) and positively correlated with SOC trends; treatments with largest SOC losses experienced the highest yield decline. At Embu, the correlation between SOC and yield trends was weaker (P<0.05, only in +N treatments) and at Machanga, yield and SOC trends were not correlated. Our findings show the importance of farmyard manure and mineral N for sustaining both SOC and maize yields in SSA. The longterm maize yield responses to organic resource additions are however affected by pedo-climatic conditions with variable effects of SOC trends on crop yields.

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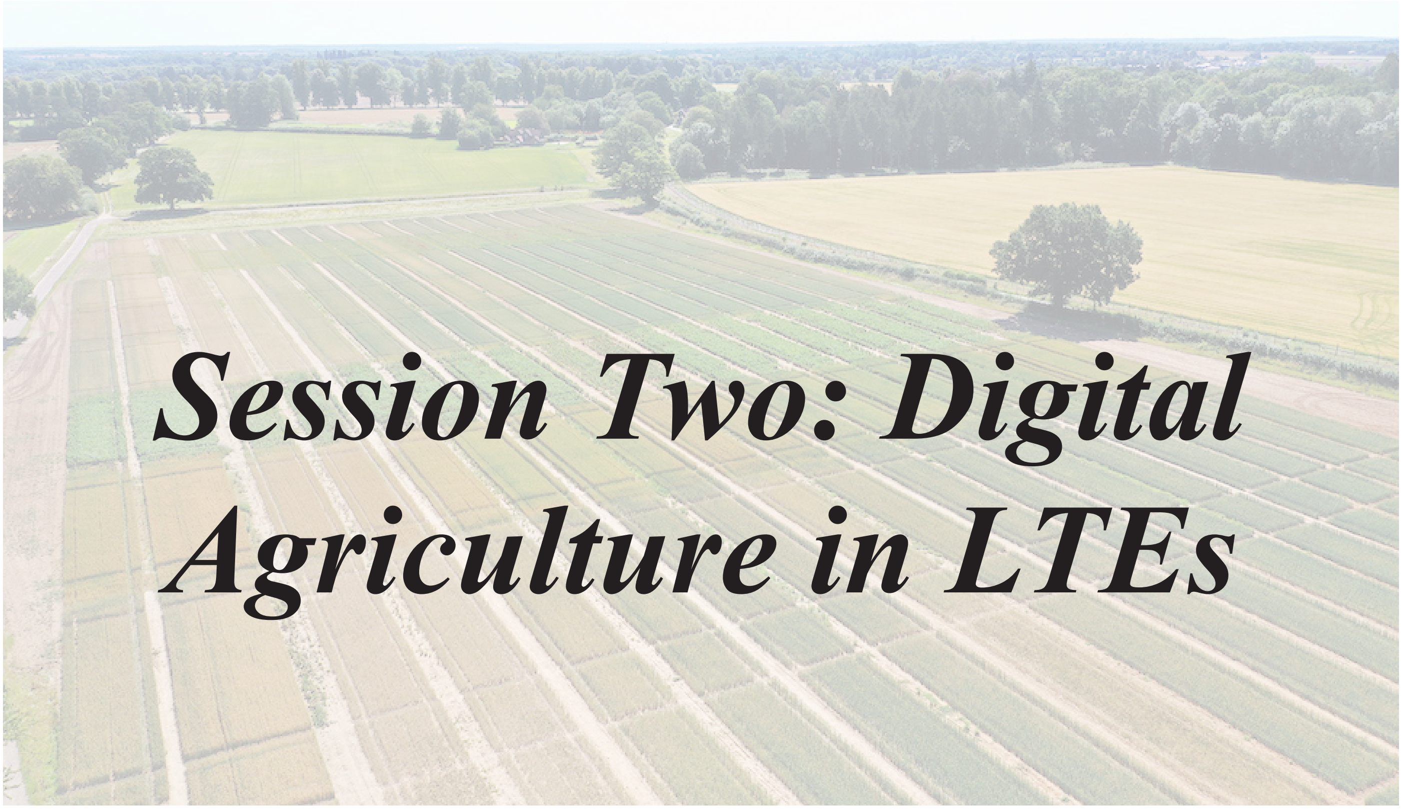

Session Two: Digital Agriculture in LTEs

A contemporary long-term farming systems experiment for the digital age

JOHN KIRKEGAARD[1], BRENDAN MALONE[1], MARK GLOVER[1], EUSUN HAN[2], STU BROWN[1], ALAN RICHARDSON[1], TONY SWAN[1], ENLI WANG[1], DI HE[1] and JAMES MALONEY[1]

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[2]*University of Copenhagen and Aarhus University, Denmark*

ABSTRACT

Long-term experiments are research platforms that provide unique opportunities to explore a range of biological processes influencing the productivity and sustainability of agricultural systems over long time scales. Numerous reviews of the value, strengths and weaknesses of different approaches and experimental designs have been conducted. In Australia, long-term experiments were reviewed in the late 1990's, followed by a rationalisation in their number justified by the high cost of maintenance and the obsolescence of many of the outdated treatments with some ongoing exceptions. In 2018, we reviewed global approaches to long-term experiments with a view to identify contemporary design features more relevant to emerging trends in agriculture including: the rise of digital technologies, adaptation/mitigation to climate change and GHG emissions, the need to consider variability at scale, and increasing consumer/market engagement in agricultural production systems. Based on these insights we have established a contemporary long-term farming systems experiment on a 10ha site at CSIRO's Boorowa Agricultural Research Station (BARS), a newly established 290 ha digital research farm in the mixed farming region of SE Australia. Four "farming philosophies" have been established in the study, all legitimate but generating different system outcomes. Features of the study include a focus on embracing rather than avoiding site variability, use of commercial agricultural equipment, numerous digital technologies (3D digital soil map, wireless soil water sensors (0-1.8 m), temperature and humidity sensors, LORAWAN network for data storage and retrieval, drone and satellite missions). The entire site was baselined and sown to wheat for site variability studies in 2021, and in 2022 the four farming systems philosophies (6-year phases) were established and monitored. We will discuss the design features and planned approach for the experiment, and experiences during the set-up and first two years of this contemporary long-term systems experiment.

Improving climate resilience through adaptive rangeland management in the US Great Plains

DAVID L HOOVER[1], DAVID J AUGUSTINE[1], LAUREN M PORENSKY[1], EDWARD J RAYNOR[2], SEAN KEARNEY[1], HAILEY WILMER[3], JOHN P RITTEN[4] and JUSTIN D DERNER[1]

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[3]*USDA-ARS Range Sheep Production Efficiency Research Unit, Dubois, ID, USA*
[4]*Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO, USA*

ABSTRACT

Rangelands in the US Great Plains have high spatiotemporal variability in precipitation, soils, and topography, creating complex challenges for producers and land managers to balance livestock production with other critical ecosystem services. Climate change adds to this complexity by raising temperatures, increasing the frequency and magnitude of extreme events, and altering precipitation. To address these challenges, we have conducted a decade-long Collaborative Adaptive Rangeland Management (CARM) experiment in the shortgrass steppe of Colorado, as part of the US Long-Term Agroecosystem Research (LTAR) network. In 2012, an 11-member stakeholder group representing ranchers, conservation organizations, and land management agencies, were invited to develop management objectives and lead the decision-making process for the duration of the study. This participatory experiment examined if collaborative adaptive rangeland management could respond to short-term variability in weather and forage availability to improve climate resiliency and multiple ecosystem services. To facilitate adaptive decision making, we provided stakeholders with precision ranching data, including near-real time environmental data (e.g., precipitation and soil moisture), forage conditions (e.g., biomass estimates and greenness), animal health status, predictive tools (e.g., GrassCast, a grassland productivity forecast, and climate outlooks), and livestock market dynamics. Over time, this experiment has led to new understanding of the relationships among management decisions, cattle grazing distribution, weather variability, economics, ecosystem services (e.g., biodiversity), and social learning outcomes. Furthermore, CARM highlighted the social and ecological challenges of incorporating legacies of extreme droughts and heavy precipitation events in potential solutions for improving climate resilience.

Combining randomized field experiments with observational satellite data to asses the benefits of crop rotations on yields

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[3]*Stanford University, Center for Food Security and Environment, 450 Serra Mall, Stanford, CA 94305, USA*

ABSTRACT

With climate change threatening agricultural productivity and global food demand increasing, it is important to better understand which farm management practices will maximize crop yields in various climatic conditions. To assess the effectiveness of agricultural practices, researchers traditionally turned to randomized field experiments, which are reliable for identifying causal effects in the contexts of the experiments but can lack external validity. Recently, researchers have also leveraged large observational datasets from satellites and other sources, which can lead to conclusions biased by confounding variables or systematic measurement errors. In this talk we discuss how experimental and observational datasets have complementary strengths and weaknesses and present a method that uses a combination of experimental and observational data in the same analysis. As a case study, we focus on estimating the causal effect of crop rotation on corn (maize) and soybean yields in the Midwestern United States. We find that, in terms of root mean squared error, our hybrid method performs 13% better than using experimental data alone and 26% better than using the observational data alone in the task of predicting the effect of rotation on corn yield at held-out experimental sites. Further, the causal estimates based on our method suggest that benefits of crop rotations on corn yield are lower in years and locations with high temperatures whereas the benefits of crop rotations on soybean yield are higher in years and locations with high temperatures. Finally, we emphasize that our results indicate that randomized field experiments are essential for making reliable assessments of the causal effect of farm management practices. Of note, using only observational data substantially underestimated the benefit of crop rotation on corn yield, likely because fertilizer use was an unmeasured confounding variable. We also discuss the importance of access to datasets from randomized field experiments for our goals of further developing the statistical methodology and applying it to other geographical regions and farm management practices.

Spatial temporal variability in yield and nutrient use efficiency across a long-term farming systems experiment

DAVID CLARKE[1], ELIZABETH STOCKDALE[2], BENJAMIN MARCHANT[3], JACQUELINE HANNAM[4] and STEPHEN HALLETT[4]

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ABSTRACT

The New Farming Systems Experiment, Norfolk, England (The Morley Agricultural Foundation) is a replicated large plot trial established in 2008 to study the impact of cultivations and cover crops on crop performance and soil properties. In this study, the intensive soil and agronomic assessments collected have provided novel insights into managing spatial temporal variation across farm. Soil electrical conductivity (EC) was mapped across the 3 ha experiment. Targeted soil samples have revealed large variation in sand and clay content ranging from 42%–72% and 15%–37% respectively which is well correlated with the variation in EC. Soil EC explained 77% ($r2$=0.77, P=<0.001) of the variation in winter wheat yields (4 crops in the study period 2008-2022) with plot yields averaging 11.3 t ha^{-1} in the high EC (higher clay content plots) and 8.7t ha^{-1} in plots with low EC. Grain protein content was highest in the lowest EC plots (11.8% cf. 10.7%) with soil EC explaining 57% ($r2$=0.57, P=<0.001) of the variation in protein content. Grain fertiliser recovery, a measure of nutrient use efficiency (NUE) was 45% in the lowest EC plots increasing to 60% in the highest EC plots. Managing such spatial variability in NUE is important in low rainfall East Anglia. Areas with the lowest NUE also have higher sand content and are therefore at greater risk from losses to the environment through leaching. Using grain protein to indicate optimal N application, data shows that current farm standard N rates of 220 kg N ha^{-1} in winter wheat could be reduced to 180 kg N ha^{-1} on average in the low EC areas. This study demonstrates how proximal soil sensing technologies can support analysis of existing long-term experiments. It also shows how farms can use yield maps, soil EC scans, targeted soil sampling and grain nutrient testing to manage consistent patterns of spatial variation.

Session Three: (Re) Designing LTEs for the Future

Looking back to look forward – the role of LTEs in predicting the impact of future land use policy

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ABSTRACT

Future agricultural policy involves the design of mechanisms for ensuring specific outcomes for the benefits of people, society, the environment and the national economy. Current policies aim at a wide variety of outcomes including productivity of the agricultural sector, food security and preparedness, Net Zero, soil health, biodiversity and water quality. The re-integration of crops and livestock on farms and in agricultural landscapes is also currently a hot topic in terms of reversing the trend of losses in soil organic matter in arable areas. Long-term experiments (LTEs) are often used to understand the impact of single or multiple management practices on crop productivity and soil fertility. They are also commonly used to assess the impact of climate change or agronomic improvements such as crop breeding and new management practices (e.g. reduced till) on factors such as crop productivity, yield stability and soil fertility over time. However, the LTEs also provide a rich source of information that can be used to predict how future changes in agricultural policy and practice might affect crop production and quality as well as different aspects of sustainability.

We use a series of examples from LTEs in Sweden and the UK to explore issues such as 1) how the use of leys in arable systems, with and without grazing, impact arable crop production and soil organic matter and 2) how optimising the soil pH would affect yields of small grain cereals.

Never change a running system? Balancing systems approach and comparability when adapting LTEs

EVA GOLDMANN[1], DAVID BAUTZE[1], NOAH ADAMTEY[1], AMRITBIR RIAR[1], AKANKSHA SINGH[1], BEATE HUBER[1], MARC COTTER[1], JOHANNA RÜEGG[1] and LAURA ARMENGOT MARTÍNEZ[2]

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ABSTRACT

The SysCom program was initiated to provide evidence for the performance and viability of organic agricultural cropping systems in the tropics. While case studies and long-term trials were available for temperate zones, little scientifically backed-up evidence was available to assess the potential of organic agriculture in sustainable development in countries in tropical environments. Thus, in 2007, long-term trials in India, Bolivia, and Kenya were established, comparing organic with conventional systems based on locally relevant cropping systems (cotton, cocoa, maize). Combining the existing practical examples and recommendations from local agricultural institutions, organic and conventional treatments were designed, emphasizing local relevancy and prevalent practices. After the systems were established, it became clear that organic systems in our LTEs were lacking behind in profitability and productivity, not offering a valuable approach for local farmers to sustain their livelihoods. In our analysis, we had to realize that often a mere copy of conventional practices, substituting conventional with organic inputs, would not suffice to provide solid evidence of the potential of organic agriculture in the tropics. Starting in 2017, adaptations were made to the ongoing LTEs to better integrate best-practice agroecological approaches into the different systems. Using the example of the SysCom program, we want to discuss the challenges and opportunities of introducing changes in LTEs; confronting questions on how to adapt them across countries, how to balance systems approaches to optimize the different to meet the golden e and realistic, locally relevant farming approaches. The adaptations realized in the LTEs in India and Kenya, such as changing input levels and seed material, introducing more complex intercropping patterns, and crop rotations, have proven valuable additions to our experiments. The positive impacts on productivity and profitability, especially on the organic systems, can serve as examples of sustainable locally adapted production systems, allowing smallholder farmers to sustain their livelihood in the future.

Re-designing Long-Term Rotations

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ABSTRACT

Long-term crop rotation experiments offer us the ability to explore the effects of climate and management on crop productivity, crop quality and soil health. The design of long-term rotations needs to consider the short-term demands of the funding cycle and provide the ability to answer long-term questions we did not know we needed to ask when the experiments were designed. In Aberdeen, in 2021–2022 we were faced with the dual challenge of redesigning the legume-supported Tulloch organic rotations, and the Woodland's Field pH experiment. Since 2007, the Tulloch experiment has compared a stockless (plant-based) organic rotation with a traditional stocked ley/arable rotation. The reason for the current redesign was that it was clear that the plant-based system being tested was not sustainable in the long- term and a couch grass challenge had developed in the plots. The redesign of the pH experiment was forced upon us due to urban development of the original site, so we had to move the soil to a new location (see abstract from Robin Walker).

Extensive stakeholder engagement was carried out to ensure that the rotations and management adopted were relevant to needs of extension officers, educators and researchers as well as farmers and growers. The rotations needed to be statistically robust, future proofed, and speak to the current policy agendas for Scotland, the UK and the EU. This paper will explore this process.

Acknowledgements

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Designing farms of the future using LTEs

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ABSTRACT

Current changes and challenges in farming, like ambitious environmental policies, the impact of climate change and the challenge to stop biodiversity losses, ask for a different approach of the farming system; not an optimalisation of the current system, but a farm(ing system) of the future. In this system soil management, fertilization, crop diversity in space and time, precision technology, water management, production, storage and use of sustainable energy, should all come together. Results of different LTE's on these individual topics provide pieces to the 'Farm of the Future' puzzle. In the Netherlands we have designed three Farms of the Future, for different agricultural regions. We largely made use of the results of existing LTEs as building blocks for the future farming system, and addressed research questions for new systems research. However, designing and demonstrating a farm of the future is also providing a platform for the regional stakeholder process, to identify challenges, set objectives and find out potential pathways for the future farmers. It also challenges other stakeholders to reflect on their role and potential contribution to the transition to future-proof farming practices.

Reflections on the design and management of a new Long Term Experiment

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ABSTRACT

Rothamsted Research is famous for its Long Term Experiments (LTEs) that have been running for 180 years. Although these experiments continue to be a unique and valuable resource for agricultural and ecological research today, they are limited by the original treatment structure and questions they were originally intended to address. In 2015, a working group at Rothamsted was tasked to envisage a new LTE that would address contemporary challenges related to agriculture and exploit modern approaches to statistical design. The ambition at the outset was to design an experiment that would contrast the response of multiple response variables (including yield, soil carbon and biodiversity) to different combinations of management interventions and to understand the underlying properties of the system that explain those different responses.

The resulting experiment, the Large Scale Rotation Experiment (LSRE), was the product of discussions between scientists from different disciplines and practical input from the farm management team. Balancing the ambition of the experiment to compare multiple factors (rotation, tillage, organic inputs and crop protection) with the constraints of physical resources (field size, operation of machinery, finance) necessitated a novel approach to experimental design that used the concept of ‘hidden replication’ in a completely randomized split-plot design, also enabling a model-based analysis. An important feature of the experiment is that it is multi-site, enabling the interaction of treatments with the local environment to be studied but this also introduced an added complexity to the design and analysis as the crops vary between sites. The management of the experiment has been adapted over the initial three years based on our observations while maintaining the integrity of the original design. The LSRE is proving to be a valuable platform for interdisciplinary research and a useful demonstration site for farmers to facilitate discussions around the principles of sustainable agriculture.

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Soil organic carbon stocks and greenhouse gas emissions in two long-term conservation agriculture experiments in sub-humid Zimbabwe

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ABSTRACT

Soils store significant amounts of carbon (C) and play a critical role in mitigating climate change through C sequestration. This study evaluated the potential contribution of each conservation agriculture (CA) principle or their different combinations to soil C stock and greenhouse gas emissions. A CA component emission experiment was established in 2013 in Zimbabwe on an abruptic Lixisol (DTC site) and a xanthic Ferralsol (UZF site). The main crop was maize (*Zea mays* L.) and treatments with rotation included cowpea (*Vigna unguiculate* L. Walp.). Gas samples were regularly collected using the static chamber method in the maize rows and inter-rows during the 2019/20 and 2020/21 seasons. In 2021, soil samples for SOC were taken down to 1 m soil depth and SOC stocks were calculated using the equivalent soil mass approach. In the 2019/20 cropping season, cumulative N_2O-N emissions were significantly higher in mulch and cowpea rotation treatments at DTC and UZF, respectively and ranged from 215 to 496 g and 226 to 395 g N_2O-N ha^{-1} yr^{-1}. There were no significant differences in yield-scaled N_2O emissions between treatments at both sites for the two seasons. Cumulative CO_2-C efflux was not significantly different between treatments, but it was significantly higher in the rows than in the inter-rows. Significantly higher cumulative SOC stocks were found within the top 20 cm at DTC and UZF in the no-tillage plus mulch (NTM) treatment compared to no tillage (NT) and conventional tillage (CT). SOC accumulation rate was highest in NTM (0.30 and 0.26 Mg C ha^{-1} $year^{-1}$ at DTC and UZF, respectively) compared to CT. Overall, the study showed generally low greenhouse gas emissions but a potential trade-off between additional SOC storage and N_2O emissions in the mulch and rotation treatments.

Leveraging long-term experiments to assess the carbon sequestration potential of diverse agroecosystems on Mollisols of the North Central US

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ABSTRACT

Soil organic carbon (SOC) sequestration is an important outcome of ongoing efforts to improve soil health, playing a critical role in building on-farm climate resilience while simultaneously mitigating climate change by reducing atmospheric CO_2. A suite of farming practices have been championed to promote carbon accrual that generally discourage tillage while emphasizing the importance of diversity, living cover, and crop-livestock integration. These techniques are attractive “natural climate solutions” because they can be adopted immediately using readily available technologies and have, as a result, become the target of several national and international initiatives to fight climate change through SOC sequestration. For such efforts to effectively lower atmospheric CO_2 they must be supported by accurate estimates of SOC stock changes. However, accurately documenting changes in SOC stocks requires a long-term (≥5 year), scientifically rigorous monitoring commitment, limiting our ability to assess the natural climate solution potential of regionally appropriate agricultural management practices in real time. Fortunately, long-term agroecological experiments can serve to bridge this knowledge gap by enabling retrospective assessment of the carbon sequestration potential of regionally appropriate agricultural management while simultaneously serving as experimental platforms for evaluating early or “sensitive” indicators of system change. Here we draw on three decades of data from the Wisconsin Integrated Cropping Systems Trial (Wisconsin, USA) to evaluate the impact of 1) soil disturbance, 2) living cover, 3) species diversity, 4) perenniality, and 5) livestock integration on deep carbon stocks and other key soil indicators. Our results reveal the difficulty in stabilizing or accruing organic carbon with annual-based cropping systems and highlight the importance of integrated perennial- and grass-based systems for building soil resources in the carbon-rich Mollisols of the North Central US.

Rotation with forage crop and fertilization slowed down soil carbon loss from Swedish long-term field experiments

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ABSTRACT

Maintaining soil fertility is vital for sustainable food production. Increased frequency of perennial forage crops in rotations and improving fertilization are considered to have great potential to increase soil carbon storage and thus mitigate climate change. In the Swedish long-term soil fertility experiments, crop rotation and fertilization treatments were set up at several sites across Sweden to represent farming systems with and without livestock. We analyzed the effects of crop rotation and fertilization on soil carbon content at seven sites (3 in central Sweden, 1966- and 4 in southern Sweden, 1957-) using mixed models, and investigated the relationship with estimated carbon input to soil and microbial community composition derived from phospholipid fatty acids (PLFAs) analysis. Overall, we found positive effects of rotation with forage crops and fertilization at all experimental sites although topsoil carbon (0–20 cm) decreased over time in all treatments. Rotation with forage crops and applying manure had significantly higher total topsoil carbon than rotation with only annual crops at both central and southern sites, mainly due to differences in the quantity of carbon input to soils. Topsoil carbon content was higher at a higher nitrogen fertilization rate, but this positive effect started leveling off at high application rates. We observed significantly higher viable microbial biomass and bacteria/fungi ratio in rotation with forage crops at sites in central Sweden compared to the rotation with only annual crops. However, this effect on microbial biomass and community composition was not observed at sites in southern Sweden, suggesting that sugar beet, which was only grown in southern Sweden, may have affected the carbon input quality and microbes. In conclusion, rotation with forage crops and fertilization slowed down topsoil carbon loss, and the amount and quality of carbon inputs to soil determined the dynamics of soil carbon content.

Soil organic carbon and nitrogen dynamics under long-term conservation agriculture systems in Cambodia

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ABSTRACT

This study quantified soil organic carbon (SOC) and soil total nitrogen (STN) changes in three long-term (14 years) experiments comparing conventional tillage (CT) and different no-till (NT) cropping systems using a diachronic approach and an equivalent soil mass approach. The three experiments were established in 2009 in a randomized complete block design with three replicates and comprise maize (MaiEx)-, soybean (SoyEx)-, and cassava (CasEx)-based cropping systems. Soil samples were collected in 2021, 10 years after the first sampling (2011), at 7 depths: 0–5, 5–10, 10–20, 20–40, 40–60, 60–80, and 80–100 cm. At 0–10 cm depth, NTs significantly increased SOC stock at a rate of 0.35, 0.51 and 0.73 Mg C ha^{-1} y^{-1} for CasEx, SoyEx and MaiEx, respectively. CT exhibited a positive trend only on CasEx with an accumulation rate of 0.14 Mg C ha^{-1} y^{-1} (0-10 cm). A significant SOC accumulation was observed under NT cropping systems for CasEX and MaiEx up to 60–80 and 80–100 cm depth, respectively. By contrast, STN stock significantly increased under NT cropping systems only at 0–5 cm depth with an accumulation rate of 13.9, 22.9 and 34.0 kg N ha^{-1} y^{-1} under CasEx, SoyEx and MaiEx, respectively. A depletion of N stocks was observed under CT and NT cropping systems at deeper soil layers. Over 10 years of time, SOC accumulation rate of NT, at 0-100 cm depth, reached 1.08 and 1.73 Mg C ha^{-1} yr^{-1} for CasEx and MaiEx, respectively while non-significant change was observed under NT SoyEx and CT of the three experiments. The findings suggest that long-term NT cropping systems with high amount of biomass-C inputs and crop rotation enhance SOC sequestration even at deeper soil layers. However, these results raise questions about the dynamics of N under NT cropping systems.

Soil organic matter stocks decrease despite increasing plant productivity - Insights from 14C analyses of an 80-years-old field experiment

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ABSTRACT

The objective of this study was to understand how eight decades of agricultural production and phosphorus (P) addition affect soil organic matter (SOM) stocks, SOM stoichiometry, and SOM decomposition.

For this purpose, we studied one of the oldest cropland experiments in Europe that has been maintained over the last 80 years in South Sweden. We analyzed the development of soil total organic carbon (TOC) stocks, the stoichiometry of SOM, several soil P pools, and the crop yields in the three treatments (Control, inorganic P addition every year, and inorganic P addition every six years). Further, we measured Δ14C of the soil organic C to elucidate the dynamics of soil TOC. We found that TOC, total nitrogen (TN), total organic P (TOP), and total P (TP) in the uppermost 20 cm of the soil decreased by 13.7, 13.8, 11.6, and 11.0%, respectively, from 1968 to 2021 across all treatments, and there were no significant differences between the three treatments after 80 years of experimental duration. The molar TOC:TOP ratio was 139, and 31% of the TOP was formed by phytate-P. Crop yields (across all three treatments) increased from approximately 220 g dry weight m^{-2} in the beginning of the experiment to more than 500 g dry weight m^{-2} in the last years of the experiment. Based on modelling of Δ14C, we found that the size of the slow soil C pool declined over time by about 54% from 1968 to 2021, which was partially compensated by an increase in the size of the fast cycling pool. P addition significantly increased the yields by 26 and 30% in the two P addition treatments throughout the period of the experiment (1936 to 2021). We conclude that the high crop yield in the control treatment is based on substantial plant P uptake from the soil below 20 cm since the soil TOP and TP stocks in the uppermost 20 cm in the control treatment did not differ significantly from those of the P addition treatments. Further, we conclude that the current agricultural use in all treatments is not sustainable since it leads to a continuous decrease in soil organic C stocks, in particular from the slow cycling C pool.

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Session Five: Innovative Methods

Challenges and approaches in data management of LTE trials in tropical field sites: Experiences from two trials in India and Bolivia

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ABSTRACT

Quality data is the key commodity of research projects. But with the size of a research project, number of parties involved and range of data collected, the complexity of data management increases significantly. In long-term experiments (LTE), continuity and comparability of collected data throughout the study duration is important but being challenged by personnel changes and development in infrastructure and technology, as well as changes to the trial itself. Managing a long- term trial remotely at field sites in the tropics adds another layer of challenges, including timely transfer of new data, time consuming pre-processing and validation of data between field and scientific staff, data literacy of local field staff and language barriers due to varying levels of English and local languages within the project team.

We share our challenges in data management and the strategies and tools used in the context of two LTE trials with field sites in India and Bolivia, managed by local partner organizations and coordinated by the Research Institute of Organic Agriculture in Switzerland, highlighting the technical infrastructure in use, definition of responsibilities and workflows.

Our main considerations are a) finding a balance between data security, easy and timely sharing of data in both directions and minimising number of different data repositories and file versions, b) the use of simple, well-known tools that are flexible enough to consider (evolving) needs of different involved parties including field staff, and c) the importance of quick data availability for analysis to serve as a basis for decision making in trial management.

Application of Bayesian Regression to data from long-term field experiments

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ABSTRACT

Bayesian methods have become increasingly popular due to more flexibility in model development with better access to statistical software and sampling algorithms. Using Bayes' Theorem, Bayesian estimation estimates model coefficients by incorporating any prior knowledge we may have on model terms. Including prior knowledge in this way requires a different estimating procedure for a fitted model. Bayesian model coefficients are usually sampled from thousands of runs of a plausible model via a Markov Chain. We present the use of Bayesian analyses through three examples: a single regression example showing how the estimated model changes with more uncertainty in our prior knowledge of model coefficients; a multiple regression example modelling grain yield from correlated seasonal weather variables, using data from the Broadbalk Long-Term Experiment; a final example is given estimating changes of soil carbon under crop rotation and fertilization treatments with a hierarchical time series model, using data from the Swedish soil fertility experiments. The purpose of this work is to present and introduce Bayesian analysis to the wider Long-Term Experiment community and how modelling process differs from traditional statistical analyses.

From Long Term Experiment gross results to soil nutrient critical concentration: Which adjustment method can be used with best robustness and precision? Case study of P

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ABSTRACT

The procedure for assessing soil phosphorus fertility level for crops relies on a measurement of a soil-P test and its comparison to critical concentrations (Steinfurth *et al*., 2022). Long Term Fertilisation Experiments (LTE) provide abundant soil-crop paired results for these calibrations. The way critical concentrations are estimated from LTE data is, however, hardly described, although several statistical adjustments are provided in the literature (Mallarino & Blackmer, 1992).

In France, the critical concentrations have remained unchanged for more than 30 years now (Jordan-Meille *et al*., 2012, COMIFER 1995), in spite of ongoing LTE and more recent numerous annual trials. We have therefore undertaken a deep re-examination of the current critical concentrations used by farmers. This study focuses on an upstream work, which consists in determining the best method that should be used to calculate the critical concentrations derived from the relationships between soil-P tests and crop yield values.

Four French LTE are used, providing data on six crops grown under various soil and climate conditions. They provide more than 200 "trials" (one crop *1 year * 1 site, with generally 4 repetitions and at least 4 soil P levels). For each trial, we compared the critical concentrations according to the four methods most used in the literature (linear-plateau, quadratic-plateau, Mitscherlich and Cate-Nelson). The "best" model would be the one that would provide, for the largest set of trial groups (1 crop * 1 site * n years), the lowest coefficient of variation, the best adjustment (RMSE) and that would maximize the robustness.

Our results show that the "Linear-plateau" method is the best one, especially for precision and robustness criteria. We conclude that only LET can serve as resource for choosing the best data processing method for establishing reference values from all field trials.

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A comparison of 16 soil-crop models using four term experiments in sub-Saharan Africa to guide improvement

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ABSTRACT

Food insecurity in sub-Saharan Africa (SSA) is partly due to low staple crop yields, resulting from low soil fertility and low nutrient inputs. Integrated soil fertility management (ISFM), that includes the combined use of mineral and organic fertilizers, can contribute to increasing yields and sustaining soil organic carbon (SOC) in the long term. Soil-crop simulation models help assess the performance of ISFM under current and future climate. Yet, uncertainty in model predictions can be high, resulting from poor model calibration and/or inadequate model structure. Multi- model assessments help understand model uncertainty and reduce it.

We compared the performance of 16 soil-crop models using data from four long- term experiments at sites in SSA with contrasting climates and soils. Each experiment had four experimental treatments: i) no exogenous inputs, ii) addition of mineral nitrogen (N), iii) organic amendments, and iv) combined mineral and organic inputs. We assessed model performance after partial and full calibration.

Model ensemble accuracy was greater with full calibration than with partial calibration, and improved more for crop yields (rRMSE 53 *vs* 17%) than for SOC (RMSE 21 *vs* 12%). Uncertainty of model simulations increased over the course of the long-term experiments. Uncertainty with SOC simulations increased when organic amendments were added to the soil, whilst uncertainty with yield predictions was largest when no inputs were applied. Differences between individual models were linked to uncertainties in simulating roots and soil N dynamics. The discrepancies between models increased when organic amendments were applied. Our study is the first multi-model comparison for long-term simulations of crop yield and SOC and their feedbacks in SSA. The results highlight the need for long-term experiments that monitor roots and N dynamics and provide the corresponding data required for soilcrop model improvements and calibration.

The importance to consider analytical method changes for soil organic carbon in long-term experiments

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ABSTRACT

Long-term experiments (LTE) have served over decades providing data to modelers and agronomists to investigate changes and dynamics of soil organic carbon (SOC) under different cropping systems. As treatment changes have occurred due to technological advancements, so have analytical soil methods. This may lead to method bias over time and could affect the data basis for robust interpretation and conclusions if not properly considered. This study aimed to quantify differences in SOC due to changes occurred for dry combustion method over time, using soil samples of a LTE established 1963 that focusses on mineral and organic fertilizer management in the temperate zone of Northeast Germany. For this purpose, 1059 LTE soil samples, taken between 1976 and 2008, were analyzed twice, once with a varying historical laboratory method right after sampling, and a second time in 2016 all being analyzed with the same elementary analyzer. In nine out of eleven soil sampling campaigns, a paired t-test provided evidence for significantly different historical SOC values than the reanalyzed value of the same LTE sample. In the sampling years 1988 and 2004, the historical analysis obtained about 0.9 g kg^{-1} lower SOC compared with the reanalyzed one. For 1990 and 1998, this difference was about 0.4 g kg^{-1}. Correction factors could be applied for only five out of eleven sampling campaigns to account for systematic or proportional method error. For this particular LTE, the interpretation of SOC changes due to agronomic management (here fertilization) deviates depending on the laboratory method which may weaken the scientific explanatory power of the historical data. Method changes over time present one out of many great challenges for time series analysis of SOC dynamics if reliable and detailed SOC analytical information are lacking. Therefore, LTE site managers need to ensure providing all necessary protocols and data in order to retrace method changes and if necessary recalculate SOC.

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Session Six: Soil Health

Organic Carbon and Texture Dependent Emergent Soil Behaviour

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ABSTRACT

The interactions between soil microbes and organic matter are critical to shaping soil the physical structure (e.g., aggregation and soil pores) and function of soil ecosystems. Organic matter in soil is broken down by microbes: resulting metabolites associate with mineral particles, contributing to physical structure formation. The developed structure influences various soil functions (Zhang *et al*., 2021), including nutrient delivery to plants, and water retention. In turn, these physical processes exert selective pressures on the microbiome metagenome, shaping the functional potential of the microbial community (Neal *et al*., 2020).

Evidence from several of Rothamsted's long-term experiments indicates that the pore connectivity in clay loam soils responds to differences in organic inputs. The nature of the response indicates that these soil-microbe systems are in a self-organized critical state, sensitive to inputs and turnover of plant-derived organic carbon. In contrast, no evidence for self-organized criticality is observed in sandy loams. In the clay-rich soils of the Broadbalk long-term experiment, this self-organized criticality results in organic matter inputs being effective in reducing nitrous oxide losses while supporting system resilience (Neal *et al*., 2023).

We hypothesize that adaptive self-organization in clay-rich soils acts to maximize microbial respiration and organic matter turnover in organic-rich soils. When carbon input rates are high, the self-organized state permits maximal microbial metabolism, nutrient and water flux to plants is increased, water storage is greater, and there are lower greenhouse gas emissions. However, the soil stores less carbon than would be the case in the absence of self-organization. Under reduced organic inputs, preferential accumulation of low oxidation state organic compounds is promoted because of their poor thermodynamic yield compared to more oxidized compounds under anaerobic respiration (Keiluweit *et al*., 2017). This is likely to result in soil storing more carbon when input rates are lower than would be the case in the absence of self-organized criticality (i.e., sandy loams).

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A bayesian belief network with which to infer soil quality and health

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ABSTRACT

Soil quality or health are intuitive terms that are widely used by the scientific community but a precise, quantitative definition of either remains elusive (e.g. Powlson 2020). For this reason, the scientific community often reaches for indicators. Such an approach risks losing sight of (i) the functions soil is expected to perform, (ii) the fact that the same indicator may mean different things in different contexts, (iii) the processes involved and (iv) any interactions between separate processes.

Expert opinion has been suggested to overcome these issues, but a strong subjective element inevitably remains. To make progress we developed bespoke software (Hassall *et al*.,2019), and elicited then structured experts' views of the extent to which soil delivers the functions expected of it, within a Bayesian Belief Network (BN), with inferences beginning from measurable properties of soil (Taalab *et al*., 2015). With this network we assess the quality and health of plots on the Broadbalk field experiment. This independent validation provides confidence that the method is (a) fit for purpose and (b) works at fieldscale. Having validated the BN in this way, we compare estimates of soil quality and health in field experiments that have continued to yield well and appear to be in good health with those where yields have declined or health and quality have clearly deteriorated.

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Bioprospecting for plant growth promoting microbes: Rich seams in long-term agricultural field experiments?

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ABSTRACT

Interactions between plants and microbes are believed to have facilitated the conquest of land itself and to this day profoundly affect the success of plants in both ecological and agricultural contexts. Naturally occurring soil microbes – especially the subset that can live associatively with plant's roots – offer the potential to contribute to the sustainable intensification of agriculture by a variety of means, including the suppression of plant diseases and provision of limiting nutrients. However, the effects of different agricultural management practices and cropping systems on the proliferation of particular sets of microbes may determine the manifestation of these beneficial functions. The design of the Broadbalk winter wheat experiment at Rothamsted has ensured that a diverse range of biotic and abiotic selective pressures associated with different combinations of these treatments have acted continuously on resident soil microbes over the last 180 years. Moreover, with continuous cropping, plants subjected to the specific conditions in each of the different plots may promote and suppress specific members of their root-associated microbial communities accordingly, further reinforcing the diversity of relevant plant- microbe associations fostered by the experiment. Screening robust microbial isolate libraries established via a high-throughput, partially automated culture collection pipeline has revealed the distributions of key functional traits amongst microbes isolated across disparate nutrient regimes. The prevalence of several putatively plant-growth-promoting functions such as *in vitro* phosphate solubilisation depended largely on the history of inorganic nitrogen applications in this field setting, highlighting the central role of the treatments that formed the basis for the experiment *c.*1843 for this historically neglected biotic component of crop production. Alongside detailed soil physicochemical characterisations these data will enhance our interpretation of a comprehensive field-wide amplicon sequencing survey aimed at dissecting the determinants of effective microbial plant-growth- promotion in the field and help guide future bio-prospecting efforts towards agriculturally relevant plant-associated microbes.

Higher plant species diversity increases the estimated abundance of key genes involved in soil phosphorus turnover

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ABSTRACT

Plant diversity effects on biomass yields have been well-documented (e.g. Isbell *et al*., 2017), though whether microbiome-mediated soil nutrient turnover, especially of phosphorus (P), underpins this effect is currently unknown. Soil samples were taken (May 2021) from the Jena Biodiversity experiment (est. 2002), an un-fertilized grassland which manipulates sown plant species diversity (SPSD) across 1, 2, 4, 8, 16 and 60 species. Soil DNA was extracted and metagenomic sequencing conducted on the Illumina Miseq platform. SqueezeMeta (v1.5.0) was used to calculate estimated abundance of detected genes involved in soil P turnover (Tamames and Puente-Sánchez, 2019), with linear mixed effects models then used to test the effect of SPSD. Of 32 detected genes, 9 showed a significant increase in estimated abundance with increasing SPSD, while 3 significantly declined (all at least $P \leq 0.05$). The *gcd* gene (mediates gluconic acid production for inorganic P solubilization) showed the strongest increase with SPSD (regession coefficient (β) = 31.54). Contrastingly, *ppa* which encodes an inorganic pyrophosphatase, significantly declined with SPSD (β = -4.53). Eight genes in the *phn* gene cluster, involved in phosphonate degradation and transport, all increased with SPSD (β = 0.28 – 3.63). Finally, *pstA* and *pstB*, involved in P transport under low phosphate conditions, significantly declined with SPSD (β = -8.63 and -10.29, respectively). These results demonstrate that higher SPSD can enhance the potential of the soil microbiome to mobilize specific forms of plant unavailable P. Such mechanisms may underlie the diversity effects on aboveground biomass yields observed in managed grassland systems.

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From LTE data to the sustainable control of soil fertility

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ABSTRACT

Sustainable agriculture requires that soil fertility be optimal to maintain levels of food production whilst also maintaining environmental quality and even improving both together. Like inorganic fertiliser, organic amendments such as manure can increase crop yield and could partly replace artificial nitrogen, but we need a multi-year strategy, because yields may decrease when amendments cease. Other measures to manage arable land such grass and clover leys used in rotation can also enhance crop yield and mitigate soil degradation. Here we propose a way to assess the sustainability of agricultural practices by seeking optimal means for improving the fertility of land that takes account of the dynamics of the yield-enhancing benefits of organic amendments and leys alongside annual applications of artificial fertiliser. Using optimal control theory, we shall present a rational basis for combining applications of inorganic fertiliser and organic matter treatments of arable land to a sequence of crops grown in consecutive seasons that ensures maximum profit from crop production and improves soil fertility. Instead of a complex mechanistic approach, we use the empirical idea of a nutrient response curve, which is extended to include both the effects on yield of the nutrients themselves and also the long- lasting benefits of different types of organic matter management using ad hoc recurrence relations to model the carry-over of soil carbon and nitrogen from one season to the next. We will discuss useful key features of the design of an organic manuring long-term experiment at Rothamsted which allowed for the selection and the parameter identification of a single nutrient response curve valid for different organic treatments. Our control theory approach suggests that growing wheat for four years in rotation with one year of a ley can both reduce the use of nitrogen fertilisers and maximise the farmer's annual profit compared to other organic amendments.

Session Seven: Responses to Weather and Climate Change

The role of LTEs for designing future cropping systems

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ABSTRACT

Innovating and developing cropping systems for the benefit of high production of quality foods as well as the support of soil resources and other services such as low environmental footprint and climate impacts requires deep understanding of the ecological functions of cropping systems. This is of importance in systems that rely on biological cycles for sustaining production, where optimizing nutrient supply and crop protection are critical to maintain long-term fertility critical for ecosystem services and the support of productivity. Ongoing long-term experiments (LTE) have provided critical evidence on the short- versus long-term implications of the interacting processes between soils, plants, and the soil fauna. They have also provided important information about fertility management and effects on yields, nitrogen balance and soil carbon.

The green transition of agriculture requires substantial reductions in the use of external inputs while reducing nutrient losses, greenhouse gas emissions, maintaining soil health and increasing crop yields. Such massive changes in the performance of agricultural systems require efforts beyond the field scale, including livestock management, manure management, biorefining of biomass and novel design of landscapes for nutrient retention and biodiversity protection.

Cropping systems that meet the requirements for the green transition will likely have to meet the following conditions: 1) Complete and continuous soil coverage with vegetation or residues, 2) As little soil disturbance as possible and avoidance of soil compaction, 3) Building greater biodiversity in the soil, on the soil surface and in the landscape through variation in plant species and varieties, 4) Effective technologies to reduce nutrient losses and eliminate chemical pesticide use, and 5) Mixture of crops (incl. grasses, herbs and trees) to enhance resource use efficiency. Such efforts will need to be supported by new technologies such as 1) New digital technologies for monitoring and managing crops and soils, and 2) New genomic technologies for targeting beneficial soil-plant interactions.

Prediction of maize yields under conservation agriculture using crop and machine learning models in Eastern Southern Africa

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ABSTRACT

Field experiments are critical to inform researchers of how conservation agriculture (CA) cropping systems can potentially improve crop productivity, and enhance climate change adaptation and mitigation. Field experiments however do not completely provide information on the response of CA cropping systems to climate change due to the complexity in establishing and managing the scenarios. Crop and machine learning (ML)models are alternative tools to predict yields and impacts of climate change on cropping systems. The study therefore used ML and crop modelling tools to predict yields and also predict yields under climate change. The study used long term data from Chitala, Malawi; Gorongosa Mozambique; Bako, Ethiopia and Meru, Kenya. From each site data from 2 treatments: CA and control (CP), from 2010–2017 were used to calibrate DSSAT Crop model and train the Random Forest machine learning model. Climate change scenarios from CIMIP6 data was used to evaluate the impacts of climate change on maize yields using the DSSAT crop model. The results showed that both DSSAT and RF ML models were successfully calibrated and validated for yield prediction under both CA and CP cropping systems as realized by the low root mean square error of less than 30%. Both the crop model and ML were able to predict future yields under both CA and CP, highlighting yield differences between the cropping systems. The predicted yield differences between CA and CP using ML were however constant. Yields predicted using the DSSAT crop model however showed irregular differences between CA and CP. This was attributed to the different rainfall regimes, which led to low CA yields under high rainfall and vice versa. Maize yield prediction under climate change using the crop model showed consistently higher yields under CA as opposed to CP. Both crop models and ML models can be used to predict crop yields with considerable accuracy but crop models are more advantageous due to ability to account for crop weather and management. ML can become more valuable to predict climate change with additional data in different agro-ecologies.

The signature of the North Atlantic Oscillation on long-term aboveground primary production dynamics through 160 years of the Park Grass long-term experiment

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ABSTRACT

Worldwide, precipitation and temperature are the main biophysical controls of aboveground net primary production (ANPP) inter-annual dynamics. However, for grasslands located in northern Europe, we lack a deep understanding of how seasonal variations of global atmospheric patterns, such as the North Atlantic Oscillation (NAO) affects either precipitation and temperature and ultimately how these factors affect ANPP. This lack of knowledge relies on the availability of long- term ANPP data. To shed light, we harnessed data from the world's most extended ecological experiment, 'Park Grass' at Rothamsted Research, SE England, UK. Specifically, we investigated ANPP estimations of one of the experiment's control treatments (no nutrients addition) from 1873 to 2018. First, we correlated ANPP to monthly precipitation and temperature (from 1873 to 2018) from the Park Grass site, and to NAO monthly standardized values from a global database (from 1950 to 2018 only). Second, through a (hierarchical) structural equation model (SEM), we investigated how NAO either affected precipitation and temperature and how these, in turn, affected ANPP. Analysis results indicated that spring precipitation was positively correlated with ANPP, while June's precipitation and NAO were negatively correlated; and where NAO had a positive correlation with temperature from January to March. The SEM indicated that ANPP's inter-annual variation was significantly explained by June's NAO and precipitation, but not by temperature. Here, the observed pattern indicated that as NAO June's values were negative, precipitation was relatively high and ANPP was also relatively high. Our study represents the lengthiest description of NAO effect on ANPP to date and has clearly revealed that the NAO's influence on ANPP has been mediated by precipitation rather than temperature.

Climatic effect of no-tillage and mulch due to albedo change differs with soil type: A field study in Zimbabwe

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ABSTRACT

Biogeochemical effects of conservation agriculture (CA), i.e. soil organic carbon storage and greenhouse gas emissions have been investigated in numerous studies. Recent ones suggest that management practices also have significant biogeophysical impacts on local and global climate through changes in surface albedo and energy partitioning. For Africa, relevant studies are scarce. In this study, we assessed the biogeophysical effects of CA in maize fields over the 2021/22 and 2022/23 seasons at two sites established in 2013 in Zimbabwe on an abruptic Lixisol at Domboshawa Training Center (DTC) and on a xanthic Ferralsol at the University of Zimbabwe Farm (UZF). We hypothesised that CA would have different effects on albedo dynamics and radiative forcing (RF) depending on 1) the presence/absence of crop residues at soil surface, 2) soil type/colour. We monitored dynamics of albedo, longwave radiation, LAI, soil moisture/temperature under three different treatments: conventional tillage (CT), no-tillage (NT) and no-tillage with mulch (NTM). Our results showed that NT and NTM induced a RF cooling effect (higher albedo compared to CT) in the clayey soil at UZF but the mean annual RF of NT was higher than that under NTM with -0.83 $W.m^{-2}$ and -0.43 $W.m^{-2}$ respectively. In sandy soil (at DTC), we observed a warming effect due to the soil darkening effect induced by mulching. The mean annual RF of NT was -3.4 $W.m^{-2}$ (cooling effect compare to CT treatment) against 1.2 $W.m^{-2}$ for NTM (warming effect).

Next step is to compare the albedo induced RF induced by NT and NTM with the other biogeophysical effects and the biogeochemical effects on climate of those treatments. These results suggest that application of mulch or crop residues on sandy soils might not be relevant for a climate change mitigation perspective, even if it provides benefits for soil health and adaptation to climate change.

Mud, mud, glorious mud - impacts of modern farming and extreme weather on soil loss revealed by the North Wyke Farm Platform

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ABSTRACT

Soil is a vital resource for agriculture and its erosion and redistribution causes a number of well-known on-site and off-site unintended consequences including nutrient and carbon loss, sedimentation of aquatic environments and elevated treatment costs for potable water. In the UK, long-term datasets on soil loss at field scale are uncommon and previously widely used methods including the application of fallout radionuclides to establish medium-term average erosion rates are now known to suffer from important limitations and uncertainties. Against this background, the North Wyke Farm Platform, at Rothamsted Research North Wyke, has now assembled over a decade of data on soil loss at field scale. This has provided a unique opportunity to progress our understanding of the elevation of erosion rates by modern agriculture and of the incremental impacts of extreme weather events on soil loss from both grass and arable land. An overview of the lessons will be presented to illustrate the value of the data from a relatively young LTE.

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Session Eight: LTE Networks and Platforms

The First Decade of the USDA Long Term Agroecosystem Research (LTAR) Network: Successes and Strategy Moving Forward

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ABSTRACT

Long-term, transdisciplinary networked science is essential for advancing agricultural research and solving systems-level agricultural challenges. The United States Department of Agriculture (USDA) Long Term Agroecosystem Research (LTAR) Network was formed in 2012 to create a platform for inclusive and collaborative research, education, and outreach to improve food security and economic viability of rural communities while promoting climate-smart and resilient production systems, enhancing environmental services of agricultural lands, and ensuring sustainability of our food, feed, and fiber supply chains. The network is comprised of 18 sites representing the wide diversity of US agriculture, including eight cropland sites, five grazingland sites, and five integrated systems (both croplands and grazing/pastureland) and spanning a wide range in climate and edaphic conditions. The network supports over 22 working groups consisting of researchers with shared interests but highly diverse skillsets. These collaborative efforts have generated several successful network projects addressing topics such as phenology, carbon fluxes, nutrient management, agroecosystem erosion, and water budgets. Fundamental to the LTAR network is the common experiment, where individual sites compare business-as-usual to aspirational management that is targeted to the agricultural systems, culture, and practices common to each region. In 2022, the network reached its 10-year milestone and revised the network priorities and projects with a strategic plan for the next decade. This presentation will highlight several of the major successes of the LTAR network in its first ten years and share the vision of the path forward for the network to address climate change, integrate stakeholders, and develop benchmarks for critical indicators to assess sustainability in agroecosystem research as the network grows into the next ten years. The LTAR network can serve as a resource and blueprint for other countries eager to develop long-term networks.

USDA long term agricultural research: Carrying out multi-site research in the cropland common experiment

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ABSTRACT

The USDA Long-Term Agroecosystem Research (LTAR) Network was established to measure productivity and environmental footprints of agriculture across the U.S. Understanding how cropland agriculture affects the balance of ecosystem services under different forms of management over the long-term is largely unexplored. The LTAR network has a Croplands Common Experiment (CCE) within the portfolio of coordinated research activities to 1) develop and evaluate production systems that promote the sustainable management of cropland, 2) identify, quantify, and understand mechanisms underlying tradeoffs and synergies among ecosystem services, and 3) use common measurements across multiple systems in different regions to understand and model ecosystem service outcomes. A major research goal within the CCE is to compare commonly used practices, termed “Business-As-Usual (BAU)”, to those considered more novel within a region, termed “Aspirational (ASP)”. This simple design maximizes participation, longevity, and comparability over the intended 30-year timeline at two scales (plot and field). Within this design, primary metrics are collected and based on standardized protocols. Although the specific treatments defined as “BAU” or “ASP” vary across sites, the metrics have been developed with variation in experimental design, treatments, and site nuances in mind. Development of primary metrics, standardized protocols, and implementation have also facilitated the design of the data infrastructure to align with these metrics for greater ease of entry by team members and greater long-term usability of data due to this upfront harmonization. This presentation will highlight the primary metrics, protocol weblinks, and initial outcomes from the CCE.

Bringing metadata of European Long-Term Field Experiments through an open-access geospatial platform

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ABSTRACT

Long-Term Field Experiments (LTEs) are valuable agricultural infrastructures for examining the impact of management and environment on crop production and soil resources on different soil textures and types under changing climate conditions. These LTEs comprise long-term studies over decades and, in some cases, for more than 100 years, delivering valuable information for soil science and agronomy regarding soil use and yield critical for future food security; however, LTE-related information is dispersed worldwide. To bring LTE information together with the BonaRes project, we developed a geospatial data framework, including an LTE overview map (lte.bonares.de) to collect and analyze the meta-information of the LTEs for better visibility and reusability of these experiments. At this stage of research, our LTE map provides a spatial representation of European LTEs and their meta-information collected by extensive literature review and factsheets clustered in different categories (management operations, land use, duration, status, etc.) (Grosse *et al*. 2021; Donmez *et al*., 2022). Special attention has been applied to LTEs with an explicit scientific question and a minimum duration of twenty years due to identifying long-term trends/outputs in agricultural practices. Our LTE map comprises over 600 agricultural experiments across Europe; among those, 532 LTEs have already been running for over 20-yr duration with mostly fertilization treatment, followed by crop rotation and tillage trials. The collected LTEs were geospatially analyzed to provide inputs for the agricultural sector, scientists, farmers, and policy-makers and reused for interpreting LTEs regarding the effect of climate change (Donmez *et al*., 2023a and 2023b). An extensive database of scattered LTEs through the LTE overview map is expected to help developing a mutual management framework of efficient agricultural production by revealing the LTE potential internationally. This will contribute to increasing the visibility of LTE owners as well as scaling up the agricultural practices from site to landscape level for improving the climate change adaptation to agricultural yield and management.

This paper will present the recent state of LTE information and (meta)data management and its provision in the LTE map and outline analysis options for the data using 1-2 scientific case studies.

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Current and future adaptation strategies to heat stress for global livestock production systems in the context of climate change

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ABSTRACT

Ruminant livestock contribute to global food security by delivering highly nutritious food in different regions of the world and provide livelihood benefits while improving the sustainability of agroecosystems (Eisler *et al*., 2014). However, climate change (CC) imposes challenges to sustainably exploit their beneficial role since increased heat stress (HS) risk may have detrimental effects on animal health, welfare and overall performance. Moreover, the extent to which HS affect systems behaviour may vary according to the agroclimatic conditions and production circumstances at which the systems operate, thus the need to apply adaptation strategies appropriate to the specific settings.

The Global Farm Platform (GFP, www.globalfarmplatfrom.org) is a network of 16 research farms, some of which host long-term experiments, and 26 institutions with the exceptional capability for carrying out research to address the sustainability of ruminant livestock under a variety of agroclimatic conditions and production systems globally. In our latest workshop (Chicago, February 2023), working with the UK Met Office, we delineated a quantitative and qualitative concept paper, and defined the datasets required from each member to: i) calculate the Temperature & Humidity Index (THI) time series from global model data for the past (1979-2021) and future (2060-2080), ii) assess the impact of previous heat stress events on ruminant livestock key phenotypes (e.g., milk yield, growth, reproduction), iii) predict the potential impact under different future climate change scenarios, and vi) present the findings through case and intervention studies. We will propose adaptation strategies relevant to each production system that the GFP represents under nutritional, genetic, engineering and systems-level. We will also propose HS-relevant phenotypes to be recorded on farms, discuss wider implications of HS beyond livestock performance and recommend further measures to improve our understanding of HS risk and abatement.

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GLTEN 5 years on

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ABSTRACT

The Global Long-term Experiments Network was established in 2018, at the last Rothamsted LTE conference, with the aim of establishing and supporting a collaborative network within the agricultural science community. Since its launch GLTEN has had several notable successes. Through the development of the GLTEN Metadata Portal, the visibility of nearly 300 LTEs across 6 continents has been increased using an infrastructure grounded in FAIR principles to provide rich and consistent LTE descriptions. Collaborative projects have facilitated new research, for example the GLTEN Africa project developed new approaches for quantifying the contributions of cropping system diversity by comparing LTEs across Europe and Africa. Recently Rothamsted in collaboration with IITA have provided data management and analysis training focused on LTE data. But perhaps most importantly GLTEN is helping to prompt a discussion across the community about how we value and reuse the unique datasets LTEs provide. However, sustaining the GLTEN as a network is not without challenges. Crucially development of the network has relied on piecemeal funding. Without strategic funding it has been unable to retain a Network Co-ordinator, and this impedes growing GLTEN and supporting the community despite clear needs to develop capacity. What then should be the role of GLTEN going forward for supporting LTE managers and researchers. This presentation will review the first 5 years of GLTEN then look to the future of the network, what it can do and what it should aspire to do.

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Session Nine: The Wider Impact of LTEs

Crop response to soil potassium under diverse pedoclimatic conditions in multiple environments – implications for fertilization recommendations

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ABSTRACT

Due to its outstanding role in plant water balance, potassium (K) is increasingly being recognized as a key factor for adapting crop production to climate change (Sardans and Peñuelas, 2021). Optimal K supply alleviates water stress of arable crops. At the same time, temporal and spatial variability in site conditions strongly affects critical soil K values for maximum crop yield.

To understand crop response to soil K and concurring pedoclimatic conditions, we used data of a 30-year long-term field experiment located at six sites covering different soil types and climatic regions of Switzerland. The dataset comprised 2184 observations (91 site-years) of ammonium acetate EDTA-extractable soil K and yields of wheat, barley, maize, and potato as well as K fertilization intensity, soil clay content, soil pH, mean annual temperature and precipitation and deviation of spring precipitation from the norm. The data were fitted to a three-parameter ("Mitscherlich") model with fertilization intensity and pedoclimatic variables as fixed effects on all model parameters and year/site as nested random effects on maximum attainable yield.

Mean critical soil K values at 95% yield were considerably larger for potato (454 mg K kg^{-1} $soil^{-1}$), than for barley (124 mg K kg^{-1} $soil^{-1}$), maize (119 mg K kg^{-1} $soil^{-1}$), and wheat (97 mg K kg^{-1} $soil^{-1}$). They changed most prominently with changes in soil clay content (2.4-fold), mean annual precipitation (1.8-fold) and deviation of spring precipitation (1.7-fold). Further evaluations will reveal, whether the Swiss K fertilization recommendations need to be updated against the backdrop of shifts in precipitation patterns projected for Switzerland.

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Sardans J, Peñuelas J. 2021. Potassium Control of Plant Functions: Ecological and Agricultural Implications. *Plants* (Basel), **10** (2):419. doi: 10.3390/plants10020419.

Long-term conservation agriculture effects of wheat production on the economy and environment

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ABSTRACT

Global wheat yields are under pressure to meet global demand despite the increasing threats to production due to a changing climate. The Western Cape of South Africa has adopted conservation agriculture (CA) as a possible mitigation strategy and was included in the SmartAgri-plan for the Western Cape province. This study conducted a stepwise Life Cycle Assessment (LCA) to estimate the environmental and economic impacts of switching from conventional wheat production to CA's zero tillage (zero-till) and no-tillage (no-till) systems. The data was based on data collected from the long-term trials of the Western Cape Department of Agriculture's Langgewens and Tygerhoek research farms. It included a data set of 1,043 plot-level wheat observations from 2002 to 2020. The results indicate that CA is more profitable and has a higher environmental efficiency than conventional tillage wheat production. In Langgewens, zero-till and no-till are respectively 113% and 55% more efficient than conventional tillage when comparing the environmental impact of producing one kg of wheat. Findings also suggest that, compared to 100% conventional tillage wheat production, CA systems have reduced environmental damage in the Western Cape, valued between £12.8 and £19.2 million.

Long-term experiments to investigate contemporary global challenges: Genetics × environment × management effects on soil organic carbon sequestration

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ABSTRACT

The “4-per-1000” initiative to increase soil organic C (SOC) stocks to help offset C emissions has sparked considerable debate on its merits and feasibility. The debate can be simplified as one of the effects of genetics (e.g., vegetation type) × environment (e.g., climate, soil type) × management (e.g., land use) (G×E×M) on SOC. We analysed the G×E×M effect on SOC in 16 of the Rothamsted Research long-term experiments (LTEs) at three UK sites, covering different crops or vegetation, and soil types, and a multitude of management practices, to give 114 treatment comparisons over 7–157 years (Poulton *et al*., 2018).

In 65% of cases, annual SOC increases exceeded the 4-per-1000 target. In two LTEs (>150 years), annual farmyard manure (FYM) applications at an equivalent of 3.2 Mg C/ha/year gave annual SOC increases of 18- and 43-per-1000 in the topsoil during the first 20 years, and this remained above 4-per-1000 for 60 years. In other LTEs, with FYM applied at lower rates or less often, there were annual increases of between 3- and 8-per-1000 over several decades whereas other treatments gave annual increases of between 0- and 19-per-1000 over various periods.

Whilst certain G×E×M combinations can achieve annual 4-per-1000 SOC sequestration, often enhancing wider soil health, many of the management practices required are likely to be unfeasible (e.g., unavailability of sufficient organic inputs) or undesirable (e.g., water pollution from manure applications, food insecurity from removing land from agriculture) in practical agriculture over large areas. We demonstrate the continued importance of long-term experiments as platforms to investigate contemporary global challenges.

Reference

Poulton P, Johnston J, Macdonald A, White R, Powlson D. 2018. Major limitations to achieving “4 per 1000” increases in soil organic carbon stock in temperate regions: Evidence from long-term experiments at Rothamsted Research, United Kingdom. *Global Change Biology* **24**:2563–2584. https://doi.org/10.1111/gcb.14066

Using Long-term experiments (LTEs) as platforms for knowledge exchange and capacity development

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ABSTRACT

LTEs are especially relevant for perennial crops such as cacao. In Bolivia, the LTE of the SysCom Bolivia project, established in 2009 by FiBL Switzerland in partnership with the Union of Farmers' Cooperatives EL CEIBO, ECOTOP Foundation and the Institute of Ecology from UMSA, compares different production systems in agroforestry or monocultures under organic and conventional farming[1]. Along with the high scientific output on topics such as productivity, profitability and ecology over the past 13 years, a basic but complete, infrastructure, knowhow and capacities have been developed together with the LTE in a very remote area, and a research and training center for organic cacao production and agroforestry has evolved.

The LTE reflects local and international practices, and it will contribute to develop more resilient cocoa production systems. Exchange between scientists, advisors and practitioners is constant and results and urgent topics are discussed and addressed when necessary in additional on-farm and on-station trials. Thereby, a wealth of knowledge and practical experience on design and management of cacao agroforestry systems has been built up within the project team. The long-term partnerships, as well as the very stable staff team were key in building up this knowledge.

Today, the LTE project is efficiently used by complementary training and capacity building projects, allowing to reach out to more farmers and technicians in Bolivia as well as worldwide, through advisory services of partners as well as through technical publications and dissemination materials[2]. More than 10.000 visitors from four continents show the huge interest in the SysCom LTE.

We recommend to invest in long-term relationships and in field and scientific staff continuity and capacity around LTEs as well as the development of key messages and dissemination materials not only from scientific results but also from practical learnings.

[1]https://systems-comparison.fibl.org/project-sites/bolivia.html
[2]https://youtube.com/playlist?list=PL1dOum9RiVPh-gU6NI3krPsof2_IPDR4H

Conservation Effects Assessment Project Watershed Assessment Studies: A long-term national research network to assess environmental impacts of agricultural conservation management practices

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ABSTRACT

The United States Department of Agriculture (USDA) spends US$6 billion annually on agricultural conservation programs to implement conservation practices (CPs). In 2003, the USDA Natural Resources Conservation Service (NRCS) partnered with the USDA Agricultural Research Service (ARS), and other federal agencies and external partners to create the Conservation Effects Assessment Project (CEAP). The goal of CEAP is to quantify the environmental effects of CPs and programs and develop the science base for managing agricultural landscapes for environmental quality. Conservation effects are assessed at national, regional, and watershed scales on cropland, grazing lands, wetlands, and for wildlife. One CEAP component, the Watershed Assessment Studies (WAS), was initiated in 2003 to provide in-depth analyses and quantify effects of CPs at catchment and watershed scales. Primary resource concerns were on soil and water quality and water conservation on rain-fed agricultural land. Information derived from these watersheds is used to verify accuracy of national assessment models and help interpret model results. Data are accessible in the Sustaining the Earth's Watersheds–Agricultural Research Data System (STEWARDS) database. Subsequent US Farm Bills have recognized the impacts of CEAP over the last 20 years while acknowledging that much work remains to achieve environmental quality goals in most major water resource regions in the US. Over two decades, the CEAP WAS network expanded to 24 watershed studies and new initiatives that address legacy pools of nutrients and sediment, ephemeral gully erosion, enhancement of watershed assessment tools, and influence of drought, climate, and extreme weather events on CP performance. At this critical juncture, CEAP leadership is addressing a vision for future research direction and to explore how CEAP can leverage the power of network research both within the network and beyond. Expanding partnerships and coordinating with other networks are key to addressing issues on regional, national, and global scales.

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Posters: Sustaining Cropping Systems

P1
Ecological intensification can increase yields with lower inputs: Evidence from long-term experiments

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ABSTRACT

High yielding, low input agricultural systems are needed to provide sufficient food, fibre and fuels without causing unsustainable environmental degradation. Long-term experiments (LTEs) provide a unique data resource to reliably identify such systems, allowing long-term mean yields to be clearly distinguished from interannual variability, short-term perturbations and transitionary dynamics. However, a single LTE can only test a few different systems, so in this study we brought together data from 30 LTEs around Europe and Africa in a meta-analysis to investigate the potential for ecological intensification (EI) to achieve high yields at low input levels. We found that EI practices (specifically, increasing crop diversity and adding fertility crops and organic matter)

generally increase the yield of staple crops, but have a substitutive interaction with nitrogen (N) fertiliser. EI practices substantially increase yields when N fertiliser rates are low, but have little or no effect when N fertiliser rates are high, due to overlap in the key function of N provision to crops. In contrast, we did not find an interaction between EI practices and tillage: EI practices had comparable effects across different tillage intensities, and reducing tillage did not strongly affect yields. This presentation is based on methods and results described in MacLaren *et al*. 2022.

References

MacLaren, *et al*. 2022. Long-term evidence for ecological intensification as a pathway to sustainable agriculture. *Nature Sustainability* **5**(9):770–779. DOI:10.1038/s41893-022-00911-x.

P2
Impact of pH on grass-white clover growth and nutritional quality in grassland soils: A long term experiment study in Scotland

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ABSTRACT

The pH of grassland soils in Scotland is declining in large areas due to less frequent lime applications. Soil nutrient availability, grassland yield and crop diversity are highly influenced by soil pH values. The consequence of acidic soil on grassland nutritional quality have not yet been comprehensively assessed. Grass-white clover sward samples were collected in 2019–2021 from a long-term pH field experiment, Woodland's Field in Aberdeen, Scotland. This experiment is part of the larger ACE platform in Aberdeen. This was an 8-course ley-arable crop rotation which included a pH gradient (4.5–7.5 at pH 0.5 increments) superimposed across each crop row resulting in 7 target values. Collected crop samples were separated into grass and clover, and analysed for impact of pH on yield, protein and digestibility. These were analysed in the 1st, 2nd and 3rd year grass-clover ley.

White clover growth in the sward was inhibited at pH 4.5≤5.0. Increasing soil pH above 5 increased the clover presence from 0.1–14% to 33–58%, a 800–1650% increase in clover biomass. This significantly increased the nutritional quality of white clover in the sward. This was exhibited through greater percent nitrogen, crude protein content and proportion of more quickly digested fibre fractions. Increasing soil pH from 4.5–6.0 increased total sward (grass and clover) biomass yield by 122–282.1%. The positive impact of pH on nutritive qualities of white clover in the sward are likely to increase dry matter intake of grazing animals and therefore liveweight gain and/or milk production. A simple measure to increase human-available products. By not increasing soil pH out of a highly acidic range, there may be sward nutritional quality and overall biomass yield consequences that are easy to remediate.

P3
Yield dynamics of crop rotations response to farming type and tillage intensity in an organic agricultural long-term experiment over 24 years

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ABSTRACT

High productivity and yield stability over time in combination with a reduction in the crop failure risk have to be achieved in organic agriculture through agronomic practices such as balanced crop rotations and the application of organic amendments. Reduced tillage constitutes an important practice that limits the disturbance to the soil, but deep ploughing is frequently used in organic farming for weed control and aeration of heavy soils.

This study aimed to assess the impact of stockless and mixed organic farms with their respective crop rotations and fertilization management, and the effect of reduced tillage on yield dynamics.

We compared yield dynamics i.e., crop yield, yield stability and the production risk, of three organic farming systems involving four levels of tillage intensity at the Organic Arable Farming Experiment Gladbacherhof (OAFEG), Germany, based on a long-term (24 year) dataset. The six-year crop-rotation of a mixed farm was compared to stockless farming with rotational alfalfa ley and stockless farming with cash crops. The levels of tillage intensity ranged from deep inversion ploughing to non-inversion tillage. The yield data were normalized to enable comparison. We calculated the yield dynamics of the complete crop rotation as well as three crops within the rotations i.e., winter wheat, winter rye and potato.

The most promising combination of high yield and yield stability was mixed farming with deep (30 cm) and shallow (15 cm) ploughing, in contrast to stockless farming (with ley) with non-inversion tillage. Similar results were recorded for cereals, but not for potatoes. Stockless farming with cash crops and non-inversion tillage had the highest production risk.

Stockless farming was highlighted as a practical alternative for good yield dynamics provided that rotational ley was part of the crop rotation. Ploughing depth can be reduced on heavy soils without affecting yield dynamics compared to deep ploughing.

P4
Assessing sward management on biological nitrogen fixation from a white clover grass mixture

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ABSTRACT

White clover biological nitrogen fixation (BNF) in mixed swards can be reduced by management or unfavourable soil conditions. In this study, the BNF of a grass-white clover pasture was examined under set-stocking conditions with different management. A split-plot block experiment was run at the North Wyke Farm Platform, in the SW of England. Plot treatments were grazing, pasture for silage and simulated grazing. The split-plot treatments were 0 or 14 ton ha^{-1} of Farm Yard Manure (FYM). During one-growing season, herbage production, species composition and BNF (^{15}N natural abundance method) was analysed monthly, macro- and micronutrients once.

The herbage production ranged 4 – 10 tonne dry matter (DM) ha^{-1}, significantly higher in the silage compared to the grazed and simulated grazing treatments. The clover content in the herbage ranged from a few percentages to 40 % (DM base), significantly lower in the grazing treatments than in the other treatments. The estimated %N derived from the atmosphere (Ndfa) ranged 84 – 93%, but was not determined by management or FYM addition. The BNF ranged 7 – 76 kg N ha^{-1}, significantly higher in the silage treatments compared to the other treatments. The BNF was strongly determined by herbage mass production (P = 0.72) and clover content in the pasture (P = 0.68) but not by the %Ndfa. The FYM addition had a positive effect on the mineral N concentration in the soil and on the K and Mo concentration in the herbage, however the FYM at the tested rate did not affect the BNF nor the herbage mass of the white clover-grass pasture under set-stocking conditions. The BNF under the conventional NWFP management was 7.4 (2.2) kg N ha^{-1} in Dairy East under sheep grazing and 33 (9) kg N ha^{-1} in Dairy South under silage followed by cattle grazing (mean with standard error between brackets, n=3).

P5
The Broadbalk Wheat Experiment, 1843–2023

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ABSTRACT

Started by Lawes and Gilbert in 1843, the Broadbalk Wheat Experiment at Rothamsted is the *exemplar* of sustainable cereal production. But to maintain and increase yields with organic manures or inorganic fertilisers for 180 years and to ensure relevance to modern farming and current scientific questions, changes have been necessary. Changes, such as fallowing, the use of herbicides, and liming to maintain a soil pH suitable for wheat, were needed to ensure that the experiment continued. Other changes, such as the introduction of modern cultivars, testing greater amounts of fertiliser N and a comparison of continuous wheat with wheat grown in rotation ensured the experiment remained relevant agronomically and useful scientifically.

Short-strawed cultivars, introduced in 1968, doubled grain yield where sufficient nutrients were applied. Wheat grown as the first crop after a two-year disease break resulted in even greater yields as did the later use of fungicides, greater N application and newer cultivars. Best grain yields now exceed 12 t ha^{-1} in some years.

Where fertiliser N has been applied the larger crops leave more organic matter as roots and stubble which, when ploughed-in, increases soil organic carbon towards a new equilibrium value. Where 35 t FYM ha^{-1} has been applied annually, the increase is much larger.

Broadbalk, the accumulated data and the archive of crop and soil samples dating back to 1844, are a unique resource which continues to be used by scientists world-wide to address the key global challenges of sustainable agriculture, food security and climate change. We present a new summary of results from Broadbalk from the last 50+ years. Further information can be accessed through the Electronic Rothamsted Archive (http://www.era.rothamsted.ac.uk/).

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P6
Long-term effects of tillage on soil carbon and crop production within a diverse crop rotation

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ABSTRACT

The continued use of conventional tillage practices in the Swartland region of South Africa led to a decline in soil organic carbon and quality. Subsequently, farmers adopted no-tillage practices, which became the preferred method for establishing crops. More recently, a larger variety of crops were introduced into rotations to combat yield loss due to disease and weed pressure. The effect of tillage and crop rotation on crop production and soil quality remains a point of interest for local farmers and researchers. Therefore, a long-term study was introduced in 2007 on the Langgewens Research Farm in the Western Cape province of South Africa (33°16'0" S 18°42'0" E). The study aimed to evaluate the effect of multiple tillage practices on a four-year crop rotation system (wheat (*Triticum aestivum*)-canola (*Brassica napus*)-wheat-lupin (*Lupinus*)). Every crop in rotation was present each year. Four tillage treatments were identified, ranging from aggressive soil disturbance to almost zero soil disturbance (conventional-tillage, minimum-tillage, no-tillage, and zero-tillage). Crop yield and quality for wheat and canola were determined every year, with wheat protein and canola oil content serving as quality indicators. Soil samples were intermittently taken for soil carbon analysis. Wheat zero-tillage produced the lowest yields, whilst the other treatments produced similar yields. Both canola yield and wheat protein content increased with more aggressive soil tillage treatments, whereas canola oil content increased with less aggressive tillage treatments. Soil carbon content showed significant differences in treatments over time, with less aggressive treatments sequestrating higher amounts of carbon. By decreasing soil disturbance, conservation tillage has historically provided positive results on soil quality. However, as shown by this study the positive effects of more aggressive tillage practices on canola yield and wheat protein, as well as the already-known effects on weed suppression, and soil acidity may threaten the continued use of conservation tillage, and subsequently, soil carbon and quality. Therefore, negotiation needs to occur between farmers and the amount of soil disturbance that is to be allowed to build soil quality whilst remaining profitable.

Acknowledgments

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P7
Root - and fine seeded crops in reduced tillage on a sandy loam soil

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ABSTRACT

Soil quality is decreasing and in the light of climate change becoming more and more important. Arable farmers are looking for farming systems like reduced tillage and controlled traffic farming to restore soil quality. Both systems have positive effects on physical soil properties and emission of greenhouse gasses, and reduced tillage has a positive effect on biodiversity and resilience. There is limited data on the effects of reduced tillage with Dutch arable crops (especially root crops and small-seeded crops) on a sandy loam soil. This was a reason to set up the BASIS experiment in 2009 near Lelystad, NL. There is a four year conventional and a six year organic crop rotation. Soil consists of 17% clay and an average organic matter content of 3,5%. Reduced tillage with (RTS) and without (RT) subsoiling after harvest is compared to conventional inversion tillage (CT) with a mouldboard plough. Crops are grown in a Controlled Traffic farming system with 3.15m strips and the trial is in total 10 hectares in size.

Research was conducted mainly on yield and soil properties, but also on biodiversity, weed abundance and greenhouse gas emission. We found that marketable yield of 12 (RTS) and 11 (RT) of the 13 crops grown in one of the reduced tillage systems was similar or even higher over a 10 year period, compared to conventional tillage. There is an increase of fungal and bacterial biomass, labile carbon and nitrogen, a higher earthworm diversity and aggregate stability and a, non-consistent, increase of soil organic matter content in reduced tillage compared to mouldboard ploughing.

We see from 2009 on that arable farmers in the Netherlands are converting their farm partly or completely to a reduced tillage system, showing the relevance and impact of this long term experiment.

P8
Harvest index is reduced by high nitrogen application in monocropping paddy rice

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ABSTRACT

Nitrogen is one of the macro-nutrients for plant growth and development, and is commonly presents in fertilizers to improve the productivity of crops. Nitrogen application supports food production but also can bring nitrogen pollution to the environment. Rice is the most cultivated crop (224,000 ha) in Taiwan, effective fertilization on rice is therefore crucial for both crop productivity and environmental protection. The long-term experiment of different nitrogen inputs to monocropping paddy rice 'Tainan No. 11' was conducted in Chi-Kuo branch station (CKBS, code in DEIMS: LTER-EAP-TW-8) and Yuin Lin branch station (YLBS, code in DEIMS: LTER-EAP-TW-7). High nitrogen inputs (120 to 180 kg ha^{-1} in CKBS and 160 to 200 kg ha^{-1} in YLBS) resulted in more above-ground dry matter and yield compared with moderate nitrogen inputs (80 to 100 kg ha^{-1} in CKBS and 100 kg ha^{-1} in YLBS). However, the harvest index (ratio of grain to total above-ground dry matter) decreased significantly (P = 0.0006 and 0.0450 in CKBS and YLBS respectively) under high nitrogen inputs without the change of nitrogen use efficiency (NUE), revealing there is a limit for the amount of N that rice can into a grain. On the other hand, high nitrogen inputs also lead to more nitrogen loss by leaching (P < 0.0001 and = 0.0003 in CKBS and YLBS respectively) by leaching in fields. These results demonstrate the conflicts between yield and nitrogen pollution during rice production in Taiwan, and suggest the harvest index can be used as the indicator for efficient N application.

P9
A multi-year evaluation of the effect of green manures in crop rotation systems

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ABSTRACT

The future trend in agriculture will move towards sustainable farming techniques with the lowest possible ecological footprint. CO_2-neutral, regenerative farming methods are seen as added value in production. We set up our experiment in Hungary, University of Debrecen Research Institute of Nyíregyháza in 2019, intending to evaluate the effect of green manures in crop rotation systems based on 7 plant species. We examined the effect of green manures (*Lupinus albus, Vicia sativa, Raphanus sativus var. oleiformis, Fagopyrum esculentum*) on the yield of cash crops and their effect on the soil water content. The experiment is based on four crop rotations, each with a different plant order. We applied green-manured, fertilized, and control treatments in a randomized block design in four replicates. The experiment provides an opportunity for the complex evaluation of multi-year crop cycles.

We found higher soil moisture content levels in May-July after green manure treatments. Based on our experience, the yield of triticale after common vetch and oil radish green manure treatments was equivalent to the fertilized treatment and significantly higher than the control. When green manuring was applied two years before triticale cultivation, yields in areas treated with common vetch and oil radish were still significantly higher than in control areas, which results in supporting the long-term effect of green manuring. For oats yield, in the case of wet a autumn period, the results of the common vetch green manure treatment significantly exceeded the other treatments, but in a drought year, no significant difference in yield was observed between treatments. In maize, in a regular cropyear, the effect of leguminous green manure plants proved to be equivalent to the fertilized treatment, however, in an extremely dry season, in the case of plots treated with leguminous green manure plants the corn yield significantly exceeded the values of the control and fertilized areas.

P10
The long-term effect of crop rotation on wheat production and selected soil nutrients in the Mediterranean region of South Africa

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ABSTRACT

The adoption of conservation agriculture (CA) principles as well as climate change brought a new dimension to the importance of information gathered from long-term trials. Long-term trials can be regarded as the primary source of information to determine the long-term effects of cropping systems and soil management on soil productivity. A principle of CA is crop rotation, preferably including a legume crop.

The long-term trial was established in 2007 on shale-derived sandy loam soil with a high stone content at Langgewens Research Farm (33˚16'34" S, 18˚45'51" E; altitiude191 m). The farm has a Mediterranean climate with wet, cool winters and dry, hot summers. The trial consists of the following crop rotations: lupine/wheat/canola/wheat (LWCW), alternating wheat and medic pasture (MWMW) and wheat monoculture (WWWW). The soil organic carbon (SOC), phosphorus and potassium were compared between the systems. Wheat biomass produced, yield and grain protein were used as an indication of the crop productivity of the rotation systems.

Over 14 years, the mean biomass produced, wheat yield and protein were the highest in the WMWM system, followed by LWCW, both significantly higher than wheat monoculture. Incorporation of leguminous crops into cropping systems can ensure N availability and maintain better plant biomass production to increase residue cover after harvesting. Because of the grading system of wheat, wheat with a higher protein generates more income. No significant differences were found in the soil between the WMWM, LWCW and WWWW systems in terms of carbon (1.3%, 1.3% and 1.4%), phosphorus (76 mg kg^{-1}, 79 mg kg^{-1} and 72 mg kg^{-1}) or potassium (241 mg kg^{-1}, 230 mg kg^{-1} and 230 mg kg^{-1}).

The wheat produced in the WMWM system had a higher biomass production and yield with better quality wheat without depleting the soil nutrients. A crop rotation that includes a leguminous crop is sustainable in the semi-arid Mediterranean climate of the Western Cape.

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P11
Organic cropping systems maintain yields but fail in yield levels and yield stability compared to conventional

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ABSTRACT

Sufficient and stable crop yields are the basis for feeding a still growing world population. Limited cropland, climate change, loss of soil quality and biodiversity, and overuse of nonrenewable resources require new solutions for future cropping systems beyond existing management practices.

We analyzed mean yields, temporal yield trends and stability of organic and conventional cropping systems of the currently longest-lasting cropping system comparison, the *DOK experiment* (Switzerland), over a period of 40 years.

Yield data comprised winter wheat, potatoes, grass-clover, maize, and soybean in a seven-year rotation, where bioorganic and biodynamic systems have been compared with conventional mixed and sole mineral fertilized systems, at reduced half and regular fertilization level

Yields were significantly reduced in organic systems in non-legumes between 13% and 34%, dependent on crop, while in legumes, no yield reduction was observed in soybean and only 10% in grass-clover. Half fertilization reduced yields by around 10% in all systems. Applied mineral N determined yields mainly in winter wheat and potatoes. Temporal yield trends were not different between organic and conventional systems, nor between half and regular fertilization. However, in winter wheat, conventional and biodynamic managements with regular fertilization, showed a stronger temporal increase in yield, while yield of grass-clover under biodynamic management with half-fertilization decreased. Increased yield differences between systems in single years were due to poor performance of organic systems rather than better performance of conventional systems. Absolute stability, measured by the variance, was not different, but conventional systems were more stable than organic in relative stability, measured by the coefficient of variation. We found no difference in both absolute and relative stabilities between half and regular fertilization. This suggests that the variation in relative stability between organic and conventional management might be more related to plant protection than to fertilization intensity.

P12
Long-term grassland experiments in Norway: Grassland yields and botanical succession at Fureneset

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ABSTRACT

More than 2/3rds of Norway's agricultural area are grassland, and more than half of it is older than 5 years. Renewing old grassland usually increases annual yield but causes yield loss in a year of renewal. Replacement of low-productive species with high production species and cultivars results in higher yields but loses biodiversity. Finding the optimal rate of renewal frequency in unilateral grassland systems requires long term experiments. Several field experiments were established to compare different management systems in late 1960-ies. Three of them are still ongoing and located at Særheim (58.5°N, 5.6°E, established in 1968), Fureneset (61.3°N,5.0°E, established in 1974) on mineral soils, and on peat soil at Svanhovd (69.5°N,30.0°E, established in 1968).

All experimental locations included non-tilled and tilled treatments, with renewal every 3rd or 6th year and two fertilisation levels. At Fureneset and Særheim, they were cut either two or three times a year, with spring and autumn or only autumn grazing combined with the two-cut regime. The experimental design was simplified in 1992, removing combined grazing-cut treatments. Another non-tilled treatment was introduced and thereafter all treatments were cut thrice yearly at Fureneset and Særheim. A new fertilisation strategy was introduced, with contrasting levels of mineral fertilizer with or without cattle slurry. This phase lasted until 2011, followed by a period with limited activities. The third phase started in 2016, with renewal of all treatments at Fureneset and Særheim, except the permanent grassland plots from 1968/1974. Renewal frequency was halved, and fertilizer applications revised.

Here we will present results from the third phase at Fureneset, that emphasize requirement for five to six years to recoup and significantly over-yield the still productive permanent grassland. We will also discuss differences in soil chemical and physical properties between treatments, how fertilizer applications affect yield and botanical composition over time.

P13
Park Grass over 160 years: Carrying capacity and nutritional composition are driven by fertilisation strategy

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ABSTRACT

Two-thirds of the global agricultural land consist of meadows and pastures for grazing livestock. Whilst herbage yield is important to feed livestock, so is its nutritional composition. Rothamsted Research's Park Grass experiment has run continuously since 1856 (Warren and Johnston, 1964). The experiment investigates herbage yields in response to varying soil fertiliser and liming treatments. Samples were taken from the Park Grass' Archive at 10-year intervals, from 1860 to 2020, representing a range of treatments including no fertiliser, organic fertiliser, and sodium nitrate (SN) and ammonium sulphate (AS) at varying applications rates, liming, and application of P and K. Samples underwent proximate analysis for herbage's nutrients content which, combined with yield data, were used to estimate pasture's carrying capacity (CC). Nitrogen application rate was the primary driver of plot CC; however, fertilizer type was also important with SN outperforming AS on a weight-for-weight basis and providing more consistent results. Organic fertiliser performed broadly equivalently to 48 kg ha^{-1} of SN. Plots receiving P and K had mean CC of 1.60 livestock units (LU) per ha compared to 0.63 LU ha^{-1} for those without. Liming was also impactful with limed plots supporting a mean of 1.69 LU ha^{-1} compared to 1.34 LU ha^{-1} for those without. Mineral compositions also varied based with treatment; for example, Ca, Mg, S contents varied with the application of lime and P and K. An effect of time was observed across the experiment, including fluctuations resulting in particularly high/low carrying capacity years, highlighting the value in long-term data sets to allow us to see past the noise and observe long-term effects.

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P14
Ten years of YEN: Learnings for the future

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ABSTRACT

The YEN (Yield Enhancement Network) has been run by ADAS for the last ten years, and first began with a focus on identifying arable innovators and supporting their innovation to enhance productivity. This has been achieved, with entrants in our YENs achieving World record-breaking yields. The YEN also aims to provide a platform to enhance learning through knowledge exchange, providing metrics for farmers and benchmarking them against others, sharing and developing ideas, and encouraging testing ideas on-farm. This has led to the development of a knowledge exchange website, FarmPEP and farming innovation groups and field labs. Over the ten years, the data collected through YEN have created a valuable database of over 5,000 crop yields with around 1 million explanatory data points, which can be interrogated to ask questions surrounding agronomy and decisions. Analysis of the YEN dataset has revealed important associations with yield variation. However, it has highlighted that a significant amount of the variation is being caused by a 'farm factor'. YEN has also highlighted that there is still scope for progress in yields using potential yield models. Since its inception in 2012, YEN has diversified to a variety of issues and crops, such as YEN Nutrition, which focuses on nutrient use efficiency, and YEN Zero, which examines greenhouse gas emissions. In this presentation, we describe what the YEN has created and achieved in the last ten years and our learnings and lessons from the Crop YENs, YEN Zero and YEN Nutrition. We will also set out our vision for developing YEN for the future, including the introduction of 'YEN Farm' to adopt analysis at a rotational farm level rather than field approach and dynamic benchmarking, which can be carried out by farmers on their metrics of interest against farms of interest.

P15
Use efficiency of different nitrogen sources applied to wheat fields

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ABSTRACT

Nitrogen (N) is a driving force to fight food security and is contributing significantly after green revolution. However, its excessive use for food, feed, and biofuels is a threat to the environment and human health particularly challenging the climate actions. Several approaches have been under discussion including enhanced N use efficiency of crops, slow-release nitrogenous fertilizer, use of nitrification inhibitors and coating of nitrogenous fertilizer. Furthermore, in Pakistan nitrogen use efficiency for wheat, cotton and rice is much lower as compared to many agricultural countries (Shahzad *et al*., 2019). Current study aimed to use different fertilizer management practices along with agronomic techniques to alleviate the N losses in the environment. Various N fertilizer sources (urea, calcium ammonium nitrate and animal manure) at two tillage depths were compared in a long-term study for three consecutive years in the same field with same treatment subplots. Although a significant increase in grained yield was noted in recommended dose of N application and 25% more than recommended N fertilization (N-125), however the N use efficiency was better where recommended fertilizer was applied leading towards low N losses. Furthermore deep tillage has also shown high N use efficiency with relatively higher grain yield comparing shallow tillage. Nevertheless, the highest utilization efficiency was found where 25% less N fertilizer was used, however the total grain yield was compromised. Furthermore, with respect to NO_3 - leaching, an increasing trend have been observed up to 30 cm soil depth followed by a decrease in 45 cm among all treatments. Also, the highest NO_3 - was estimated in N-125 at 15-30 cm depth over to control. Same trend has been seen with respect to NH3 volatilization among the various treatments. The results indicated that NH3 volatilization increased linearly with the N level. In each split, NH_3 volatilization was highest in N125 treatment plot over to control. So, it has been concluded from this study that excessive use of N above recommended level has significant effect on yield compared to N100 but contributed much in N losses such as NO_3 - leaching and NH_3 volatilization. Also, deep tillage reduces the N losses due to reduced ammonia emission. Furthermore, continuous application of organic N sources enhances the soil health. Reduced N fertilizer improves the nitrogen use efficiency but with compromised yields.

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P16
Nitrogen Use Efficiency of integrated crop livestock systems in 'Palo a Pique' long term experiment

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ABSTRACT

Nutrient use efficiency is a well know approach to benchmark nutrient management at farm level and is confirmed as a valuable indicator to guide decision making and improve sustainability of production systems (Gerber *et al*., 2014). The aim of this work was to quantify the nitrogen use efficiency (NUE) in four mixed crop livestock systems with different intensity of soil use with data collected over a 3-y period (2019–2022) at the Palo a Pique long term experiment (Uruguay). Systems evaluated were Continuous Cropping (CC), 2-y CC plus 2-y pasture (SR), 2-y CC plus 4-y pasture (LR) and continuous pasture with Tall Fescue (FR). Most of the information used in this study was collected as primary data at the field level. Inputs considered were N fertilizers, N biological fixation, N atmospheric deposition and feed N. Outputs included N in oats, wheat, soybean, livestock produced in each system, as reported by Pereyra-Goday *et al*., (2022). There were differences in NUEs (system-level NUE, P<0.0001), being 43.4, 28.1, 29.3 and 5.5% for CC, SR, LR and FR respectively, annual average. At component level differences were detected in livestock (P=0.0001); NUEL (%, livestock) were 24.4, 9.9, 14.3 and 5.5% for CC, SR, LR and FR respectively. In crop, differences were not detected (P=0.0725) and NUEc (crop) were 62.5, 83.8 and 77.5% for CC, SR and LR. Our findings show differences between components and suggest the need to apply differential strategies to improve NUE, mainly in the livestock component, considering the importance to develop sustainable food production systems.

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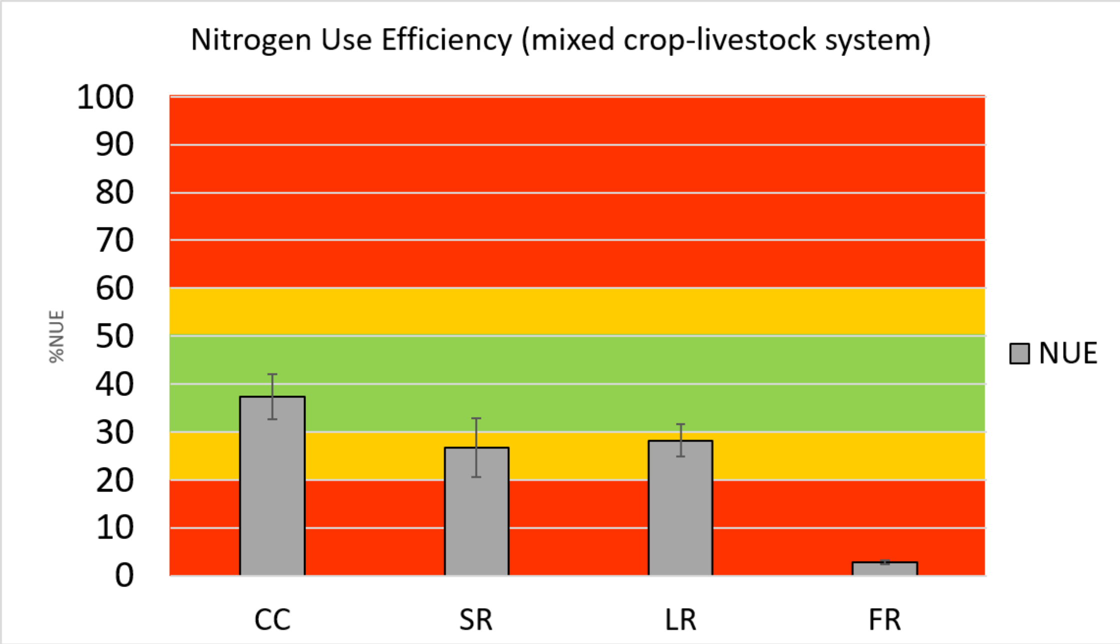
Nitrogen Use Efficiency (mixed crop-livestock system)
100
90
80
70
60
50
40
30
20
10
0
%NUE
NUE
CC
SR
LR
FR

P17
Long-term experiments show conservation agriculture practices increase cereal yields in the (sub)tropics

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ABSTRACT

Conservation agriculture (CA) – a system based on minimum soil disturbance, permanent soil cover and crop diversification – has been proposed to sustainably improve productivity of cereal crops, while mitigating and adapting to climate change. Mainly large-scale, commercial farmers have adopted conservation agriculture around the world, but its benefits for smallholder systems in the Global South have been disputed. This study analyses data from 15 long-term experiments (LTEs) that tested CA practices in India, Malawi, Mexico, Mozambique, South Africa, Zambia, and Zimbabwe. All LTEs in Africa were rainfed and those in India irrigated, while in Mexico there were rainfed and irrigated experiments. The duration of the experiments ranged from 9 to 29 years and main crops in the experiments were maize (*Zea mays* L.), wheat (*Triticum aestivum* L. and *Triticum durum* L.) and rice (*Oryza sativa* L.). Treatments in each of the LTEs were grouped into categories capturing major differences in tillage practices, crop diversification, and residue retention across multiple LTEs. In each LTE, a control treatment was defined as “conventional tillage, cereals only” system, which was then used to investigate the difference between the control treatments and comparison treatment combinations consisting of different CA practices. Yield ratios between control and comparison treatments were generally above 1, so on average, implementation of any CA practice had a positive effect on yields. Of the moderators, all except tillage had a significant influence on the yield ratio between the control and comparison treatments, usually in interaction with one another. Residue management had a strong influence: yield benefits were larger when residues were “added” (i.e., the control treatment had residues removed and the comparison treatment had residues retained) than for similar treatment pairs where both the control and comparison treatment had the same residue treatment (either retained or removed). Crop rotation also tended to increase the mean benefit of CA, but this effect varied in interaction with time, irrigation, and residues. The benefit of CA practices generally increased over time, illustrating the need for LTEs to adequately evaluate these practices. Additionally, the LTEs serve as reference sites to monitor the effects of climate change on cereal production in the regions.

P18
Nitrogen recovery and losses in a cereal- based cropping system using different organic fertilisers: FYM, compost, anaerobic digestate (AD) and straw

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ABSTRACT

Using organic fertilisers can improve soil quality and increase yield but might also increase nitrogen (N) losses to the environment compared to using mineral fertiliser alone. To address this question, we studied data from an organic amendment trial running for ten years at Rothamsted Research, UK, testing different types (FYM, compost, anaerobic digestate (AD) and straw) and rates of organic fertiliser in combination with variable rates of mineral N fertiliser. The organic fertilisers applied have equal carbon content but variable N content. The current study assessed the fate of the applied N; in the form of residual N retained in the soil (total soil N in 2020 - total soil N in 2013), recovered N (soil residual N + crop N/total N applied) and N lost from the system (total N applied - recovered N).

There was considerable accumulation of N in the soil with the FYM, AD and compost treatments where no mineral N fertiliser was applied. However, with the straw and control treatments there was no or very small soil N accumulation. Recovery of N relative to the total N applied was close to 100% with FYM, AD and compost treatments where no mineral N fertiliser was applied, but only ~50 - 60% recovery where mineral fertiliser was applied. With straw application only there was 200% recovery, showing that N was mined from the soil. Losses of N with FYM, AD, compost, straw and the control with additional mineral fertiliser were 38, 25, 37, 6 and 7% respectively.

The current analysis was completed for high organic and mineral fertiliser rates, which may over-estimate N losses. Therefore, further measurements are being performed for the other rates being tested in the trial. Furthermore, we intend to use the DNDC model (DeNitrification-DeComposition) to better understand the N losses.

P19
Fortification of micronutrient in pearl millet (*Pennisetum glaucum* (L.) R. Br.) hybrids using customized fertilizer in dryland condition of Rajasthan in India

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ABSTRACT

The micronutrient malnutrition is a major problem throughout the world. Therefore, identification of pearl millet hybrids and sources of fertilizers leads to enrichment of grain with micronutrients is very important. Thus, this area of research is highly focused in pearl millet biofortification. The present experiment was conducted at Research Farm, Agriculture University, Jodhpur during rainy seasons of 2019 and 2020. Wherein, the experiment was comprising of three fertility levels (Control, Nutrient supply through straight fertilizers and Nutrient supply through customized fertilizer) and seven pearl millet hybrids (‘MPMH 21’, ‘MPMH 17’, ‘RHB 177’, ‘RHB 173’, ‘HHB 67 (Improved)’, ‘HHB 197’ and ‘HHB 272’) in factorial randomized block design and replicated in triplicate.

Results

Reveal that application of customized fertilizer grade 6:6:2:1 (N:P2O5:K2O:Zn) to pearl millet substantially enhanced the zinc concentration in the roots, shoots, and leaf at panicle initiation (47.30, 54.31, 52.33 mg kg^{-1}), 50% flowering (40.30, 50.96, 50.10 mg kg^{-1}) and at harvest (45.27, 46.54, 47.29 mg kg^{-1}), respectively, over control.

Similarly, the iron concentration in the roots, shoots and leaf were also increased markedly due to application of customized fertilizer. Substantially higher zinc (56.42 mg/kg), iron (39.50 mg kg^{-1}), manganese (15.13 mg/kg) and copper (18.31 mg kg^{-1}) concentrations in the pearl millet grain was also fetched by applying customized fertilizer. Moreover, customized fertilizer statistically enhanced grain (2010 kg ha^{-1}) and straw (3417 kg ha^{-1}) yields over control. Among pearl millet hybrids, ‘HHB 67 Improved’ recorded substantially higher Zn (61.97 mg kg^{-1}), Fe (43.98 mg kg^{-1}) and

Mn (15.46 mg kg^{-1}) concentration in grain and Cu (25.09 mg kg^{-1}) concentration in straw. Albeit, 'HHB 173' noticed significantly higher Cu (19.60 mg kg^{-1}) concentration in grain. Further, among hybrids, 'MPMH 17' out yielded (1958 kg ha^{-1}) followed by 'RHB 173' (1795 kg/ha). In terms of straw yield, 'MPMH 17' recorded 3466 kg ha^{-1} straw followed by 'RHB 173' (3170 kg ha^{-1}), which was significantly superior over rest of the hybrids.

P20
Nutrient management through organic and inorganic sources in pearl millet in Western Rajasthan of India

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ABSTRACT

The importance of organic sources of nutrient management is well known in agriculture. Pearl millet is an important crop of India and it is grown largely (about 4.3 m ha^{-1}) in Rajasthan where soils are poor in nutrients. To enhance productivity and improve quality of pearl millet an experiment was conducted for three years (2018, 2019 & 2020) on nutrient management in rainfed pearl millet through organic sources compared with conventional inorganic source at two locations i.e. Jodhpur and Bikaner of western Rajasthan. The experiment comprised of 9 treatments which were replicated thrice in Randomized Block Design. Treatments were T1: RDF, T2: RDN through FYM, T3: 75% RDN through FYM, T4: RDN through Vermi-compost, T5: 75% RDN through vermicompost, T6: T2 + Biomix, T7: T3 + Biomix, T8: T4 + Biomix and T9: T5 + Biomix. The mean data of both the locations showed that conventional inorganic source (RDF) was better and resulted in 23.9% higher grain yield over T6 (RDN through FYM + Biomix) in first year of trial. But during second and third year, the yield was increased due to organic source T6 (RDN through FYM + Biomix) by 1.6% and 4.1%, respectively over conventional inorganic source (RDF). The mean maximum grain yield of three years (18.82 q ha^{-1}) was recorded with the application of RDF through inorganic fertilizers although its increase during second year and third year was nonsignificant. The mean stover yield was found maximum in the T8 (37.29 q/ha) and it followed by RDF (36.91 q ha^{-1}). The ancillary characters *viz*., earhead length, earhead girth and test weight were remained at par among all the treatments (T1 to T9) except plant height at location one. It was clear from the study that organic source of nutrient management can produce at par yield with inorganic source after three years of experimentation.

P21
Role of *Arabidopsis thaliana* Phosphoinositide specific Phospholipase C Isoform 5 gene in sensing heat stress and conferring thermotolerance in spring wheat

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ABSTRACT

Plant's response to heat stress involves various pathways and signaling molecules like phosphoinositide, derived from structural membrane lipid phosphatidylinositol. In this study, the role of *PLC5* was determined in two over-expressing and one knock-down mutant lines for heat stress tolerance in *Arabidopsis thaliana* at 37ºC and 45ºC to check seedling survival for acquired thermotolerance and chlorophyll content.

^{32}P labeling protocol was used to label phospholipids upon exposure to heat stress. *PLC5* over expressing lines exhibited quick and better recovery as compared to wild type and knock down mutant lines.

Additionally, *AtPLC5* gene was amplified and cloned in *pGreen0029* binary vector under *UBQ10* and *CaMV35S* constitutive promoters. *AGL1* strain of *Agrobacterium tumefaciens* was transformed with these gene constructs and used to inoculate immature wheat (*Triticum aestivum* L.) embryos cv. *Faisalabad-2008*. Putative transgenic wheat plants were validated through antibiotic selection, leaf dip assay, leaf paint assays, PCR amplification, southern blotting and by real time quantitative PCR. Successive generations of transgenic wheat plants were grown up to T4 to achieve homozygosity of selected wheat lines. Transgenic wheat plants were further investigated for possible heat tolerance at 40ºC for three hours (every day) for a period of 14 days at pre-anthesis and post-anthesis stages. Upon completion of heat treatments, plants were allowed to grow at 25ºC until maturity. Transgenic and wild-type wheat plants were evaluated for their physiological and agronomic traits at pre-anthesis and post-anthesis stages. Transgenic wheat lines HT1, HT2, HT8 and HT10 demonstrated to perform significantly better than wild type in their biochemical, physiological and agronomic attributes under heat treatment at 40ºC. These results revealed the involvement of *AtPLC5* in heat stress tolerance and it could be exploited further in other crop plants to ensure food security in changing climate scenarios.

P22
Integration of ridge and furrow rainwater harvesting systems and soil amendments improve crop yield under semi-arid conditions

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ABSTRACT

Low crop productivity due to prolonged droughts, inappropriate water saving practices, low soil fertility and soil erosion is a major threat to food security in semiarid areas. The objective of this Meta-analysis (MA) was to assess whether the integration of ridge and furrow rainwater harvesting systems (RFRHs) with soil amendments, namely biochar or mulches affect crop yield and soil properties relative to traditional no-till flat planting. An MA of data from 42 published articles based on PRISMA guidelines was used to assess the impacts of ridge-furrow tillage with and without mulching on potato (*Solanum tuberosum*, L.), wheat (*Triticum aestivum*, L.), and maize (*Zea mays*, L.) yield relative to traditional no-till flat planting in the Loess Plateau of China. Plastic film mulched ridge-furrow planting compared with flat planting without mulching increased potato yield by 34.01% in Gansu, 32.99% in Ningxia, and 12.78% in Shanxi. Maize yield increased by 33.10% in bare ridge-furrow planting with mean of 10,936.81 kg ha^{-1} compared with flat planting with a mean of 8217.07 kg ha^{-1}. Conversely, in areas where precipitation was higher than 500 mm, integrated plastic film with straw in ridge-furrow significantly (P<0.00001) increased wheat yield by 60% compared to flat planting without mulching, which can be attributed to the soil alkalinity (pH>7-8) of the soils in these areas. The observed differences in crop yield could also be ascribed to the influence of phosphorus availability. Results from the MA showed that the effect of straw mulched-ridge-furrow on crop yield was stronger in soils with higher available phosphorus at 20 mg kg^{-1} (5.31%; P=0.0003) than flat planting without mulching. Findings of the MA suggest that the adoption of integrated plastic film mulch with straw in ridge and furrow system can improve soil properties and crop yield under rain-fed conditions.

P23
No-tillage and liming long-term trial for sugarcane-soybean crop rotation system

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ABSTRACT

Brazil has the largest area planted to sugarcane and soybean cropping system using no-tillage practices. Despite the well-known benefits of no-tillage, adopting a sugarcane crop system without burning before harvesting rarely occurs because of some obstacles (pests, soil compaction, and subsoil acidity). To understand the impact of no-tillage in a sugarcane crop system with soybean in rotation, a long-term experiment was started in 1998 in a clayey Oxisol soil, at the Sugarcane Research Centre – IAC, Ribeirao Preto city, Brazil. The trial was installed according to a split-plot experimental design with four replications, in which the main treatment being soil management (no-till and conventional) and the sub-plot treatment of dolomitic limestone rates (0, 2, 4, and 6 Mg ha^{-1}) applied four times (in 1998, 2003, 2008 and 2018) before planting soybean, during the renovation of sugarcane field. After 25 years, this research provided twenty green sugarcane harvests and four soybean harvests. Also, it provided soil samples to study changes in terms of soil physics, fertility, and microbiological aspects. After ten years, the trial verified the effects of surface liming only at the uppermost layer (0-10 cm depth) on acidity-related variables, CEC, exchangeable Ca^{+2}, and Mg^{+2}. Soybean yield was significantly lower in no-tillage at the first and second renovation, but was higher at the third and fourth sugarcane renovation. Sugarcane stalk yield was higher in no-tillage since the first cycle, between 8 and 10 Mg ha^{-1} more than conventional tillage. For both crops, the quadratic trend was verified, and the highest yield was obtained with 4.0 Mg ha^{-1} of limestone. In conclusion, no-tillage can increase the sugarcane and soybean yield with increased organic matter, even though a high level of soil compaction occurs and the need for a little amelioration using surface liming to improve pH below 20 cm.

P24
Impact of occasional tillage after 26 years in no-till on soybean yield and soil attributes changes

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ABSTRACT

The expansion of no-tillage in Brazil is similar to the growth in the area of soybean being cultivated; then, it can be estimated almost 40 million hectares are cultivated using this system. Conservation agriculture provides many advantages, including reduced erosion, lower costs, and enhanced soil organic carbon (SOC). While it does have challenges such as; a high level of soil compaction, a vertical stratification of SOC/nutrients, and an increase of acidification at depth. Periodic disturbance, known as occasional or strategic tillage, has been promoted as a solution to solve all the challenges of long-term no-tillage. But, this decision can decrease the soil aggregates and diminish the SOC accumulated in the long term. This study aimed to understand the effect of occasional tillage after 26 years of continuous no-tillage on soybean yield and soil characteristics. The study area was a long-term trial started in 1996 at Sugarcane Research Center (IAC) in Ribeirao Preto city, Brazil.

In September 2022, the original crop rotation treatments with corn (monoculture) as the main crop rotated with sunhemp, soybean, and sorghum/sunflower for the last 26 years as continuous no-tillage was subdivided with two additional treatments of tillage using deep ripping and moldboard plow. The trial was a randomized experimental design with four replications of treatments with five cultivars of soybeans in each treatment. The trial was evaluated for agronomic characteristics and root systems for all soybean cultivars. Several soil samples were collected in all plots, with additional samples taken in a native forest to identify changes in nematodes, fertility, soil physics, and microbiological soil attributes. Preliminary results have shown an increase in soybean grain yield after strategic tillage. No difference was observed among the soil management strategies and crop rotation treatments for the activity of acid phosphatase, microbial biomass carbon, and arbuscular mycorrhizal fungi. However, the tillage has reduced by 13% and 20% the activity of β-glucosidase and arylsulfatase, respectively, in comparison with no-tillage.

P25
Improving biodiversity within upland permanent pastures: Lessons form the brignant long-term plots

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ABSTRACT

Measures show biodiversity is now declining at a faster rate than at any time in human history. Finding the best management strategies to restore grassland diversity and achieve a compromise between agricultural use and biodiversity protection is a global challenge. The Brignant plots were established in 1994 on previously improved permanent pasture to test the impacts of alternative managements on upland-fringe pasture. Sown grass species still dominated the sward at that time, particularly *Lolium perenne* (58% cover). The plots are located at 310 m a.s.l. (O.S. Ref: SN752757) on free-draining typical brown podzolic soils and are arranged in a randomized block design with three blocks and a total of seven grassland management regimes imposed. The treatments are: sheep grazing, with (GL+) and without (GL-) lime application; hay cutting only, with (HL+) and without (HL-) lime application; and hay cutting followed by aftermath sheep grazing, with (HGL+) and without (HGL-) lime application. Control (CO) plots continuing the previous site management (i.e. limed, fertilised and continually grazed by sheep) are also included within each block. These receive an annual application of 60 kg ha^{-1} N. The plots are 0.08 ha (hay cut only) or 0.15 ha (grazed) in size. Defoliation type, irrespective of liming, has been found to be the key driver influencing plant species diversity (hay cutting followed by aftermath grazing > hay cutting > grazing). Grazing only managements support grasses at the expense of forbs. These botanical changes can be linked to treatment differences in the abundance and diversity of associated arthropods. The findings provide an evidence base for agri-environment prescriptions targeting improved biodiversity within agricultural grasslands.

P26
Effects of tillage depth on winter wheat yield and soil properties: Results of 14 years of no- till in a long-term trial in western Switzerland

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ABSTRACT

In this study we compare the effects of four different tillage treatments, i.e., conventional plough (25 cm), shallow tillage (12 cm), and minimum tillage (8 cm) that have been all applied since 1969 plus a no-till treatment that started in 2007 on: 1) grain yield of winter wheat, and 2) a set of soil properties in a clay and in a loamy soil. Soil properties were measured in samples collected at four depths (0-5, 5-10, 10-20 and 20-50 cm) in 2020. Our analysis shows that, during the last 14 years, the relative grain yield in the no-till treatment is, on average, 25% lower compared to the plough treatment. On the other hand, the minimum tillage treatment has a grain yield similar or higher than the plough treatment. It is interesting to underline that the strongest decrease of grain yield was observed in the no-till treatment after a 4-year-long wheat monoculture. No differences are observed for the grain nitrogen concentration in 2020 between soil types and tillage treatments. For what concerns the soil properties, organic carbon concentration is about the double in the clay soil compared to the loamy soil with highest values in the no-till and in the minimum tillage, particularly in the upper soil layer. Microbial biomass carbon differs in relation to soil type, soil depth and tillage treatment. Overall, the clay soil has a higher microbial biomass carbon than the loamy soil and the minimum tillage shows the highest microbial biomass carbon in the upper soil layer. Within each soil type, micro- and macro-nutrient concentrations seem comparable between tillage treatments. In conclusion, it appears that, 14 years after the introduction of the no-till, the minimum tillage is still the most effective tillage to ensure a stable grain yield while promoting soil properties comparable to the no-till treatment.

P27
Yield stability and profitability: Perspectives from a long-term conservation agriculture trial in the tropical highlands of western Kenya

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ABSTRACT

Crop management practices that enhance performance of production systems under variable seasonal weather are key in addressing challenges imposed by climate change. This study assesses the impacts of common agriculture practices (conventional [CT] and conservation agriculture [CA]) on yield and yield stability and profitability under long-term management (30 seasons) in an oxidic tropical Ferralsol. Practicing CA achieved the same maize (-280 kg ha^{-1} season; ns) and soybean grain yield (+35 kg ha^{-1} season; ns) as CT. Practicing minimum tillage without surface residue application resulted into seasonal yield reduction of 540 kg maize grain yield relative to CT. Effects on yield due to residue application increased with nitrogen application. Omitting N (under sole maize), P and/or residues resulted in low performance of maize and soybean yield across environments. In addition, these omissions and overall practice of CT resulted in maize yield declines over time, consistent with soil organic carbon (SOC) trends. Among the tested treatments, multiple criteria of temporal trends, environmental means and profitability revealed four treatments with best performance: (1) CA + continuous maize + 60N + 60P, (2) CA + continuous maize + 90N + 60P, (3) CA + maize - soybean rotation + 60N + 60P, and (4) CT + continuous maize + 60N + 60P. Rainfall and number of rainy days at mid-season stage (dekads 6 - 10), coinciding with periods of low rainfall amounts and poor distribution, affected yield ($P<0.01$). These explain 46-56% of season-to- season yield variations compared to only 19% explained by seasonal rainfall. Effect of soil organic carbon on productivity were inconsistent. We conclude that multiple criteria are important to screen technologies, and that scaling of selected four treatments with considerations of supplemental irrigation during mid-season stage are appropriate interventions.

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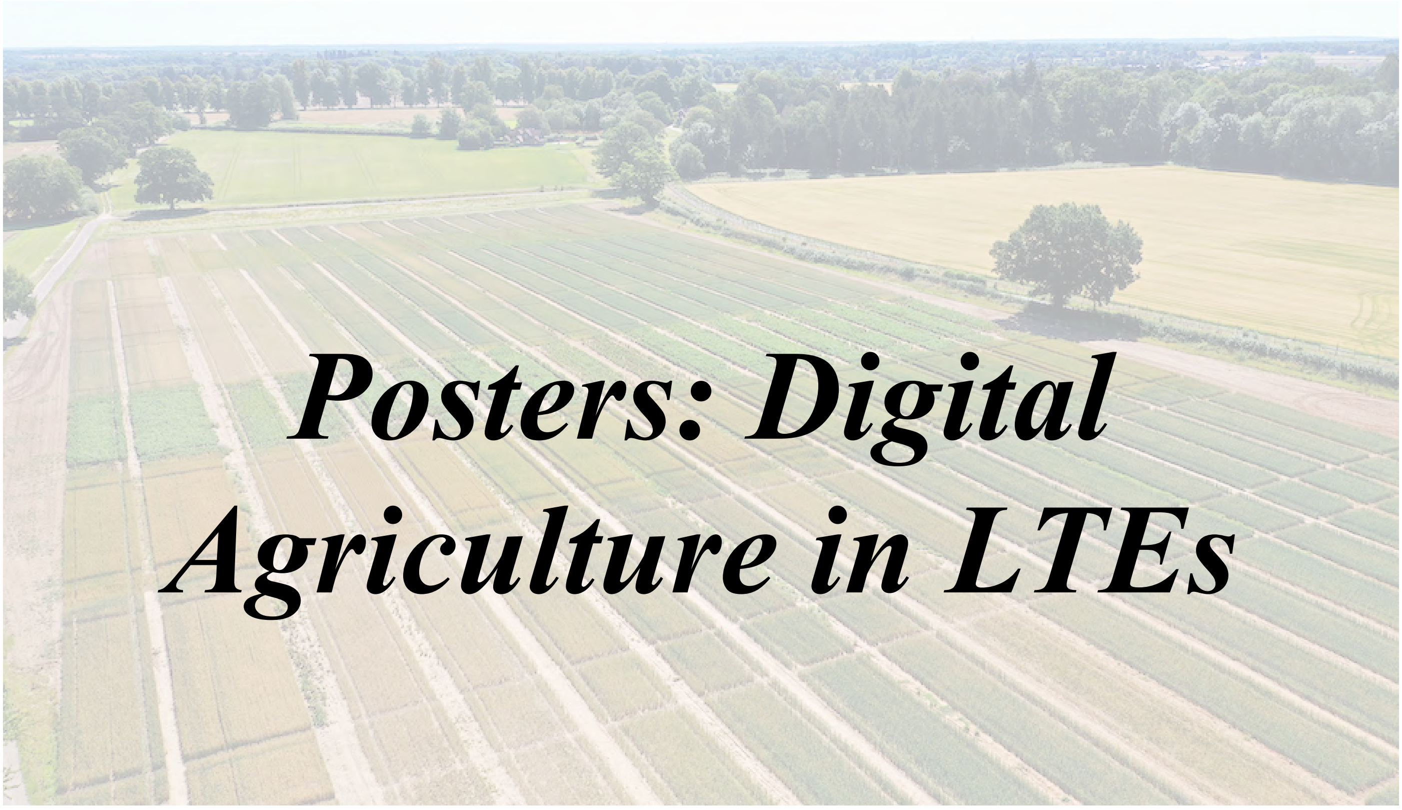

Posters: Digital Agriculture in LTEs

P28
LTEs and remote sensing to predict soil organic carbon variability at farm scale

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ABSTRACT

Monitoring, reporting, and verifying soil organic carbon (SOC) levels are essential for implementing sustainable agricultural management policies, especially during land use changes. However, this process typically involves direct soil measurements, which can be challenging, time-consuming, and expensive. Combining Long-Term Experiments with remote sensing provides various opportunities to evaluate temporal and spatial changes in SOC. Here, we compared statistical models to (1) determine the most effective environmental variables explaining SOC content variability in temperate pasture and arable land using the North Wyke Farm Platform (NWPF) in south-west England, and (2) evaluate the relationship between SOC and a remotely sensed Ecosystem Provision Index (ESPI). We compared linear, linear mixed, generalised additive models (GAM), and generalised additive mixed models to predict SOC based on sets of: (a) a mix of *non-open* and *open-source* environmental variables: ESPI, topography, climate, soil (units, total N, pH), field management (e.g., ploughing) and other farming practices (e.g., reseeding, mowing, grazing, inorganic fertilisation) recorded on the NWFP between 2012 and 2021 (Orr *et al*., 2016), and (b) only *open-source* variables: ESPI, topography, temperature, precipitation, soil type, and main land cover (arable or grassland). GAMs were the most effective at predicting SOC variability in both scenarios.

The best *non-open* and *open-source* model incorporated soil total N, management, soil units, ESPI, and mean temperature, resulting in an R^2_{adj} value of 0.98 and an RMSE of 2.9%. Upon removing TN and re-fitting the model, significant predictors were management, soil units, aspect, and temperature (R^2_{adj} = 0.82, RMSE = 9.1%), with management being the most important predictor, highlighting the impact of ploughing on SOC changes. The best *open-source* model included ESPI, aspect, and slope (R^2_{adj} = 0.64, RMSE = 13.0%), indicating that this cost-effective methodology can be useful for predicting SOC at the farm level.

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P29
Drone-based high-throughput techniques for monitoring long term experiments - building a digital archive

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ABSTRACT

High throughput phenotyping methods developed for screening germplasm collections (Holman *et al*., 2016; 2019) are equally applicable to monitoring long-term field experiments. Unmanned Aerial Vehicles (UAV) provide a platform for carrying various sensors; in this study a UAV carrying two hyperspectral sensors (400-1000 & 900-2500nm, 542 spectral bands), lidar and a high accuracy GNSS system was used to produce geo-located ortho-rectified hyperspectral high resolution image mosaics. The system was flown on seven occasions between 28th April and 23rd June 2022 imaging the Rothamsted Broadbalk long term experiment (started 1843), and 11 occasions over the WGIN Diversity experiment (started 2003) between 24th March and 8th July. From the data, various growth indices were calculated for each plot, and in this paper we show how the time course of measurements can describe the growth patterns of the different treatments in the experiment. Resources for time consuming traditional ground-based measurements are often limited, whilst utilizing high throughput systems with minimal labour requirements offer a useful alternative. A time course digital image archive of long-term experiments may well become equally important as the long-term sample archives, which have proved so valuable.

Acknowledgments

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Posters: (RE) Designing LTEs for the Future

P30
Stockless organic farming – the future of sustainable farming?

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ABSTRACT

The number of organic farms in Germany has increased considerably in the past few years. (BLE 2021). With this increase of organic agriculture, there is also an increase of specialization. More and more farms are working stockless, while the share of mixed farms is decreasing (Schulz *et al*., 2017).

Research questions related to effects of entire crop rotations require long-term research. Therefore, a long-term field experiment was started in 2017 at the Hessian State Domain Frankenhausen in Hesse, Germany, in which three stockless organic farm systems differing in crop rotation, each with three fertilization systems, are compared to a traditional mixed farm system. All crop rotations are organized in six-year cycles. The three stockless systems pursue three different focusses: *soil fertility*, *economic performance*, and *vegan farming*. The alternative simulated fertilization strategies in each system include i. cooperations with livestock farms or biogas plants and ii. transfer of legume-grass as fertilizer directly after cutting or after processing to silage or compost. Additionally, various organic fertilizers are included, besides compost (green waste and bio waste) also other purchased fertilizers such as Phyto Pearls or residues from tofu production.

The goal of the experiment is to examine parameters of soil fertility and nutrient management as well as development of crop yields and overall economic performance. First results from the first six-year crop rotation already show differences in field balances of nitrogen, potassium, phosphorus and sulfur, as well as soil carbon content and soil biology.

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P31
A new long-term experiment to explore the impact of rainfall extremes on the agronomic and environmental performances of cropping systems in the sub-humid tropics

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ABSTRACT

Extreme rainfall events, such as droughts, dry spells, and erratic and very intense rainfall events, have been more frequently observed in Southern Africa over the past decades. These events often lead to water stress or waterlogging, reducing crop growth. Soil-crop processes may also be adversely impacted, for instance through soil nitrogen (N) leaching, erosion or peaks of nitrous oxide emissions.

In 2022, we established a new long-term experiment at the University of Zimbabwe Farm (17°42'13.5"S 31°00'29.4"E) on 1.5 ha, with the objective to assess the agronomic and environmental performances of innovative cropping systems under extreme rainfall events, combining field monitoring and soil-crop modelling.

Three main treatments replicated three times were established: Reduced rainfall (-30%), Normal rainfall and Extreme rainfall events (100 mm 24 h) The reduced rainfall treatments are achieved with a rainfall exclusion system composed of transparent shelters covering about 30% of the surface. The extreme rainfall events are simulated with an irrigation system. Within these three rainfall treatments, ten cropping systems are tested in a split-plot design: Bare soil, Maize, Maize + N, Maize + Mulch, Maize + N + Mulch, Maize (100%) + cowpea (50%) intercropping, Maize (100%) + cowpea (50%) intercropping + N, Maize (50%) + cowpea (50%) intercropping, Maize (50%) + cowpea (50%) intercropping + 50% N, Sole cowpea. The mulch is obtained with 6 t DM ha^{-1} of maize residues. Mineral nitrogen fertilizer is applied at 80 kg N ha^{-1} yr^{-1}.

Many variables are currently measured: crop phenology, leaf area index, crop biomass and yield, soil water and nitrogen dynamics, mulch decomposition, emissions of greenhouse gases… Sensors will soon be installed to monitor the energy balance of the systems (albedo, heat fluxes).

This new experiment will be at least maintained for the next five years and is very much open for international collaborations.

P32
The long-term experiments of Livada

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ABSTRACT

The long term field experiments managed by Research and Development Station Livada include one amendment × fertilization experiment and three fertilization experiments and were established in 1961 and 1967, respectively. The experiments are located in North-Western Romania which has a moderate temperate-continental climate of Cfbx type (after Köppen). Experimental soils are classified as Luvisols (WRB Classification System) with an acidic pH, poor in potassium and a relatively low humus content as well as low base saturation.

The design of the amendment × fertilization experiment is of the 9A × 8B type with factor A representing lime doses and the frequency of application, and factor B representing fertilization levels. The three fertilization experiences are of the type 5P × 5N, 4NP × 4K and 4NP × 4 FYM the factors varying the concentration of various nutrients. All experiments were established in four replicates. Liming used Bucium limestone and precipitated calcium carbonate from Azomures. Fertilization was carried out with ammonium nitrate, concentrated superphosphate, 60% potassium salt and semi-fermented farmyard manure.

Among the obtained results, one of the most important was the establishment of amendment doses required to maintain the soil pH at 5.8. Other results were that systematic application of potassium led to the appearance of magnesium deficiency when applied on an unamended basis. Long-term amendment also led to an increase in the content of strontium by 2–3 and also to an intensification of the activity of microorganisms by three to four times. At the same time, the applied calcium carbonate decreased the content of humus, regardless of the doses of applied fertilizers.

P33
The rise of the pHoenix: Relocation of a 60+ year old soil pH gradient trial

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ABSTRACT

The SRUC Aberdeen based Woodland's Field pH long-term-experiment (LTE) was started in 1961 and encompassed an 8 course rotation, with every crop grown every year. A soil pH gradient was superimposed across all crops, with target soil pH ranging from pH 4.5 at one end to pH 7.5 at the other end, with 0.5 pH increments giving 7 pH treatments in total. The rotation consisted of 3 years grass and white clover followed by winter wheat, potatoes, spring barley, swedes and finally undersown spring oats leading back into the grassland phase. In 2021, housing development activity on the Craibstone Estate meant that the Woodland's Field LTE's were going to lost, and a bid to save them was made. As there is still much to learn about the influence of soil pH and the mechanisms involved in nutrient and carbon cycling through interaction with crop management and the soil microbiome (Horne *et al*., 2022), saving the pH rotation was seen as the priority. In collaboration with Aberdeen University, and with some additional funding, we were able to move the legacy pH soils to a new, more secure location nearby on very similar soil. The new pH experiment has been named the pHoneix Platform and now forms part of the Aberdeenshire Cropping Experimental (ACE) Platform at Ashtown on SRUC's Aberdeen Campus.

Topsoil (0-20 cm depth) from the different pH soils within the original experiment were moved to pre-prepared, 20 cm deep plots at the new site. These were located adjacent to plots in the recipient field which were around pH 6.0, allowing paired sets of target soil pH treatments to be maintained for each cropping bed going forward; one with a 60 year management legacy of targeted soil pH with and another which is now being altered to the same target soil pH over a 2-3 year period. The move also allowed a strengthening of the experimental design, so now the pH treatments are randomized within each cropping block, and different cropping rotations and management regimes, aiming to encompass relevance into the mid-long-term future, have been incorporated. These changes are explored in more detail in the presented material.

Acknowledgment

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P34
Development of an agroforestry LTE in the Netherland
Experimental design and monitoring choices

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ABSTRACT

Intensively managed open croplands are highly productive, but can also have negative environmental side effects. Agroforestry, the combination of woody perennials with arable farming, vegetable cultivation or grassland, can offer multiple ecosystem services, while maintaining economic viability. Therefore, agroforestry can play a major role in future-proofing our farming systems and addressing societal issues. However, research on agroforestry in the Netherlands, especially in combination with Dutch cash crops like potato, onions and carrots, is lacking. Two long-term agroforestry experiments were set up in 2021 on a sandy loam soil at the research facilities of Wageningen University & Research near Lelystad, NL.

The focus is on testing the practical implementation and economic viability of an alley cropping agroforestry system in a Dutch wind sensitive landscape. Effects on ecosystem services like biodiversity, carbon sequestration, microclimate and buffering against extreme weather events are monitored. The main goal was to develop LTEs from which the research outcomes could be valuable for different purposes and target groups.

Because the trade-offs and choices made in the design of the experiments may also be of interest to other researchers (starting with a new LTE's), we want to share and explain the background, design and data collection of the facility. With this, we hope to increase understanding and interest in the trial and also to contribute to well-thought-out designs of agroforestry systems elsewhere.

P35
Modelling the management decisions used for crop selection in a long-term sub-tropical farming systems experiment

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ABSTRACT

The decision of when and what to plant in a particular field is the decision that faces all farmers. For farmers in regions with variable climates and both summer and winter sowing options, such as the subtropical grains regions of eastern Australia, planting the wrong crop at the wrong time can have severe economic consequences, but more importantly influence future economic returns and systems decisions.

The northern farming systems projects are investigating how several modifications to farming systems will impact on performance. This involves assessing various aspects of these systems including Crop intensity – ie. the proportion of time a sequence is in crop, Increased legume frequency – crop choice aims to have every second crop as a legume across the crop sequence, Increased crop diversity – crop choice aims to achieve 50% of crops resistant to root lesion nematodes (preferably 2 in a row), Nutrient supply strategy – by increasing the fertiliser budget to achieve 90% of the water limited yield potential compared to 50%, with the aim of boosting background soil fertility and Using non-crops to build soil resilience –cover crops or ley pastures as part of the cropping rotation.

This range of system modifications have been tested for 8 years across 7 locations spanning from Central Queensland to the central west of NSW. The core experimental site aims to explore the interactions amongst these various modifications. This experiment is comparing 34 different system treatments. In partnership with the experimental sites, simulation models using a purpose-built dynamic manager extends the data beyond the timeframe of the long-term experiment.

P36
A 20-Year retrospective on the Centre for Environmental Farming System large-scale field experiment in the Southeast USA

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ABSTRACT

The farming systems research unit (FSRU) based at CEFS Field Research, Education, and Outreach Facility at Cherry Research Farm in Goldsboro, NC is comprised of 81 hectares that house a long-term, large-scale interdisciplinary study of five different systems: 1) conventional cash cropping using best management practices with no tillage and cover crops or with occasional tillage and no cover crops; 2) integrated crop-livestock system using pasture-crop rotation; 3) organic cash cropping using either legume nitrogen inputs or livestock grazing and manure; 4) silvopasture grazing; and 5) agricultural abandonment with successional plant development. The study was initiated in 1999 and has been continuously managed since then.

In 2022, it was decided that the FRSU would undergo some changes and added treatments to better orient questions relevant to growers in the regio. in the face of changing climate (ex. Silvopasture). This required abandoning treatments that were no longer a functional system (organic no-till). This transition and revitalization allows us to look back on the main findings from the study over the last 20-years from a range of research questions from soil ecology, soil carbon sequestration, forage production, crop productivity and greenhouse gas emission estimates. This is also a period of introspection, examining where the site has been underutilized and how going forward we can build multidisciplinary teams using emerging technologies to better understand fundamental systems questions on agricultural land management in the southeast U.S.

P37
EcoServ: A long-term experiment to assess agroecosystem functions and services along a gradient of functional diversity and soil disturbance

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ABSTRACT

Agroecosystems must provide multiple and diverse ecosystem services beyond the provisioning of food, feed, fibers and energy for a growing global population. Carbon sequestration, biodiversity conservation, regeneration of soil health as well as the management of watersheds, are among the most pressing demands on modern agricultural practices. Such multi-functional agroecosystems can lead to conflicts between individual and collective interests, that can only be resolved if ways are found to simultaneously improve environmental, social and economic sustainability.

To address these challenges, an interdisciplinary long-term experiment was launched in east-central Sweden in 2019. The aim of the experiment is to assess and compare ecosystem functions and services provided by cropping systems along a gradient of crop functional diversity. Recent studies have demonstrated that an increase in crop functional diversity can help to achieve the required multi-functionality of cropping systems (Blesh, 2018; Storkey *et al*., 2015). However, our understanding of the relationship between crop functional diversity and other agroecosystem functions is still very limited (Abalos *et al*., 2019; dos Santos *et al*., 2021).

In this experiment, we paired a gradient of crop functional diversity with two levels of soil disturbance (inversion tillage vs. reduced tillage). The experiment is fully phased with two replicates per treatment combination. Nutrient and pesticide inputs are adjusted at the treatment combination level and based on soil nutrient availability as well as weed, pest and disease infestation levels. Large plots (24 × 36 m) offer the possibility to apply further treatments in the future.

A comprehensive set of data is collected annually, including soil health parameters, nutrient cycling, weed seed bank as well as crop yield and quality parameters. Short-term mesocosm studies complete the data and aim to understand the links between ecosystem functions and the fluxes of carbon, nutrients, water and energy. The experiment will help to identify potential trade-offs between ecosystem functions and to define principles for the design of sustainable cropping systems.

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P38
Design of long-term experiments with perennial crops: Learnings and challenges of 15 years of research in a cacao agroforestry trial

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ABSTRACT

Long-term experiments (LTE) are especially important for perennial and tree crops because they need time until reaching full production. Here we share some learnings and challenges from an LTE in Bolivia comparing different cacao production systems, including agroforestry and organic managed systems[1].

Challenges include the delay until productivity, especially for fruit and timber trees planted with cacao, appropriate plot size of trial plots to represent good agroforestry designs, mortality of trees and difficulties for replanting due to changing light conditions, as well as the limitations set by the initial trial designs. Additionally, the response time of the systems after applying best practises like grafting with better yielding cacao varieties or adapting design or management is very long.

To overcome the limitations of fixed design agroforestry, , initially planting higher shade tree density and diversity and after selecting the most promising ones over time, made the systems more resilient, and it is a good solution to overcome the problem of tree mortality. The main drawback is that it leads to different designs in the replications. Additionally, inclusion of new crops and varieties (grafting) over time and keeping the systems in constant rejuvenation is critical for maximizing positive effects of agroforestry – bearing in mind that for perennial crops such adaptions to the LTE design take several years until they show their implications on systems level. We advocate for transparent communication of systems results including unproductive trees (mortality, freshly grafted or planted), and especially in mixed systems we recommend taking into account the real surface on which data was collected. For reporting results of yields and benefits of different species or varieties, we recommend to take data on individual tree levels in order to extrapolate results depending on different scenarios (i.e. selection of varieties, fruit tree density).

[1]https://systems-comparison.fibl.org/project-sites/bolivia.html

P39
Designing arable cropping systems for multiple benefits: The need for a long-term perspective

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ABSTRACT

The Hutton's Centre for Sustainable Cropping (CSC) and Grieves House Tillage Trial (GH) long-term arable experiments are based on iterative design, implementation and impact assessment, with the goal of achieving multiple environmental and ecological benefits from arable land. The CSC has been running since 2009 as a field-scale comparison of regenerative cropping against standard agronomic practice over multiple six-year rotations. The regenerative system integrates reduced tillage, organic matter amendments, cover and companion cropping, threshold levels, targeted applications and nutrient budgeting to reduce reliance on chemical interventions by promoting soil health, plant fitness and biodiversity. This is compared in a split-field design with a conventional ploughed system with blanket applications and prescriptive, prophylactic treatments. Replication is year-on-year, but large field sizes allow commercially realistic estimates of costs and benefits. GH was established in 2017 and complements the CSC by focusing specifically on soil biophysical properties and yields under spring versus winter rotations (including cover cropping) and no-till versus conventional plough systems. Smaller plot sizes at GH allow full within-year replication and a separation of the effects of each management treatment. Trends in systems indicators (soil properties, biodiversity, crop quality and economics) are used to review how well the sustainability objectives are met and guide further improvements in system design. Initial trade-offs between enhancing biodiversity, soil health and crop yield in the early stages of conversion from intensive to regenerative cropping appear to become less over time and the length and nature of this transition phase highlights the importance of long-term experiments in agroecological research. Short-term studies can over-emphasise trade-offs between environment (e.g. biodiversity) and economics (e.g. crop yield) due to a focus on changes at the early stages of transition. In the long-term, there can be a positive association between these apparently conflicting goals, particularly where soil, plant and invertebrate biodiversity is actively used to stabilise yield and reduce risk from perturbation.

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P40
A decade of on-farm diversified cropping yield feeble SOC gains in central Malawi

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ABSTRACT

Crop diversification with grain legumes has been advocated as a means to increase agroecological resilience, diversify livelihoods, boost household nutrition, and enhance soil health and fertility in cereal-based cropping systems in sub-Saharan Africa. Soil organic carbon (SOC) is a primary indicator of soil health and there is limited data regarding SOC gains and grain legume diversification on smallholder farms where soils are often marginal and crop residues are rarely incorporated in soils. We established on farm trials in high, medium and low agroecological potential zones of central Malawi during the 2012 cropping season. Treatments included unfertilized maize, maize+NPK, soyabean or groundnut-maize rotation, maize/pigeonpea intercrop and groundnut/pigeonpea intercrop rotated with maize. In line with the predominant farming system, crop residues were left to be grazed by livestock after each harvest.

After 10 years and 10 cropping cycles, we measured SOC in bulk soils for the entire sampled soil profiles to 1.05 m depth in 15 cm increments, and POXC in the 0-15 cm and 15-30 cm horizons only. The unfertilized maize had significantly lower SOC, but only for 0-15 cm layer, at 1.11% C compared to a maximum of 1.33% C when soyabean was rotated with maize. The rest of the treatments had similar SOC contents for the entire horizon. Unfertilized maize had significantly less POXC content for the 0-15 cm layer, at 390 mg l^{-1}, compared to at least 455 mg l^{-1} for the rest of the treatments, proving evidence of the usefulness of good agronomy and nutrient management. However, these results generally suggest limited potential for SOC sequestration in low input systems on smallholder farms in Africa where crop residues are often taken off the field at harvest or are consumed by livestock during the post-harvest period, and soils are annually tilled.

P41
How can be managed the organic matter content of acidic sandy soil?

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ABSTRACT

There are about 2 million ha of sandy soils in Hungary from which about 430.000 ha of acidic sand can be found in the Nyírség region. The main problems of these soils are the low pH values, organic matter (OM) and clay content. Traditional OM supply (farmyard manure - FYM, rye straw manure, green manure) is studied in the 94 years old Westsik's crop rotation long-term experiment (LTE) while in the sewage sludge compost (SSC) LTE the regular use of a treated waste material has been studied from 20 years. The OM addition is essential for maintaining the fertility of soils in conventional agricultural management with ploughing. The results of our LTEs revealed that the complex OMs like FYM or SSC could stabilize the humus content of sandy soil at a higher rate depending on the doses applied. However, there are yearly variations in the humus content of soil, mainly in the SSC treatment, but the OM treated plots have always higher humus content compared to the control ones. Favourable effects of OM addition can be realized in better nutrient supply with higher crop yield, more favourable soil physical parameters and, more intensive microbial activity of soil.

In the changing climate the OM content of soils could be the key factor for the food production. Different OMs (wastes and by-products) are very valuable materials and they re-use in agricultural lands could help us to maintain the safe food production in a good quality in the changing environmental conditions.

P42
N, P and C storage, and N and P leaching in cropping systems with cover crops and pig slurry amendments

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ABSTRACT

The first experiment at the Mellby field (sandy loam) was constructed in 1982 to study nutrient leaching from treatments with manure applications and cover crops. The field data and soil have been used for numerous studies since then. Here we highlight three findings from finished and on-going studies.

Phosphorus leaching from pig slurry applications, direct versus long-term effect
Top-soil from treatments with 30-year applications of pig slurry at different rates was collected in soil columns for a leaching study, where all treatments were exposed to artificial rain events before and after a single application of pig slurry. The legacy effects from historical applications of pig slurry were more important for the P losses than the single application (Liu J *et al*., 2012). This confirms the importance of adapting P applications in order to avoid accumulation of P in the soil.

N mineralization, storage and leaching in spring cereals with cover crops
The results from the Mellby experiment guided the introduction of subsidy systems for cover crops in Sweden. Undersown perennial ryegrass grown until spring reduced N leaching by an average 43% compared with soil ploughed in autumn (Aronsson H *et al*., 2016). Long-term effects and future scenarios for N mineralization, leaching and storage are currently studied in a PhD project with the COUP model (Villa Solis *et al*., 2022).

Cover crop effects on C storage in the soil
Investigations on C stocks at Mellby revealed significant increases in soil C storage after two decades with undersown ryegrass cover crops (320 kg C ha^{-1} yr^{-1}; Poeplau *et al*., 2015). A follow up of the earlier study with soil sampling is ongoing.

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P43
Effect of plough on CO_2 fluxes from temperate grazed pastures on the North Wyke Farm Platform

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ABSTRACT

Grasslands represent one of the most extensive ecosystems globally, occupying ~25% of the Earth's ice-free land surface, mainly used for forage and livestock production and are considered to contribute significantly to carbon (C) sequestration and increased biodiversity particularly in grazing systems. Cultivation of grassland to produce arable crops can be harmful to the environment due to soil and nutrient losses, loss of soil fertility and biodiversity.

In this study we evaluated pasture management interventions at the Rothamsted Research North Wyke Farm Platform (NWFP, Orr *et al*., 2016), under commercial farming management, over two years (2017-2018) and considered their impact on net CO_2 exchange. We measured the fluxes using Eddy Covariance towers at about 1.6 m high until the plough, that were then raised to 2.7 m. We also assessed the effect of plough on net emissions as one of the three NWFP farmlets was converted to grow arable crops in 2019. We investigated in three farmlets: i) if the permanent pasture system (PP) is, in the short-term, a net sink for CO_2, ii) whether reseeding this with deep-rooting, high-sugar grass (HS) or a mix of high-sugar grass and clover (HSC) might increase the net removal of atmospheric CO_2, iii) the effect of plough on CO_2 emissions.

The baseline emissions (pre-plough) for PP, HS and HSC were 0.76, -0.91, 8.02 t CO_2 ha^{-1}, respectively (Cardenas *et al*., 2022). It was concluded that in the short-term, the reseeding of these pastures did not result in a sink of CO_2 and that it is more likely that the seasonal and inter annual variability are more important factors affecting the net fluxes. After HS was ploughed in 2019, CO_2 emissions from this farmlet increased by a factor of four compared to baseline emissions, and emissions from PP and HSC for the same period.

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P44
Depletion of soil organic carbon and porosity after only two arable harvests decreased nitrogen use efficiency

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ABSTRACT

Land-use and management changes can result in soil organic carbon (SOC) depletion, loss of soil structure, an increase in greenhouses emissions, and, in general, altered soil functions. This study aimed to assess soil structure and biological functions associations and the role of carbon fluxes as the result of changes in farming management. It was carried out on three fields of the North Wyke Farm Platform (NWFP) under different agricultural systems: permanent pasture (unploughed for at least 20 years), improved pasture (ploughed and reseeded in 2013 and 2017), and arable land (converted from improved pasture to arable in 2019, harvested, ploughed and sown with wheat in 2020 and 2021). For this purpose, we used (a) long-term existing data from the NWFP (Orr *et al*., 2016) to investigate trends over time in SOC, and (b) new measurements obtained in 2021 to determine SOC, soil porosity (by X-Ray Computed Tomography), soil water retention curves, microbiome genotype and phenotype (by metagenomics and PLFA analysis), and gas emissions (by automatic and static chambers).

We found that, as a result of the management, the arable field showed a negative trend in SOC dynamics, a reduction in SOC (% and stocks) and in soil pores, and a lower capacity to retain water compared to the permanent pasture. Gram-negative bacteria were more abundant in arable soils and saprotrophic fungi was more abundant in improved pasture soils. The % of nitrogen loss from May 2021 to November 2021 was 1.89×10^{-5} and 12.22×10^{-5} for the permanent pasture and the arable field, respectively. In summary, we identified altered soil multifunctionality with consequences for carbon sequestration, water resilience and atmospheric emissions only after two harvest events.

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P45
Long-term effect of tillage practices on soil carbon in the Mediterranean area of South Africa

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ABSTRACT

Traditional conventional cropping practices have contributed to increased carbon emissions and loss of soil organic carbon (SOC). Reduced tillage has been promoted as part of Conservation Agriculture (CA) principles to save costs, reduce fossil fuel consumption, and combat soil erosion as well as other negative impacts on soil health caused by tillage practices.

A long-term trial was established in 2007 on shale-derived sandy loam soil with a high stone content at Langgewens Research Farm (33˚16’34” S, 18˚45’51” E; altitiude191 m). The farm has a Mediterranean climate with wet, cool winters and dry, hot summers. The trial consists of 4 tillage practices: zero tillage (ZT), minimum tillage (MT), no-tillage (NT) and conventional tillage (CT) in a combination of different crop rotations.

After 14 years, the SOC in the 0-15 cm layer was compared between the 4 tillage practices over all the rotation systems. SOC is naturally very low in South Africa. Initially, the soil had a SOC of 0.98 %. After no-tillage (NT), using a no-till tine planter, for 14 years the soil organic C increased to 1.43%, significantly higher than all other tillage systems included in the study. In the ZT, using a disc planter, the SOC increased to 1.32 %. In the MT system, SOC also increased (1.21%) even when the soil was scarified before planting followed by planting using a no-till tine planter. In the soil under CT, where the soil was tine tilled followed by ploughing with a mouldboard plough, SOC decreased to 0.88%.

With the exception of ZT, the study showed that SOC decreased as the degree of soil disturbance increased. The higher SOC in the topsoil, may be due to reduced soil disturbance and retention of crop residues. This proves that a cropping system with reduced soil disturbance can build SOC in a dry Mediterranean climate as was the situation at Langgewens.

P46
Using LTE data to map soil carbon loss and gain on different land treatments and its implications for rewilding

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ABSTRACT

Agricultural land across the globe has seen widespread declines in soil carbon. This is echoed with declines in biodiversity, which is also observed in numerous other ecosystems. In these other, more natural, ecosystems, rewilding has been put forward as a mechanism for restoration, but empirical data on rewilding is scarce. The long-term soil organic carbon (SOC) measurements from the Broadbalk and Geescroft wildernesses provide a unique resource of empirical data on passively rewilded former arable land. We combined SOC measurements from the Broadbalk and Geescroft wildernesses with SOC measurements from 6 other agricultural long term experiments at Rothamsted to determine and compare timescales of SOC loss and gain, and determine if differences exist between treatment types. Our findings clearly demonstrate that SOC is gained approximately three times slower than it is lost. We also found differences between treatment types, with the conversion of cropland to passively rewilded forest leading to accumulation of SOC significantly faster than cropland to grassland or cropland to cropland treatments. Converting grassland to bare fallow also leads to a faster loss of SOC than converting grassland to cropland, which in turn leads to a faster loss than cropland-cropland treatments.

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P47
Soil organic carbon pools as early indicators for soil organic matter stock changes under different tillage practices in inland Pacific Northwest

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ABSTRACT

Soil organic carbon (SOC) is essential for sustaining soil and crop productivity. However, changes in SOC stocks in response to agronomic practices manifest slowly. Identifying early indicators of SOC dynamics will allow early management decisions and quick remedial action. We evaluated long-term effects of tillage intensity and timing on SOC pools to determine the most sensitive SOC pools to tillage practice. Soil from a 53-old winter wheat (*Triticum aestivum* L.)-spring pea (*Pisum sativum* L.) rotation(WP-SP) experiment and undisturbed grass pasture (GP) in inland Pacific Northwest (iPNW) was sampled to evaluate the effect of four tillage systems [no-till (NT), disk/chisel (DT/CT), spring plow (SP), and fall plow (FP)] on SOC, total nitrogen (TN), particulate organic matter carbon (POM-C) and nitrogen (POM-N), permanganate oxidizable carbon (POXC), water extractable organic carbon (WEOC), total dissolved nitrogen (TDN), KCl-extractable nitrogen (KEN), microbial biomass carbon (MBC) and nitrogen (MBN), basal respiration (BR), carbon mineralization (Cmin), and metabolic quotient (qCO2). SOC was higher in GP than in cultivated treatments. Tillage decreased SOC and TN by 28 and 26%, respectively, compared to GP. Among the cultivated soils, tillage did not affect SOC and TN, except for DT/CT, which had slightly higher SOC than FP (P = 0.08). On the contrary, NT and DT/CT significantly (P < 0.05) increased levels of POM-C, POM-N, POXC, WEOC, MBC, BR, Cmin, and qCO2 over FP or SP. However, tillage did not affect TDN, MBN, and KEN. The C-pools were more strongly correlated with SOM than the N-pools, with an exception to POM-N. Under the WP-SP rotation, reduced tillage systems (NTand DT/CT) have the potential to maintain or increase SOM, which can be assessed early through its physical (POM), chemical (POXC, WEOC), and microbiological (MBC, BR, Cmin) indicators. POXC and WEOC were the most sensitive indicators of tillage-induced changes in SOM dynamics.

P48
Soil organic carbon and nitrogen cycling in an arable crop rotation in Flanders, Belgium, after 25 years of vegetable, fruit and garden waste compost application

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ABSTRACT

The effect of 25 years compost addition on the soil organic carbon (SOC) and nitrogen (N) dynamics was investigated in an arable crop rotation. A complete randomised block trial started in 1997 in a loamy soil, with an unfertilised and an only-mineral N fertilized control and with compost added at 3 doses and 3 rates. Three fallow (sub)plots are present, with and without compost. The initial SOC was 0.9 % and soil pH was 6. Initially, no mineral N was added to the compost plots, later, the required N was compensated with compost N between 8 and 100%, on average 45%. Without compost addition, the SOC decreased with 0.012–0.014 % of SOC per year. After 25 years, the cumulative C addition from compost ranged 25 to 200 ton C ha^{-1}. Compared to the only-mineral N control, the SOC increased with 0.0059 % of SOC per ton C ha^{-1} applied, with no plateau observed, indicating that the C-saturation level of the soil to protect organic matter is not reached. Compared to the unfertilized fallow, the SOC increased with 0.004 % of SOC per ton C ha^{-1} applied in the fallow plots. This resulted in the highest compost addition treatment to an increase of 0.4% SOC due to presence of the crop, while in the only mineral N- fertilized treatment, roots and crop residues were not sufficient to maintain SOC. This is not related to difference in crop yields, as the crop yields of the compost treatments are usually not different from the mineral N treatment. The soil N residue in the top 90 cm soil, measured just before winter, of the compost treatments could be up to 3-fold higher compared to the only-mineral N fertilized treatment. The relative soil N residue increased with increasing cumulative compost addition, however only significantly for the highest compost addition.

P49
Perennial cropping systems increased soil C and N stocks over annual systems – a nine-year field study

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ABSTRACT

Pursuing high biomass yield while enhancing soil carbon (C) sequestration is a key aim of climate-smart cropping system, and perennialization may contribute to this goal. Long-term continuous field-based observations may provide reliable results to evaluate the biomass yield and effects on soil C stock in cropping systems. In this study, based on a nine-year field experiment in central Denmark established in 2012, we examined biomass yield, yield stability, and the changes in soil C and nitrogen (N) stock among two annual cropping systems (triticale and maize) and three perennial systems (miscanthus, tall fescue, and legume-grass mixture). Our results showed that perennial cropping systems did not in all cases have significantly higher biomass yield and yield stability over annual cropping systems. This finding challenges the conclusion based on the initial five years where perennial crop significantly increased biomass yield and yield stability compared to annual crops (Chen *et al.*, 2022). Across three perennial systems, topsoil (0-20 cm) C stocks increased by 4.8% (1.6 Mg C ha^{-1}) and 0-1 m C stocks increased by 10.8% (6.8 Mg C ha^{-1}) over the nine years. As a contrast, topsoil C stocks were reduced by 9.9% (3.4 Mg C ha^{-1}) across the two annual cropping systems, while their 0-1 m C stocks showed little changes. Topsoil N stocks declined by 3.0% (79.3 kg N ha^{-1}) in annual systems while increased by 6.8% (181.6 kg N ha^{-1}) in perennial systems. Soil 0-1 m N stocks increased in all fertilized systems. In general, both perennial and annual systems can obtain high biomass yield and yield stability, but perennial crops could accrual more C. Our results highlight the significance of long-term observation in agronomical studies and indicate that perennialization is an option for climate-smart cropping system.

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P50
Soil response to eight different fertilisation schemes - results from a long term (55 years) field experiment

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ABSTRACT

Long-term field experiments (LTEs) are rare, but a pre-requisite to understand changes in pH, humus and organic carbon dynamics in the soil (SOC). This trial was initiated in 1968, approved by DFG and comprises eight fertiliser trials for fruit trees at Klein-Altendorf. This is the experimental farm of the University of Bonn (50ºN), Germany with *ca*. 600 mm annual precipitation and 9.6ºC and a fertile luvisol on loess, a climate similar to Southern England.

Both the grass mulch from the alleyways and the prunings remain in the orchard. The four treatments of 40 trees each were 1) control trees without fertilisation. 2) lime (1 t CaO ha^{-1} 10 years to stabilise the pH near the optimum for stone fruit. 3) lime as above plus organic fertiliser, and 4) lime with inorganic NPK – on the herbicide strip.

Results after 55 years were:

1. Control apple and cherry trees without fertilisation grew well without nutrient deficiency symptoms or any yield depression.
2. lime (1 t CaO ha^{-1} 10 years) increased soil pH from pH 6.3 to pH 6.7, whereas the pH in the un-fertilised plot dropped to pH 5.7–5.9, thereby confirming the proposed *slow soil acidification* in the herbicide strip reported in the literature.
3. lime as above plus *organic* fertiliser (3 t DM pig manure ha^{-1}) in the first two decades and then certified green compost (10 t DM ha^{-1} a^{-1}) in the last 12 years increased humus and nitrogen mobilisation in spring;
4. lime as above plus *inorganic* NPK fertiliser (40 kg N ha^{-1} $year^{-1}$) increased both pH and soil nutrient content;
5. lime as above plus *organic fertiliser* accumulated the largest total nitrogen (Nt) with the largest nitrogen mineralisation (28–55 kg $Nmin^{-1}$ ha^{-1}) in spring, double that of the other plots (18-28 kg $Nmin^{-1}$ ha^{-1}) primarily as NO_3 and, to a lesser extent, as NH_3.
6. lime plus organic fertiliser increased the humus content by *ca.* 2.5 fold from 1.8% (in 1968) to 4.3% (in 2021) indicating an annual rate of 0.028% SOC $year^{-1}$ and a potential for *carbon sequestration*, at a rate of 0.7 t CO_2 ha^{-1} $year^{-1}$, if organic matter was regularly supplied.

Conclusion

Tillage-free fertile soils, particularly fruit orchards, offer the possibility of carbon sequestration, if organic matter with limited nutrients (plus lime) is regularly applied at a moderate rate (<10 t DM ha^{-1} a^{-1}).

P51
Long-term changes in soil characteristics and ley yields on an organic dairy farm in Norway

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ABSTRACT

Organic milk production was established at Tingvoll experimental farm in 1989, replacing the previous conventional sheep production. Since then, soil nutrient supply has been manure from its own herd, biological nitrogen fixation and liming. Soil samples for concentrations of nutrients and soil organic matter (SOM) have been taken every 5–7-year intervals since 1990, and grass-clover yields have been annually measured since 1991. Overall, changes in SOM concentration and nutrient content in the topsoil (0-20 cm) were greater than in the subsoil (20-40 cm). In the topsoil, in the cultivated areas, SOM concentration and plant-available phosphorus (P-AL), calcium (Ca-AL) and magnesium (Mg-AL), were lower in 2021 than 1991. Potassium (K-AL) content has increased from 1991 to 2021. In permanent pastures, the SOM concentrations were higher than in cultivated areas. Overall, decrease in SOM and soil fertility may be related to the land use change, high initial contents, soil drainage, and climate change. The average air temperature in the growing season has increased about 0.05° C per year during the 30-year period, and three cuts of the ley instead of two cuts per year became more often. The yield of the first cut of the ley has slightly decreased since 1991, but the quality of the ley and the proportion of grass and clover has been stable until the fifth production year within each crop rotation.

ASSOCIATION OF APPLIED BIOLOGISTS
CROPPING AND THE ENVIRONMENT

Posters: Innovative Methods

P52
Can conservation agriculture principles mitigate greenhouse gas emissions? A scoping review and meta-analyses

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ABSTRACT

A comprehensive literature search was conducted to review evidence on the effect of conservation agriculture principles on greenhouse gas (GHG, nitrous oxide–N_2O, carbon dioxide–CO_2, methane–CH_4) emissions. Over three thousand (N=3,452) papers were retrieved from Web of Science (1984–2022). Relevant papers (N=451; excluding overlaps) reported at least two of the three principles of conservation agriculture: 1. A form of conservation tillage (N=112); 2. Ground cover (N=146); 3. Crop diversification (N=55). Fertiliser management strategy (N=161) was included as an additional principle as proposed by Vanlauwe *et al*. (2014). Control treatments included conventional tillage, zero mulch, monocropping and standard mineral nitrogen fertiliser application. We considered the relative strength of the evidence using the following descriptive categories: >66% of studies = "Good evidence"; 33–66% = "Some evidence"; <33% = "Little/no evidence". Based on this scale, there was good evidence (67%) that "conservation" tillage practices reduce GHG emissions

possibly due to reduced mineralisation and gas diffusion (Cooper *et al*., 2021). There is some available evidence that fertiliser management strategy (45%) and ground cover (35%) reduce GHG emissions. A meta-analysis on crop rotation effects on GHG emissions (N=55) is currently in progress. Our study demonstrates the continued importance of field experiments, particularly long-term experiments (LTEs), and how data can be pooled to investigate global challenges. This review is part of the wider project under the EJP soils programme–CropGas, in which GHG emissions will be measured in several locations, including LTEs, adding new data to this dataset.

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P53
EJP soil CropGas project: The effect of conservation agriculture interventions on greenhouse gas emissions

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ABSTRACT

Conservation agriculture (CA) is a mitigation strategy to address climate change as it may increase the resilience of crop yields and improves soil structure and health under fast changing climatic conditions. Avoiding soil disturbance during tillage increases soil organic matter, which will affect greenhouse gas emissions (GHGs) compared to those systems under conventional tillage. The CropGas project aims to provide evidence of the effect of tillage on the GHG budget, and to develop country-specific emission factors, data resources and modelling tools for analysing the impacts of CA activities. To achieve this, a consortium of experts from seven counties, three in European and four in sub-Sahara African countries, are working together on field experimentation, method development and training, literature review (results reported in this conference by Manzeke-Kangara et al.), data analysis and modelling. Emissions of GHGs are being monitored in the following long-term experimental sites with undergoing crop rotations: Large-Scale Rotation Experiment (UK), Lyons Research Farm (Ireland), Brody Research Station (Poland), Chitedze Agriculture Research Station (Malawi), Domboshawa Training Centre (Zimbabwe), Liempe Farm (Zambia), and Kenilworth experimental farm (South Africa). Within each site, experimental plots were selected to study the effect of soil management (conventional

P54
Greenhouse gas emissions from the Large Scale Rotation Experiment: Metric options

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ABSTRACT

The Large Scale Rotation Experiment was established in 2018 at the Rothamsted Research Harpenden site. The experiment aims to test the effect of conservation agriculture: plough *vs*. zero till; three contrasting rotations (each phase present every year in each cultivation regime); and the presence of compost and cover crops, on several interacting parameters. Productivity and environmental impact are being assessed every year in a three-year rotation aiming at short-term economic return, a five-year rotation with a greater diversity of crops (including cover crops) and a seven-year rotation designed for increased environmental sustainability (also including cover crops and a two-year ley). In 2019, greenhouse gas (GHG) emissions (nitrous oxide (N_2O), carbon dioxide from soil respiration (CO_2) and methane (CH_4)) were measured between 26thMarch and 28th November 2019 in twelve plots under different tillage management and no organic materials additions. The static chamber was the methodology used (Chadwick *et al*., 2014). Soil parameters and the resulting crop yields from each plot were also measured during this period.

We aim to do an integrated study where all the greenhouse gases are assessed. We will also use different metrics to express emissions: the annual cumulative emissions per surface area; and total emissions expressed per ton of harvested crop. The choice of metric will depend on the purpose, whether it is to report emissions complying with IPCC methodology, or to assess the efficiency of the system.

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tillage versus no tillage) and fertilization (N application versus no-N application) on GHG emissions. Static chambers are be used to monitor GHGs, and this data will be supported by data from soil sensors monitoring changes in soil physical properties.

We expect to observe significant temporal and spatial variations on the resulting GHG emissions between soils under different tillage practices as well as significant differences in soil composition, structure and crop behaviour when comparing both types of soil management.

P55
Simulation of the effect of soil compaction on wheat, barley and winter bean yield using DSSAT

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ABSTRACT

Soil compaction causes changes in soil characteristics (e.g., decreased water infiltration rates and air permeability, increased mechanical resistance for roots) that negatively affect crop growth and yield. A measurable characteristic that can be used to quantify soil compaction is bulk density, which is increased in compacted soil due to the denser arrangement of particles and the compression of pores between them. Soil bulk density is one of the inputs to the DSSAT crop modelling framework, hence the possibility to use DSSAT to simulate the effect of soil compaction on crops. While there has been a vast number of field studies into the effect of soil compaction on crop growth and yield, crop modelling (using frameworks like DSSAT or APSIM) is a promising, lower-cost approach, alternative or complementary to field studies. However, there is a need to verify the model results based on field data.

We have attempted to validate the DSSAT model accuracy in the context of soil compaction based on soil and crop data from a long-term (10 years as of 2023) controlled traffic experiment at Harper Adams University, Shropshire, UK. The researched crops were: winter and spring wheat, winter barley and winter bean. A series of crop simulations with DSSAT was run with soil bulk density as an independent factor. The modelled crop yields were compared to real yield data from the site, and the model accuracy has been assessed.

P56
The challenge of soil sampling in a long-term agricultural trial with permanent crops and agroforestry systems

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ABSTRACT

In agricultural trials, often only pooled samples are taken, which reflect the homogeneity of the cultivated sites. On a non-arable experimental plot with permanent crops, especially in agroforestry systems, the soil sampling design is much more challenging. In order to get an indication of the significance of pooled samples for a heterogeneous agroforestry site, pooled and individual soil samples were compared statistically.

Comparisons between pooled and single samples were made using 36 soil samples taken in a regular grid on four 24 × 24 m plots with a soil auger. The pooled samples were generated from the 36 single samples. Both the single samples and pooled samples were analysed for soil chemical properties.

Single samples were statistically compared with the pooled samples by using the equivalence test. In addition, it was determined which sample size is required for a hypothetical second sampling, so that it differs only on a tolerable level from the initial sampling.

The results of the equivalence tests showed that the composite samples are only representative with limitations for the plots. These limitations are especially the case for plant-available and easily mobilisable soil parameters like carbon, nitrogen and phosphorus. The statistical calculations of the sample size prove the small-scale variability of these soil nutrients.

This results in either an increase of the sample size or the analysis of single samples to obtain representative results. An analysis of individual samples should be carried out especially when small-scale and temporal changes in ecosystems with high diversity are concerned.

Based on these results, the sampling design for further studies was modified to take into account different conditions like fertilizing and pruning residues in the agroforestry systems. Samples were taken at a distance of 0.5 m from cacao trees (main crop) and at a distance of 2 m from the cacao tree (intermediate rows).

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Session Six: Soil Health

P57
Leveraging 132 years of Continuous Research at Sanborn Field to Understand Soil Health

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ABSTRACT

Sanborn Field, established in 1888, is the 3rd oldest continuous research site in world. The 40 experimental plots focus on crop rotation, crop species, and fertility inputs with 15 plots relatively unchanged for the past 135 years. Approximately every 25 years beginning in 1915, four 1.2 m soil cores are taken from each plot and divided into fixed, 10 cm increments. Historically, sample analysis focused on basic soil fertility measurements. More recently, samples from the upper 7.5 cm indicated that soil health indicators were greater in monoculture wheat compared to monoculture corn or soybean and were greater with manure inputs compared with no fertilizer or commercial fertilizers. For example, water stable aggregate stability (WSA) was 280 mg g^{-1} for continuous wheat with manure, 220 mg g^{-1} for continuous wheat no fertilizer inputs, 210 mg g^{-1} for continuous corn with manure, and only 80 mg g-1 for continuous corn with no fertilizer inputs. In addition, WSA was 290 mg g^{-1} in a corn-wheat-red clover rotation with manure versus 130 mg g^{-1} with commercial fertilizer. However, WSA values were reduced to 220 mg g^{-1} when soybean replaced red clover in the rotation with manure and was unchanged in the commercial fertilizer treatment. Manure treatments also demonstrated greater total organic carbon, active carbon, total nitrogen, and microbial biomass relative to commercial fertilizer treatments; however, the effect of crop rotation on these soil health indicators was minimal. To further investigate the effects of long-term management on soil health indicators through the soil profile, soil cores were collected in 2020 and divided by horizon. Laboratory analyses for a suite of biological, physical, and chemical soil health indicators is underway and the results will be presented.

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P58
The role of cultivations and rotations in building resilient farming systems in a long running UK field experiment

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ABSTRACT

The STAR project (Sustainability Trial in Arable Rotations) is a long-term field study at Stanaway Farm, Otley, Suffolk, UK on a Beccles/Hanslope Series (heavy) clay soil. Research is delivered through NIAB, supported by The Morley Agricultural Foundation (and historically The Felix Thornley Cobbold Trust and the Chadacre Agricultural Trust) and guided by an independent steering group. The aim of this long running experiment is to examine different cultivation and rotational systems for sustainable arable production (further described in Morris *et al*., 2018). This paper presents findings on the impact of soil tillage on soil physical properties over 13 years (2006-2019) and examines how changes in soil structure and pore continuity may impact on winter wheat productivity. Findings showed that long- term use of seasonal cover cropping combined with non-inversion cultivation at shallow depth resulted in lower penetration resistance and increased soil moisture. The increased moisture persisted later into the season compared to the control. Non-inversion cultivation at shallow depth provided the most significant benefits to soil water retention, root morphology and pore characteristics as measured by X-ray CT.

P59
Long-term slurry inputs increase soil Cu concentrations and raise the risk of earthworm community decline in a Northern Irish grassland soil

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ABSTRACT

A long-term grassland experiment established in 1970 at Hillsborough, Northern Ireland, UK. Originally the site was sown as a perennial ryegrass sward. The experimental design is factorial with two factors. There are eight nutrient treatments which are comprised of two slurry types (cow and pig) x 3 slurry rates (Low, Medium and High), an unfertilised control, and an inorganic fertiliser treatment. In 2019 half of the plots were re-seeded with a multi-species mixture. Each treatment factor combination is replicated three times. The aim of the study was to investigate the effect of slurry inputs on earthworms. The objectives were: (i) how do slurry inputs effect soil Cu and Zn concentrations? (ii) what are the effects of slurry inputs on earthworm communities? (iii) is there a relationship between soil Cu and Zn concentrations and the earthworm communities? In 2021 all treatment plots were observed for soil Cu and Zn (EDTA) and for earthworm communities in the month of October. The control plots had <5 mg kg^{-1} of Cu compared to >150 mg kg^{-1} in the high cow slurry treatment. The high pig slurry treatment had a Cu concentration of 40-50 mg kg^{-1}. Observations of earthworms showed that there was significant decrease in earthworm biomass under cow slurry treatments compared to pig slurry and the inorganic fertiliser treatment. An historical evaluation was undertaken on previous observations. Between 2003 and 2006 earthworm communities were found in greater biomass under cow slurry treatments compared to pig slurry. Analysis of soil Cu concentration for the high cow slurry treatment in 2005 was significantly reduced compared to 2021 and had a mean concentration of <10 mg kg^{-1}. The observations of earthworm communities and soil Cu suggest that heavy applications of cow slurry have had a significant negative impact. This has implications for sustainable grassland management.

P60
Ecosystem Resilience: A variational approach applied to some of the Rothamsted Long-Term Experiments

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ABSTRACT

Resilience can be a difficult concept to define in a quantitative manner (Todman *et al*., 2016). For this reason, resilience is sometimes related to an assay of functioning such as respiration or assumed to be represented by an indicator such as the soil organic matter content. Here we explore the idea that it emerges from the action of a *potential* or *capacity* to recover. Viewed in this way, resilience is not simply the capacity itself (as an approach based on a simple assay or an indicator might imply) but also a continuous process that restores and maintains that capacity.

The Highfield ley-arable experiment and associated fallow plot at Rothamsted began in 1949 (fallow, 1959) and compares soils under long-term grass and arable cropping alongside 3-year leys. In addition, reversion plots begun in 2008, examine more recent transitions from arable to grass and vice versa. Respiration was measured on soils taken from these plots with and without the addition of barley powder (Todman *et al*., 2018). Soil samples were then stressed by drying and re- wetting and the respiration measured once more. In all, 12 such stress cycles were carried out and the effect on respiration measured after 6 of the cycles as well as initially.

We analysed the integral of the differences between respiration from stressed and unstressed soils during the whole of each assay and found that stressed grassland soils returned to baseline functioning more quickly than the other soils. Soils became partly acclimated to the stress during the sequence of 12 dry-wet cycles. Our results lend weight to the idea that well-functioning, undisturbed soils such as grasslands are more resilient than disturbed soils with little or no annual inputs of organic matter (arable or fallow).

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P61
Transforming green waste into precious biochar: An organic soil amendment source

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ABSTRACT

Biochar has a potential of mitigating climate change and soil quality improvement through sequestering C into soils and lowering greenhouse gas emissions. It has been demonstrated that the application of biochar can rapidly improve the soil carbon pool and at large soil health. Soil supplemented with biochar has shown increased organic matter and pH, but lower EC and absorbed Na+ characteristics. Globally, large amounts of agricultural and urban green waste is either buried into landfills or burned to ash that have serious environmental consequences. The conversion of this green waste into valued biochar may help to redirect waste away from the landfills or open burning and is a long-term strategy for carbon sequestration in the soil. However, the concentration of carbon, organic matter and nutrients vary with the plant feedstock material and species. Therefore, studies were carried out on four green waste feedstock materials obtained from date palm, *Prosopis juliflora*, wheat straw, and turf grass clippings. These feedstocks were transformed into biochar through pyrolysis and were used as a soil amendment to observe its impact on soil properties and plant growth attributes of cucumber and okra plants. Results showed improved soil electrical conductivity, pH, organic matter, and soil water holding capacity with the application of biochar. The results also revealed that the soil supplemented with biochar enriched the soil mineral contents e.g. iron, sodium, potassium, calcium, magnesium, manganese, zinc, and boron. Soil added with biochar showed increased plant growth and yield traits of cucumber and okra at low concentrations of biochar. Further, among the contrasting four-feedstock plant materials, *Prosopis juliflora* showed the best feedstock that improved the soil health and crop productivity compared to other feedstocks.

Key words: Biochar; bioremediation; feedstock; carbon sequestration, soil organic matter

P62
Effect of treated wastewater irrigation on heavy metals accumulation in fruit trees

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ABSTRACT

Acute water shortage is an important global concern because of ever-changing climate patterns and growing population. Worldwide, available freshwater resources are exhausting rapidly and it is imperative to devise alternate means of irrigation approaches to save the fresh water particularly in water-limited areas for sustained crop production. Oman is ranked among the water-stressed countries because of limited annual precipitation (<100 m) and minimal fresh water recharge. The sustainability of the freshwater resources is under extreme stress unless the pressure on aquifers is not minimized. Likewise, other nations Oman aims to use the treated wastewater to reduce the water shortage in the agricultural sector and harvest the benefits from this alternate source, especially wastewater that carrying added amounts of nutrients too. Although, the use of treated wastewater is still not common because it may be contaminated with heavy metals that can harm the plants and human health.

Therefore, studies were conducted to investigate the possible impact of treated wastewater on the accumulation of heavy metals in fully-grown fruit trees and soil. Mulberry and Ziziphus leaves, fruits and soil samples were collected from the contrasting locations of the Agricultural Experiment Station fruit orchard being irrigated with treated wastewater or groundwater. The heavy metal contents were analyzed by ICP instrument and data were tested statistically by two-way ANOVA method using R studio software. Results exhibited higher levels of heavy metals than FAO recommendation in the soil but the levels did not show toxicity to the plants irrigated with both water sources. Moreover, trees that irrigated with treated wastewater showed higher levels of Born (B) than the Omani standards but still it did not show any stressful effects on the fruit trees. Largely, the heavy metal levels were within the Omani standards in the mulberry and ziziphus fruit trees that were irrigated with groundwater or treated wastewater. Overall, this study showed that the treated wastewater carries a potential to be used as an alternate irrigation source. However, we suggest extending the investigations for a longer period to other crops to examine heavy metals buildup in plants and soil.

Key words: Mulberry, ziziphus, heavy metals stress, soil toxicity, icp

P63
Long-term field experiments in Water quality management, Sweden

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ABSTRACT

The long-term field experiments in water quality evaluates how nutrient management, crop sequence and other practices affect nutrient leaching, mainly of nitrogen and phosphorus. The oldest experiment started in 1984 and the experiments are financed by SLU´s program for long-term experiments.

Nine field experiments are situated at four locations in Sweden representing different climates and soils. The experiments are constructed with separately tile-drained plots for leaching measurements. The plots are large, from 840 to 4000 m^2. Water flow is measured continuously by tipping buckets or V-notch, and recorded with data loggers. Automatic flow-proportional water sampling is used and composite samples are collected every fortnight. The analysis program include total nitrogen, nitrate nitrogen, total phosphorus, phosphate phosphorus and potassium, with some variation between experiments and years. Measurements include soil samples for mineral nitrogen determination down to a depth of 90 cm in order to assess how nitrogen is transported through the soil profile. Yields of crops and biomass of cover crops are determined and contents of N, P, K and C are analysed. Periodically, basic soil mapping samples are collected. Data is stored in Microsoft Access databases and grains and soil are archived.

The long-term field experiments in water quality assess the impact on nutrient leaching of several factors, separately or in combination:

- Cover crops, long-term and short-term effects
- No-till and conventional moldboard ploughing
- Autumn and spring tillage
- Application of manure
- Organic crop rotations including ley, with and without livestock
- Permanent grass/fallow
- Row hoeing
- Mineral fertilizer
- No application of N and P

The field experiments, along with additional separately tile-drained experiments, constitutes an infrastructure, which is used for other projects and measurements. Over the years, these experiments have contributed to substantial knowledge for development of decision support tools, legislation and subsidy systems as well as advisory programs and practical advices to farmers.

P64
Extracellular enzymes as promising soil health indicators: Assessing response to different land uses using long-term experiments

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ABSTRACT

Extracellular enzymes play a key role in soil organic carbon (SOC) decomposition and nutrient cycling and are known indicators for soil health; however, it is not understood how these enzymes respond to different land uses and their relationships to other soil properties have not been extensively reviewed.

We examined the relationships among the activities of three soil enzymes: β-glucosaminidase (NAG), phosphomonoesterase (PHO) and β-glucosidase (GLU). The impact of soil organic amendments, soil types and land management on soil enzyme activities were reviewed, and we hypothesised that soils with increased SOC have increased enzyme activity. Long-term experiments at Rothamsted's Woburn and Harpenden sites in the UK, were used to evaluate how different management practices affect enzyme activity involved in carbon (C) and nitrogen (N) cycling in the soil. Samples were collected from soils with different organic treatments such as straw, farmyard manure (FYM), and compost additions, and cover crops and permanent grass cover to assess whether SOC can be linked with increased levels of enzymatic activity, and what influence, if any, enzymatic activity has on total C and N in the soil.

Investigating the interactions of important enzymes with soil characteristics and SOC can help us to better understand the health of our soils. Studies on long-term experiments with known histories and large datasets can help us. SOC tends to decrease during land use changes from natural ecosystems to agricultural systems, therefore it is imperative that agricultural lands find ways to increase and/or maintain SOC in the soil.

P65
Long-term organic fertilization and cropping systems have an uncertain effect on tea bag decomposition

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ABSTRACT

Plant litter decomposition is a key step in the carbon cycle, which can be studied by the litterbag method. To compare the results on a regional/global scale, tea bags were proposed as standardized litter bags. Despite the large dataset from the natural systems, the tea bag data from long-term agricultural systems remain scarce. In this study, a pair of Lipton green tea (low C:N ratio) and rooibos tea (high C:N ratio) bags were buried at the depth of 8 cm in April /May at seven long-term experiments (LTE) across Europe. The tea bags were retrieved after three months and oven dried at 60 °C for at least 48 h. The mass loss was calculated from the final weight and the original weight of the tea leaves. The LTEs cover two main treatment types, i.e. long-term organic fertilizer and different cropping systems. The sites with organic fertilizer encompassed three main soil textures (silty clay, silt loam, and sandy loam) and four crop species (barley, wheat, maize, and grass/clover). The cropping system treatment included two sites with contrasting soil textures (silty loam and sandy loam) with systems of bare fallow, arable rotation, ley-arable rotation, and permanent grass. The results showed that green tea was decomposed more than rooibos tea, and long-term organic fertilizer had little or a negative effect on tea bag decomposition depending on the crop type in the field. For the cropping system treatment, tea bag composition showed no difference among the four systems in the silt loam soil while the arable rotation had the highest tea mass loss in the sandy loam soil. The results from the study enriched the global tea bag database and provided information on litter decomposition in agricultural systems in different climate zones.

P66
Phosphorus (P) budgets, P availability and P use efficiencies in conventional and organic cropping systems after four decades of continuous monitoring

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ABSTRACT

Cropping systems rely on the provision of adequate amounts of phosphorus (P) to enable stable crop yields. A balanced application of P is necessary to avoid reduced crop yields (in case of too low application rates), but also to avoid P losses to other ecosystems (in case of too high application rates). While in conventional cropping systems the use of synthetic P fertilizers is common practice, organic cropping systems mostly rely on organic P inputs such as farmyard manure or compost. By analysing soil and crop data of the DOK long-term field experiment we aim to answer if different cropping systems attain balanced P application rates in the long run, and how plant P availability is affected by different cropping systems.

Our findings indicate that conventional cropping systems risk to apply P at rates higher than actual plant removal. Negative soil surface P balances in organic and reduced farming may lead to P limitation in the long run, if current fertilization recommendations are pursued.

P67
Chemical properties of an oxisol under mineral, organomineral, and biomass ash fertilization in the Brazilian Cerrado

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ABSTRACT

The production of ornamental flowers in Brazil is of great economic importance for the country, and for the adequate development of these crops, soil fertility management is necessary. The soils of the Brazilian Cerrado generally have high acidity and low natural fertility, such as the Oxisol. Therefore, it is necessary to use fertilizers and correctives to correct soil fertility. Mineral fertilizers are generally used but the production costs become high, so alternative sources are sought. Wood ash or biomass ash is an alternative source of fertilizer and soil acidity corrective, resulting from the burning of vegetable biomass that can be used in conjunction with mineral fertilizers. In this context, this research aimed to evaluate different fertilizers associated with liming in Oxisol under chrysanthemum cultivation. The study was developed at the Federal University of Rondonópolis, Brazil. The experimental design was in randomized blocks, in a 5 × 2 factorial scheme, with five types of fertilizers (incubated biomass ash, non-incubated biomass ash, organomineral, mineral, and control) and two liming values (0 and 100% of the recommendation). The organomineral was developed with mineral fertilizer and biomass ash as a source of organic fertilizer. The variables analyzed were calcium, magnesium, and aluminum.

Fertilizers that have biomass ash in their composition, such as the organomineral fertilizer, eliminated the aluminum toxicity of the Oxisol, besides increasing the calcium and magnesium levels in the soil. Thus, it is observed that the organomineral using biomass ash as raw material is an alternative fertilizer and acidity corrective.

P68
Combination of organic and mineral fertilization on soil acidity parameters after *Panicum maximum* cultivation

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ABSTRACT

The search for alternative sources of fertilizers and soil correctives is necessary since fertilizer costs are increasing. This leads to the reflection on the need to invest in pasture and fertilizer management technologies. Among the management solutions is the combination of organic and mineral inputs. Organomineral fertilizers are on the rise because they unite the economy and environmental management. Wood ashes, resulting from biomass burning, can be used in organomineral production to provide the soil with a more varied set of nutrients, compared to the exclusive use of mineral fertilizers of industrial origin (Bonfim-Silva *et al*., 2020). A study was conducted where fertilization with wood ash, organomineral (wood ash + mineral fertilizer), and mineral fertilizers were associated with base saturation levels in the cultivation of *Panicum maximum* cv. BRS Zuri, in pots filled with Oxisol, collected under Cerrado vegetation, in Brazil. The results showed that the organomineral fertilizer improves the chemical properties of the soil, increasing the base sum, cation exchange capacity, and base saturation and reducing the aluminum saturation. Furthermore, there is no need for liming for this cultivar when wood ash is used in combination with mineral fertilizer. Thus, the combination of wood ash + mineral fertilizer is recommended as an alternative to mineral fertilizers only.

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P69
Changes in soil chemical characteristics over 40 year period depending on the use of mineral fertilisers

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ABSTRACT

It is well known that conventional intensive agriculture has negative impacts on natural resources, including soil (Mouli *et al*., 2019). Changes in the soil do not take place in a short time (Needelman, 2013). Agricultural long-term experiments (LTEs) are most valuable research infrastructures to reveal the effects of agricultural measures in the long run (Grosse *et al*., 2020).

To clarify the impact of long term mineral fertiliser use on soil chemical properties, there were data from long term experimental field in Priekuli Research Centre of the Institute of Agricultural Resources and Economics (57°19'N, 25°20'E) analyzed. The experiment under the guidance of Dr.agr.Vilnis Mikelsons was on a sod-podzolic sandy loam (*Luvisol*) soil in 1958 established. The normal mean temperature in the years of experiments varied from -6.2ºC in January to 16.7ºC in July. This paper presents forty years of results on the effects of mineral fertilizer application on soil chemical properties depending crop rotation, beginning in 1964.

The experiment included five different crop rotations: spring (s.) barley–potato–s. barley; s.barley–grass/clover–winter (w.) rye–potato; s. barley–grass/clover–s. barley–w. rye–s. barley–potato; s.barley–grass/clover–potato; s. barley–grass/clover–grass/clover–w.rye–s.barley–potato. The clover in rotations was red clover, which was established as an undersown crop in s.barley. Different fertilization treatments–unfertilised, mineral fertilizer NPK ($N_{66}P_{90}K_{135}$), and 2 NPK ($N_{132}P_{180}K_{270}$) were compared with the crop rotations as sub-plots within each fertilizer treatment.

Results from experimental field demonstrated significant changes of the basic soil chemical characters during the 40 years period. Depending crop rotation soil pH decreased 0.6–1.1 units, but the content of both–plant available phosphorus and potassium increased on 52–541%. Strong and moderete correlation (α=0.05) was found between soil charasteristics and different crop rotations depending fertilisation.

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P70
The impact of long-term anaerobic digestion treated manure on soil organic matter, soil nutrients and ley yields in Norway

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ABSTRACT

The global need to substitute fossil fuels, along with rising fertilizer costs, calls for a more efficient use of manure resources in agricultural systems. One option may be to treat more animal manure by anaerobic digestion to produce energy and co- produce an organic fertilizer. Here, we investigated the long-term effects of anaerobically digested (AD) dairy cow slurry on crop yields, soil organic matter (SOM) and chemical soil characteristics. The field experiment was established in a grass-clover ley in 2011 and comprised two fertilizer treatments, non-digested slurry and AD slurry, applied at two rates of total N (110 and 220 kg ha^{-1} y^{-1}), compared with a non-fertilised control. While the rate of manure application affected soil concentrations of extractable nutrients and pH, these variables were not affected by AD. SOM concentrations (0-20 cm) decreased in all plots, and faster on plots with high intrinsic SOM. The decrease was similar with application of non- digested slurry (US) and anaerobically digested slurry (ADS) and at low and high application rates. US and ADS gave similar yields of grass-clover ley and whole crop cereal, on average 0.79 and 0.40 kg DM m^{-2}. The proportion of clover in the ley canopy was similar in manured treatments and the non-fertilized control. With respect to crop yields and chemical soil characteristics, long-term (10 years) effects of AD in an organic dairy cow farming system seem to be minor, not compromising grassland productivity or soil quality in the long term. However, with traditional application of the slurry (no incorporation), no yield increase was achieved with AD, as has been found in other studies.

P71
Soil health and crop yields in the old rotation (Est. 1896): The world's oldest, continuous cotton experiment

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ABSTRACT

The Old Rotation was established in 1896 to document the long-term effects of crop rotation and winter cover cropping in historically eroded soils of the southeastern United States. The experiment is the oldest continuous cotton (*Gossypium hirsutum* L.) experiment in the world. It consists of thirteen plots, which can be divided into five primary treatment groups including: 1) continuous cotton with no commercial nitrogen fertilizer additions (−N) and no winter legume (−cover crop), 2) continuous cotton −N with a winter legume cover crop (+cover crop), 3) cotton-corn (*Zea mays*) rotation −N +cover crop, 4) cotton-corn rotation +N +cover crop, and 5) cotton-corn- wheat (*Triticum aestivum*)-soybean (*Glycine max*) rotation −N +cover crop. Crop yields have been collected according to plot since 1896. In 2019, soil samples were collected from the 0-15 cm depth according to plot to evaluate the Old Rotation for a variety of soil biological, chemical, and physical properties. After 125 years, continuous cotton rotations that include a winter legume cover crop yield approximately three times more lint than continuous cotton with no winter legume treatments, demonstrating the benefits of winter legume cover crops to crop productivity. Continuous cotton with a legume cover crop also resulted in improved biological, physical, and chemical properties compared to continuous cotton with no cover crop. Inclusion of corn in the rotation further improved soil health primarily due to additional residue from the corn crop. For example, soil organic matter concentration in the 0-15 cm soil depth is approximately 0.98% for the continuous cotton −N and −cover crop treatment, 2.46% for the continuous cotton −N and +cover crop treatment, and 2.95% for the cotton-corn +N and +cover crop treatment. Overall, the Old Rotation demonstrates long-term benefits of crop rotation and cover crops for sustainable cotton production in the southeastern United States.

P71a
Digging Deeper: Long-Term Experimentation Discloses the Influence of Tillage Systems on Soil Properties in Semiarid Rainfed Mediterranean Conditions

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ABSTRACT

Long-term experiments (LTEs) play a crucial role in our understanding of the long-term effects of agricultural practices and technological developments employed in agroecosystems. These experiments enable us to capture the gradual changes that occur in soil over extended periods. LTEs provide the most robust and reliable results in agricultural experimentation, making them invaluable sources of knowledge and essential tools for informing best practices.

In our study, we conducted monitoring in a LTE at the INIA-CSIC experimental farm "La Canaleja" in Madrid, Spain (40◦ 32'N and 3◦20'W; 600 m). This experimental site, characterized by a semiarid continental climate, allowed us to investigate the effects of different tillage systems on soil properties. The soil at the site was a sandy-loam Calcic Haploxeralf with a low initial organic carbon content. Starting in 1994, we implemented three tillage systems: direct drilling (no-tillage, NT), chisel ploughing (minimum tillage, MT) with a depth of 15 cm, and mouldboard ploughing (traditional tillage, CT) with a depth of 20 cm. By monitoring and comparing the soil properties under these tillage systems, we aimed to assess their long-term impact on soil bulk density and soil organic carbon (SOC) at various depths.

Our study involved measuring bulk density and SOC at three soil depths (0-0.075 m, 0.075-0.15 m, and 0.15-0.30 m) in the autumn of 2006 and again ten years later. The results revealed a significant increase in soil bulk density after the ten-year period. Specifically, the MT system showed a significant increase in bulk density, while the NT system consistently exhibited the highest values both at the beginning and end of the study, across all depths. Moreover, the observed increase in SOC after the ten-year study was primarily driven by the rise of SOC in the NT system. Notably, the highest increase in SOC was observed in the topsoil layer.

These findings confirm the significant influence of soil tillage on the studied soil properties. In our experimental conditions, particularly under semiarid rainfed Mediterranean conditions, conservation tillage, specifically the NT system, is recommended. The NT system promotes soil organic carbon accumulation, with the most pronounced differences between treatments observed in the surface layers rather than the deeper layers.

In summary, LTEs provide invaluable insights into the long-term effects of agricultural practices. By monitoring soil properties over extended periods, we can obtain robust and reliable results. These LTEs serve as essential tools for informing sustainable practices and facilitating evidence-based decision-making in the field of agriculture.

Acknowledgments

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Posters: Responses to Weather and Climate

P72
Stabilising wheat yield and quality under variable climatic conditions

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ABSTRACT

Diverse cropping systems which include legumes and increased soil carbon have the potential to lower the need for nitrogen fertilisers. This trial was conducted under rain-fed conditions in the Swartland region of the Western Cape South Africa, with a Mediterrane climate. Eight cropping systems containing wheat under conservation agriculture (2002–2021) was used. Four of the systems is cash cropping systems and the remaining four systems are a combination of cash crops and pasture systems. The four mixed pasture/cropping systems and two of the cash cropping systems contains legumes. The experimental design was randomized block design with a nested treatment design.

Less nitrogen fertilisers were applied in mixed cropping systems but these systems contained more protein in the grain and higher yields compared to cash cropping systems. In the cash cropping systems which contains legumes more nitrogen were applied on wheat compared to the mixed systems. The reason for this may be the fact that the mixed systems contains 50% legumes compared to the two cash cropping systems which contains 25% legumes. The benefits of increasing diversity in cropping systems are clear under variable climatic conditions. The more diverse systems improved and stabilised wheat quality and production under variable climatic conditions. The frequency of legumes in a cropping system and type of legume (cash crop or pasture) may influence the benefits of the legume. Cropping systems containing legumes can improve sustainability by reducing the amount of nitrogen fertilisers while improving production and increasing quality. This can reduce the negative impact on the environment whilst improving the profitability of wheat production.

P73
From controlled environment to field: Confounding factors in container trials

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ABSTRACT

Global climate change models predict an increase of extreme weather events, among them drought and heat. Maintenance of agricultural yield requires breeding of resilient crops. The bottleneck in drought tolerance breeding is phenotyping in managed field environments. Fundamental research on drought tolerance uses container-based test systems in controlled environments as a proxy. However, breeders debate the portability of results from these systems to performance under field conditions. Thus, we analyzed the effects of climate conditions, container size, starting material, and substrate on yield and drought tolerance assessment of potato genotypes in pot trials compared to field trials. The tolerance ranking in the field was obtained from seven multisite-multiyear trials. The tolerance ranking in controlled environments was highly reproducible, but weakly correlated with field performance. Changing to variable climate conditions, increasing container size and substituting cuttings by seed tubers did not improve the correlation. Substituting horticultural substrate by sandy soil resulted in yield and tuber size distributions similar to those under field conditions. However, as the effect of the treatment × genotype × substrate interaction on yield was low, drought tolerance indices that depend on relative yields can be assessed on horticultural substrate too. Realistic estimates of tuber yield and tuber size distribution, however, require the use of soil-based substrates.

P74
Modelling wheat-climate interactions today to aid future development

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ABSTRACT

Developing and trialling new crop cultivars is essential to secure food security in a changing climate. Can modelling help plant breeders and farmers develop and choose wheat cultivars that better cope with climate change? We will present initial results from our project evaluating the response of 214 wheat cultivars to different climate conditions in the UK, building upon previous work modelling maize yield in the US Corn Belt (Shirley *et al*., 2020). We are using an empirical model, trained using Bayesian inference, to predict and compare the yield of wheat cultivars under future weather scenarios. Our approach links historical cultivar-level yield data (from 21 years of AHDB recommended list trials) with meteorological records, while allowing for non-linear responses to weather variables and interactions between them. We will overview how, to date, the UK wheat model shows poorer performance than the maize model, perhaps due to differences in spatial scale and weather variability between the datasets.

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P75
Fingerprinting the effects of global environmental change on agriculture using long-term experiments

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ABSTRACT

Environmental change impacts ecosystems across the globe, including agroecosystems. Long-term experiments (LTE's) are critical to understand these impacts, which only become fully apparent over long timescales. Typically, we use agricultural LTE's to test for differences between management treatments, but we can also repurpose LTEs as a global long-term observational network of well-managed agricultural plots. Following methods previously used to quantify carbon storage in tropical forests (Hubau *et al*., 2020), we can use LTE's to detect the 'fingerprint' of global environmental change on agricultural yields and explore the implications for future food security.

In this study, we will use the highest yielding treatments of different LTE's around the world as proxies for local good practice in crop management, and investigate how cereal yields have varied over time in response to seven major global environmental changes: temperatures, precipitation, solar radiation, extreme weather, atmospheric carbon dioxide concentrations, nutrient deposition, and ozone and acid deposition. We will account for changes in agricultural practice on the LTE plots, including crops varieties and crop protection. Around 25 LTE's have already agreed to participate. The preliminary results suggest that the impacts of global environmental change may be more detrimental to food production in Africa than in Europe. We aim to include many more LTE's in the study, and we hope to connect with potential collaborators during this conference.

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P76
Sowing term as a pivotal limiting factor in winter wheat breeding strategy for climate change

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ABSTRACT

Long-term experiments are a valuable source of information regarding the impact of climate change on the growing conditions of agricultural plants. Sowing terms allow modifying the following indicators - the sum of active temperatures, the precipitation amount, the soil moisture regime, the duration of the daylight hours, the duration of the initial growth phase, and the hardening phase. The use of several sowing terms allows for assessing winter wheat plant integrity and adaptability during variable environmental conditions in one growing season.

Since 1996, the Breeding Center of the Poltava State Agrarian University has been conducting a field experiment - studying the impact of sowing dates on winter wheat yield formation. No fertilizers or plant protection agents are used, which allows for assessing the natural level of soil fertility and the value of agro-climatic conditions of the region. The experiment design allows for the analysis of many traits, which helps to assess the level of adaptability of winter wheat accessions.

During the years of the experiment, valuable data regarding the yield level and its fluctuations depending on the weather conditions were obtained. Changes in time frames for the termination of autumn vegetation, the duration of the winter rest phase, and the resumption of spring vegetation were fixed. The recorded changes help to develop practical recommendations for agricultural enterprises of the Central Forest-Steppe of Ukraine under climate change.

The use of this experiment in the breeding program allows the selection of genotypes with a high adaptive potential to present and future climate scenario.

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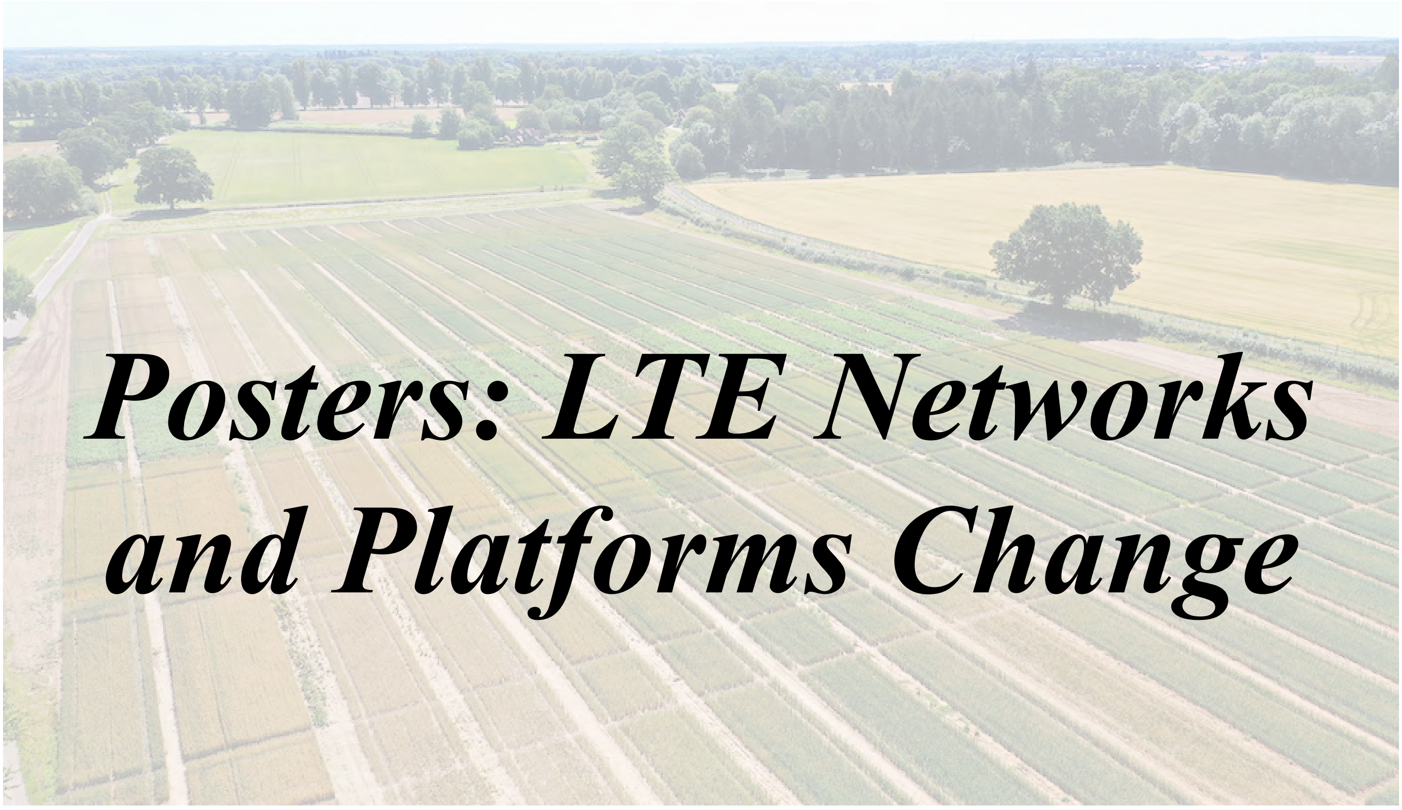

Posters: LTE Networks and Platforms Change

P77
Rothamsted long-term experiments: Historic data for current and future challenges

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ABSTRACT

The Classical Experiments at Rothamsted Research, started by Lawes and Gilbert between 1843 and 1856, are the oldest continuous agronomic experiments in the world. Meticulous written records of inputs, yields, soil and crop nutrients, species, weeds, plant diseases, and meteorological readings were kept from the outset. Released in 2013, e-RA (the electronic Rothamsted Archive, www.era.rothamsted.ac.uk) makes these unique data resources available to researchers from around the world. Data from other more recent long-term experiments (LTEs) at Harpenden, and other Rothamsted sites with contrasting soil types, enhance the original suite of Classical experiments. These data support work addressing current and future global challenges in areas such as soil health, climate change and tipping points, net-zero, biodiversity, and refining agronomic practices to improve human nutrition whilst safeguarding our environment.

We outline the data currently available from e-RA and highlight further historical data which will become accessible in future – e-RA is a continually evolving project. Case studies demonstrate the breadth of issues addressed and the relevance to scientists around the world. Since 2013, we have received over 1200 requests for data and information from 38 countries. Over 220 journal articles relating to the LTEs have been published since 2013.

This unique historical repository of agronomic and meteorological data provides a vital pool of information available for advancing science and after 180 years the Rothamsted LTEs continue to enable internationally important new findings and insights.

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P78
Farmers and Rothamsted scientists working together on a new Long-Term Experiment: The Devon Silvopasture Network

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ABSTRACT

Silvopasture is one of the most promising climate change mitigation solutions. However, there is a lack of scientific evidence from UK systems to support policy development and drive wider adoption. To address this, a new Long-Term Experiment consisting of seven sites was implemented in the southwest of England. The Devon Silvopasture Network, established in 2020 and led by farmers, is supported by FWAG South-West, The Woodland Trust, The Soil Association, Innovative Farmers, Rothamsted Research, and the Organic Research Centre. It includes six commercial farms and a research farm which are mostly on pastureland but also on arable land. At the outset of the trial, farmers in the Network identified the key research areas of interest to them and research expertise was sought to address these. Rothamsted joined the network not long after its creation to assess the effect of tree introduction in agricultural systems on productivity, carbon sequestration, soil fertility and environmental impact.

The baseline soil condition was assessed before planting the trees, following FAO guidelines (2020). The results of soil organic carbon (SOC) show that there is large variation between the sites, ranging from 15.5 to 45.9 Mg ha^{-1} (0-10 cm), and 29.4 to 53.8 Mg ha^{-1} (10-30 cm). At the Rothamsted site, SOC ranged from 4.7 to 6.4% in the topsoil (average SOC stock of 43.9 Mg ha^{-1}). At 10-30 cm depth, values varied between 2.6 and 3.4% (mean SOC stock of 53.8 Mg ha^{-1}).

The trees were planted in March 2021 following 3 designs: cluster planting, shelterbelts and regular spacing. They comprised a mix of native species (50/50 shrubs and standards at 200 stand density). The aim is to create a long-term time series tracking changes in SOC and other soil health indicators, biodiversity, greenhouse gas emissions, nutrient losses to water, animal welfare and their effect on the overall system.

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P79
Long-term experiments at the Swedish University of Agricultural Sciences

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ABSTRACT

This is a presentation of the long-term agricultural experiments managed by the Swedish university of Agricultural Sciences (SLU). The experimental locations spans over a thousand kilometers north-to-south, and the oldest still active experiment was started in 1936. The experimental series cover a wide range of subjects such as crop production systems, plant nutrition, weed control, ecology, water management, hydrotechnology, and soil tillage. Data and material from the Swedish LTEs are accessible by request.

P80
An open-source metadataset of running European mid-term and long-term field experiments

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ABSTRACT

Mid-term (MTEs, 5 to 20 years) and long-term (LTEs, 20+ years) field experiments are key sources of information to design future climate-smart agriculture. Within the European Joint Program SOIL (EJP SOIL), we built the EJP-MTE/LTE metadataset that contains metadata from 240 MTEs/LTEs across Europe. Metadata collected included precise descriptions of the treatments (combination of factors such as tillage, crop type/rotation, amendments/fertilizers, grazing and pest/weed management), soil and crop measurements collected and pedo-climatic information. Using several maps and dashboards, an overview of those MTEs/LTEs is presented and specific research themes (tillage systems, residue management, amendment type and cover crops) are further analyzed within their pedo-climatic context. The analysis enables us to identify knowledge gaps in terms of practices (e.g. grazing, pest/weed management) but also pedo-climatic variables (e.g. Western Europe, coarse texture soil) rarely investigated within European MTEs/LTEs. An interactive web portal developed in collaboration with the BonaRes project (https://lte.bonares.de), enables users to explore the metadataset and find relevant MTEs/LTEs for specific combinations of practices (e.g. all MTEs/LTEs that investigate cover crops on a Cambisol in no-tillage system). Finally, a SWOT (Strength, Weakness, Opportunities, Threats) analysis of the metadataset was carried out to highlight the potential contribution of MTEs/LTEs to a harmonized European soil observation and monitoring.

P81
Network Strategies and Studies to Advance Science for Climate-Smart Agriculture in the LTAR Network

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ABSTRACT

Agricultural systems and producers are constantly facing a variety of challenges and stressors, but perhaps the most universal and persistent of them all is climate change. Since its creation, the United States Department of Agriculture (USDA) Long-Term Agroecosystem Research (LTAR) Network has identified climate change mitigation and adaption as a focus area. Stakeholders who partner with LTAR scientists have requested greater emphasis on recommended strategies for climate change adaptation and mitigation. The LTAR “Science for Climate-Smart Agriculture” (CSA) strategic initiative exists to identify agronomic innovations to improve the resiliency of cropland and grazing land ecosystems to climate change, to identify and test climate change mitigation strategies to increase carbon storage and reduce greenhouse gas emissions, and to facilitate model development to predict agroecosystem responses to future climates. Given the national scope of the LTAR network, adaptation strategies are needed for drought stress, flooding and overly saturated soils, plant and animal heat stress, pest pressure, and identification of forward-thinking cropping regimes. Through research enveloped in the CSA initiative, the LTAR Network is poised to become a trusted source for assessing agronomic interventions that promote resilience and mitigation against climate change. Network strategies and preliminary studies will be presented with respect to measurement of greenhouse gases from agricultural systems, evaluation of net carbon storage and global warming potential of practices, identification of climate resilient management practices, and climate impact modeling. We hope to engage in a conversation with other researchers to share best practices and ideas for advancing Science for Climate-Smart Agriculture and strengthening international collaborations on this critical issue.

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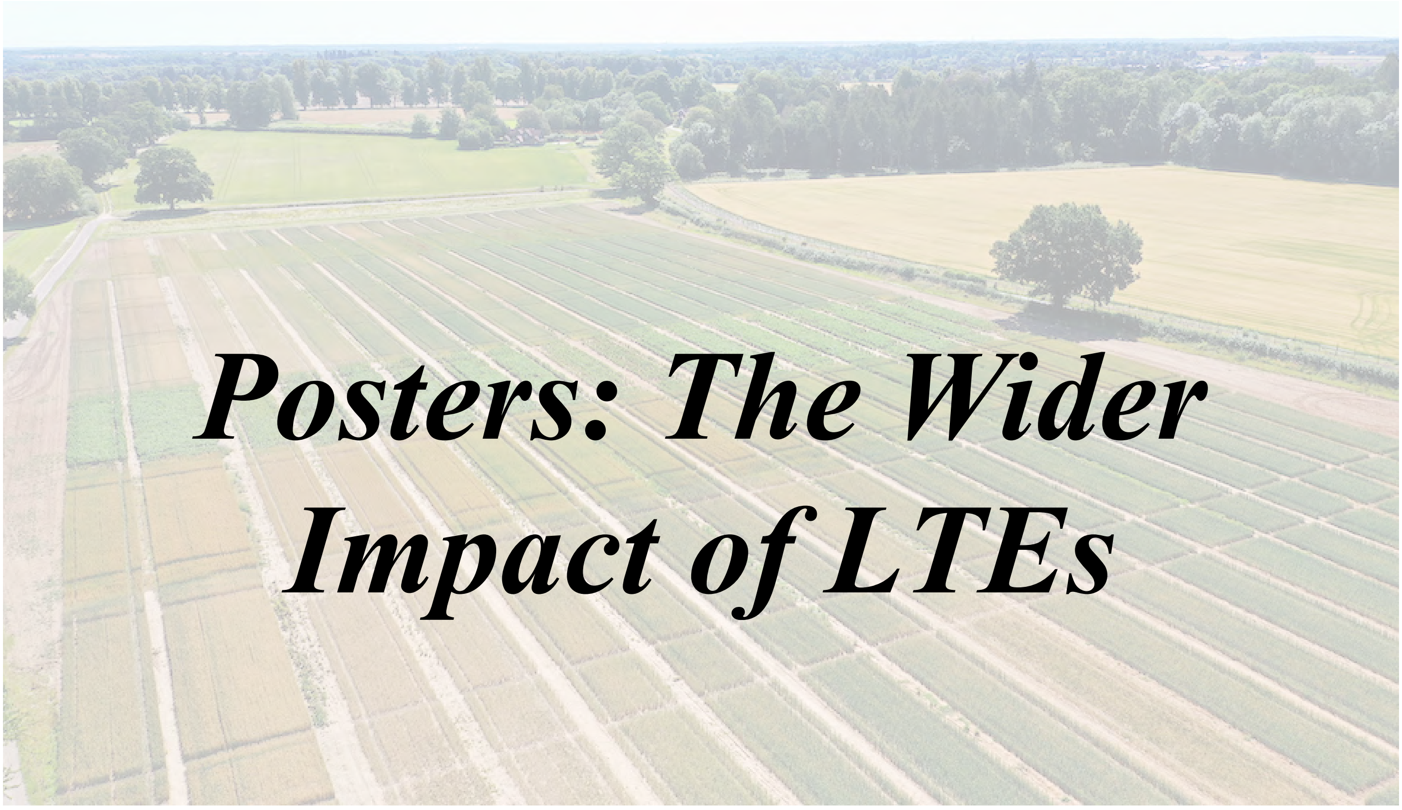

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P82
Re-evaluating the nitrogen use efficiency of selected mineral and organic fertiliser categories based on the analysis of Swiss long-term field experiments

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ABSTRACT

Using a selection of Swiss long-term field experiments (LTEs), we investigate the nitrogen (N) cycling dynamics and nitrogen use efficiency (NUE) trends, to re- evaluate the NUE of selected mineral and organic fertilisers after repeated application. Studied LTEs follow Swiss practiced crop rotation, while differing in fertiliser treatment, amounts and experiment duration. The N cycling dynamics will be assessed for each fertiliser treatment and crop-rotation based on an approximative soil-system N balance, as defined by Oenema *et al*. (2003). In DEMO (conventional management situated in Zurich and runni ng since 1989), NUE of farmyard manure, slurry, and NPK according to Swiss fertiliser norm , will be calculated for four crop rotation periods; in DOK, an experiment comparing three farming systems (biodynamic, organic and conventional), situated in Therwil since 1978, NUE of farmyard manure, slurry and NPK according to Swiss fertiliser norm will be calculated for six crop rotation periods in all three farming systems. Finally, in the Swiss oldest field experiment, ZOFE, situated in Zurich with conventional management, NUE of farmyard manure, sewage sludge, green-waste compost, combinations thereof with PK, and NPK according to Swiss fertiliser norm will be calculated for a period of 70 years since 1949 in eight crop rotation periods. The selected NUE indicators are first compared between fertiliser treatments of the same experiment to identify location related effects, and then standardised to compare analogous fertiliser treatments at differing locations. The results are then shared with Swiss policy makers to improve the overall fertiliser NUE at the legislation level, thereby fostering a reduction of the N losses at the national level.

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P83- ONLINE POSTER
Costs and benefits of reduced tillage compared to ploughing in an organic long-term trial on Loess in Switzerland

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ABSTRACT

Reduced tillage (RT) has soil conservation benefits compared to conventional ploughing (Krauss *et al*., 2021), but can lead to lower yields in organic farming. For the further development of reduced tillage systems in organic farming a long-term experiment was established 2010 on a Loess soil in Aesch BL, Switzerland. The factors are tillage (plough *vs*. reduced) and fertilization (slurry vs. mineral fertilization on two levels each (1=low; 2=high) and no fertilization). The mean yield over 13 years was reduced by 4% with RT compared to ploughing (PL). Organic carbon stocks increased significantly in the surface layer (0–10 cm) in RT compared to PL, while in the 10−20 cm layer, they were not significantly lower ($P \leq 0.01$). Life Cycle Assessment (or simply LCA) revealed an 18 to 32% lower impact of RT on climate change, mainly due to more carbon being sequestered in the soil but also less energy use. Gross margins for RT vary depending on fertilizer treatment: with unfertilised and slurry1 they were similar to PL, with slurry2 they were 9% lower than with PL. Lower gross margins for RT were due to yield reductions and thus lower revenues. However, when subsidies for RT were considered, all RT treatments had a higher gross margin than the corresponding treatments with ploughing.

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P84
Nutrient runoff in a long-term agricultural experiment in central-Southeast Norway

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ABSTRACT

The long-term agricultural experimental site at Apelsvoll in central-Southeast Norway was established in 1989, as a response to high eutrophication levels in the regions freshwater systems. It is situated at 250 m altitude in a humid-continental climate with a mean annual precipitation of 600 mm and temperature of 3.6 °C. The site is divided into twelve blocks (30 x 60 m) to test six different cropping systems (two replicates), each comprised of four crop rotations. The soil has been classified as Endostagnic Cambisol with loam and silty sand textures. The cropping systems are 1) Reference system: conventional arable cropping as was locally common in the 1980s, 2) conventional arable cropping with optimized management (e.g., catch crops and split application of fertilizer), 3) organic arable cropping, 4) conventional mixed dairy farming with 50% grass clover ley, 5) organic mixed dairy farming with 50% grass clover ley and 6) organic mixed dairy farming with 75% grass clover ley. Before 2013, surface and trench runoff water were collected separately for each cropping system and monthly analysed for nutrients and particulate organic carbon. After 2013, the trench runoff has been collected separately for each rotation within each block (n=48). We analysed crop specific trench runoff between 2014-2018 and cropping system-based total runoff between 2000-2018 using a Bayesian framework. Nitrogen losses for grains and potatoes were twice as high as grass/clover fields, independent of the cropping system. Phosphorous and particulate organic matter losses were similar between grains, potatoes and grasses, but significantly higher for the conventional arable cropping reference system. Small changes to fertilizer applications in all but conventional arable cropping reference system after 2010, as well as changing the clover ley management in the organic arable system, did not significantly change nitrogen, phosphorous and organic carbon runoffs.

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