CGIAR

aab
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

# DIGITAL POSTER BOOK


ELSEVIER

Special Issue

Long-term Experiments – redesign, reuse and repurpose for the future

*European Journal of Agronomy*

Edited by
Christine Watson, Jorgen Olesen, Oliver Knox, Kairsty Topp & Chloe Maclaren

Submit your paper >



*Association of Applied Biologists*, Warwick Enterprise Park, Wellesbourne, Warwick CV35 9EF, UK
Registered Charity No. 1195899; http://www.aab.org.uk
Tel: +44 (0)2476 999485 Email: John@aab.org.uk

# *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 tillage effects within a crop rotation system in a Mediterranean climate zone**
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 di□erent 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 (University, Denmark)

***ONLINE***

***P50***

**Soil response to eight di□erent 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 e□ciency 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***

**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)

***P84***

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

ISABELL EISCHEID (NIBIO Apelsvoll, Norway)

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Chair of Organic Farming

# Organic Arable Farming Experiment Gladbacherhof

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


Wiebke Niether[1], Janna Macholdt[2], Franz Schulz[1], Andreas Gattinger[1]

[1]Department of Agronomy and Plant Breeding II, Organic Farming with focus on Sustainable Soil Use, Justus-Liebig University Giessen, 35394 Giessen, Germany

[2]Department of Agronomy and Organic Farming, Martin-Luther-University Halle-Wittenberg, 06120 Halle (Saale), Germany


## 1 Objectives

1. **Potentials and challenges of stockless organic farming:**
   - Direct and long-term impact of different „farm types“ with and without animals on crops, soil quality and the environment.
   - Stability, resilience, sustainability and nutrient efficiency.
2. **Potentials and challenges of reduced tillage in organic farming:**
   - Direct and long-term effects of different tillage systems on crops, soil quality, and the environment.
   - Potentials of reduced tillage with different crop rotation and fertilization.

## 2 Site description

| | |
|---|---|
| **Location** | Gladbacherhof , 65606 Villmar, Limburg-Weilburg, *Hesse, Germany* |
| **Altitude** | 170 m a. s. l. |
| **Mean annual temperature** | 9,5 °C |
| **Mean annual precipitation** | 654 mm |
| **Soil texture** | Lu – Ul, Silt loam – Loamy silt |
| **Soil type** | Orthic luvisol |

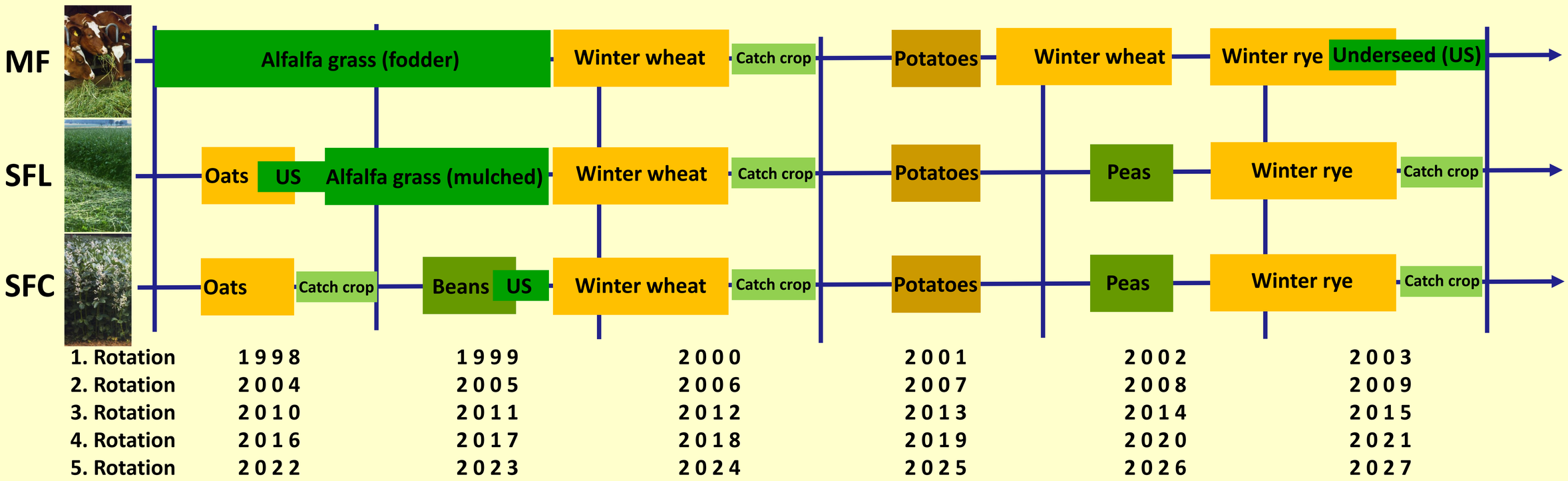
## 3 Experimental design / treatments

**Long-term field experiment since 1998, split-plot design, 4 replications:**

**a) main factor „farm type“:**
- **MF = Mixed farming with cattle**
- **SFL = Stockless farming with mulched ley**
- **SFC = Stockless farming cash crops only**

**Further information:** ***Schulz et al. 2014***

**b) subordinate factor „tillage intensity“:**
- **P 30 = Plough 30 cm**
- **TLP 30/15 = Two layer plough 30/15 cm**
- **P 15 = Plough 15 cm**
- **CR 30/15 = Cultivator & rotary harrow 30/15 cm**




## 4 Some results

| | Relative yield (%) | | aCV (%) | |
|---|---|---|---|---|
| | Mean | SEM | Mean | SEM |
| **Farming type** | | | | |
| MF | 103.1 | ± 2.3ab | 30.3 | ± 1.1 a |
| SFL | 105.8 | ± 1.6 a | 28.2 | ± 1.3ab |
| SFC | 100.5 | ± 1.8 b | 25.9 | ± 1.4 b |
| **Tillage intensity** | | | | |
| P30 | 107.1 | ± 2.3 a | 27.2 | ± 1.6 |
| TLP30/15 | 103.8 | ± 2.2ab | 28.2 | ± 1.6 |
| P15 | 105.5 | ± 2.1 a | 27.4 | ± 1.4 |
| CR30/15 | 96.1 | ± 2.2 b | 29.8 | ± 1.4 |

Tab. 2 Relative yield and yield stability (adjusted coefficient of variance: aCV) over time of the entire crop rotation (1998 – 2021)

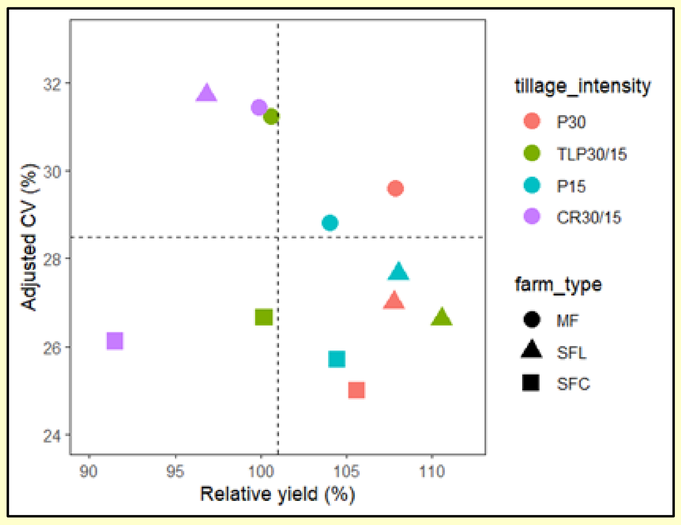



Fig. 1 Relative yield and adjusted coefficient of variance (aCV) of the treatment combinations of farming type and tillage intensity for 4 complete rotations (1998 – 2021)

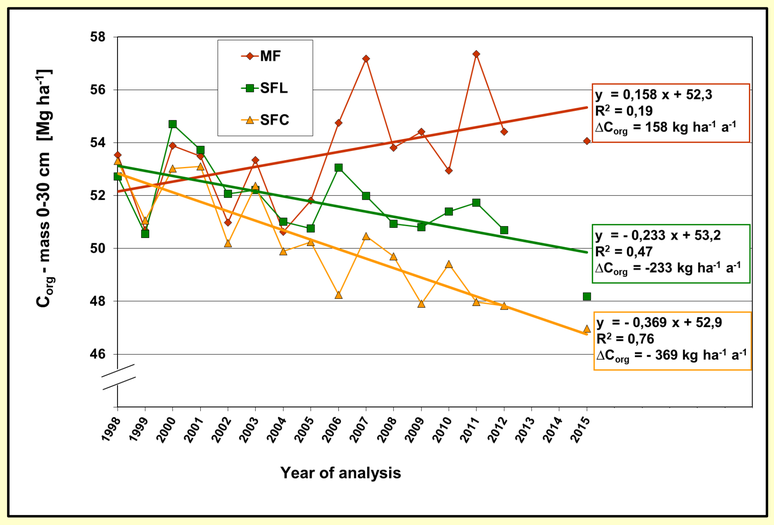



Fig. 2 Development of soil organic carbon (Mg ha$^{-1}$) from 1998 – 2015 in the topsoil dependent on farm type

- **The most promising combination of high yield and yield stability was mixed farming (MF) with deep (P 30 cm) and shallow (P 15 cm) ploughing.**
- **Stockless farming with cash crops (SFC) and non-inversion tillage (CR 30/15) had the highest production risk.**

## 5 Conclusions

- **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.**
- **Long-term reduction of humus in stockless farming is not acceptable.**

## 6 References:


*Franz Schulz, Christopher Brock, Harald Schmidt, Klaus-Peter Franz & Günter Leithold (2014) Development of soil organic matter stocks under different farm types and tillage systems in the Organic Arable Farming Experiment Gladbacherhof, Archives of Agronomy and Soil Science, 60:3, 313-326, DOI: 10.1080/03650340.2013.794935*

*Wiebke Niether, Janna Macholdt, Franz Schulz, Andreas Gattinger (2023) Yield dynamics of crop rotations response to farming type and tillage intensity in an organic agricultural long-term experiment over 24 years, Field Crops Research, in review*

# Assessing different sward managements on biological nitrogen fixation from a white clover high sugar grass mixture

Verbeeck, M., Segura, C., Louro-Lopez, A., Loick, N., De-Meo-Filho, P., Pulley, S., Hood, J., Griffith, B.A., Cardenas, L.M., Enriquez-Hidalgo, D.*
*Rothamsted Research, Net zero and resilient farming, North Wyke, Okehampton, Devon*
**daniel.enriquez@rothamsted.ac.uk*

## Introduction

White clover biological nitrogen fixation (BNF) in mixed swards is commonly reduced by management factors such as: N fertilizer addition, type of animals grazing, grazing strategy or cutting regime; such effects vary along the grazing season as time of the year influences species growth patterns.

Objective: To evaluate the growth and biological N fixation of a white clover-grass pasture under set-stocking conditions under different management conditions and to evaluate the possible trade-off between herbage production and biological N fixation.

## Methods

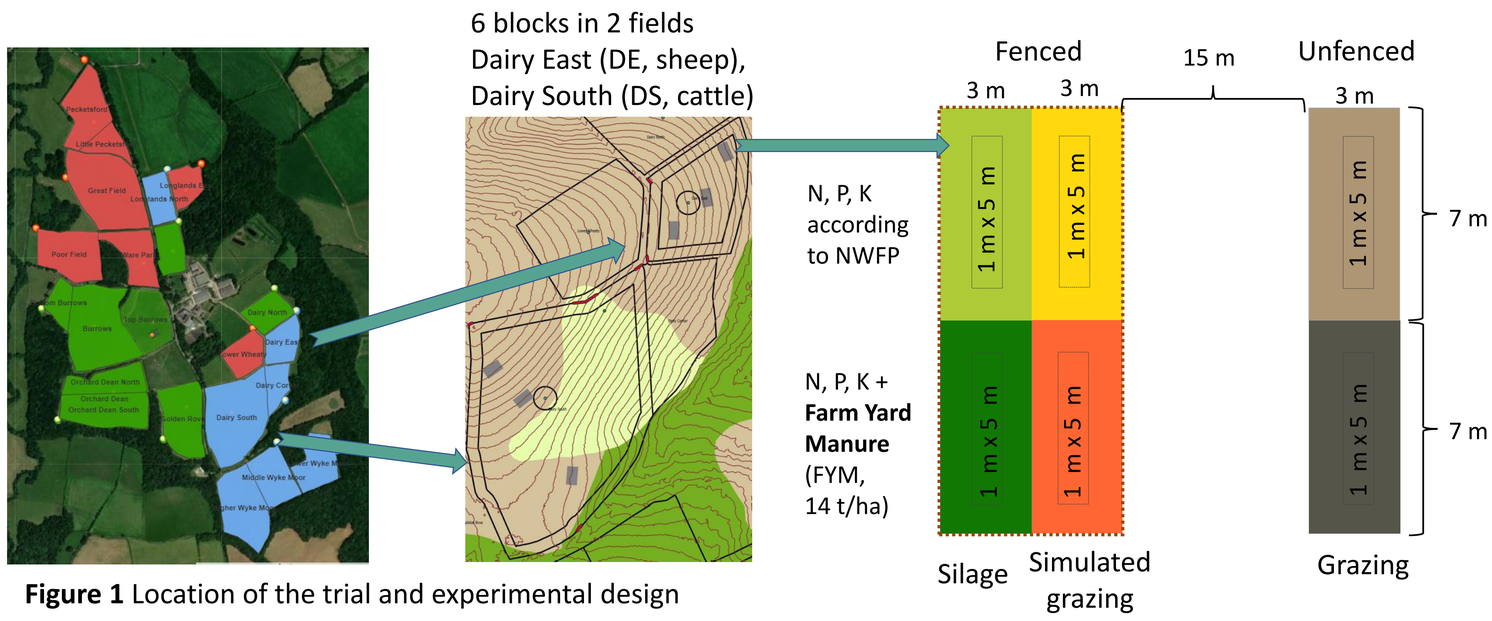



**Figure 1** Location of the trial and experimental design

**Monthly measurements throughout the 2021 growing season**

- Herbage mass production (kg dry matter/ha)
- Clover content of the herbage (dry matter %)
- Biological nitrogen fixation (kg N/ha), estimated by the natural abundance method (δ $^{15}$N of clover and grass (‰))
- Elemental composition grass and clover (mg/kg; snapshot end of July), soil variables (pH, soil moisture, soil mineral N)

**Statistical analysis**

2-way ANOVA with management and FYM as fixed factors and the blocks as blocking factors

## Results

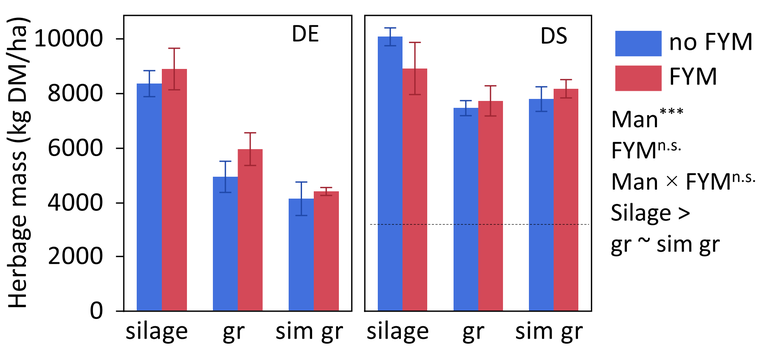



**Figure 2** Herbage mass production during growing season (mean and standard error, *n*=3).

gr = grazing, sim gr = simulated grazing, FYM=farm yard manure, Man=management (silage, gr, sim gr)

Only for DS: gr and sim gr follows spring season of silage (spring silage production presented in dashed horizontal line)

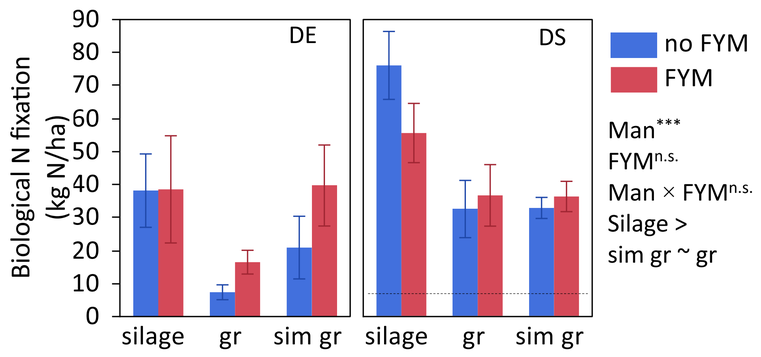
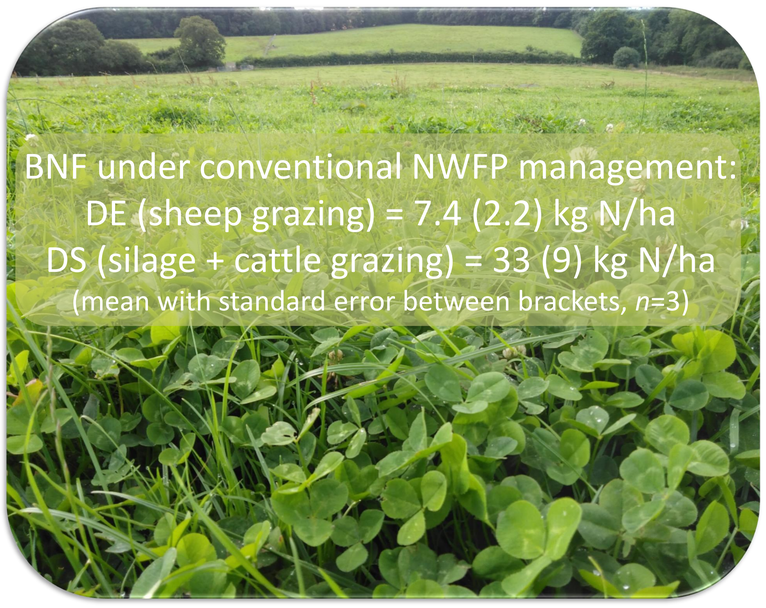



**Figure 3** Biological N fixation during growing season (mean and standard error, *n*=3).

gr = grazing, sim gr = simulated grazing, FYM=farm yard manure, Man=management (silage, gr, sim gr)

Only for DS: gr and sim gr follows spring season of silage (spring silage BNF presented in dashed horizontal line)




The % of N in the clover derived from the atmosphere was high (on average 90%) but not determined by the field management or FYM addition. The biological N fixation (kg N/ha) under the tested conditions was most strongly determined by herbage mass production ($\rho = 0.72^{***}$) and clover content (DM%) in the pasture ($\rho = 0.68^{***}$) but not by the % of N in the clover derived from the atmosphere.

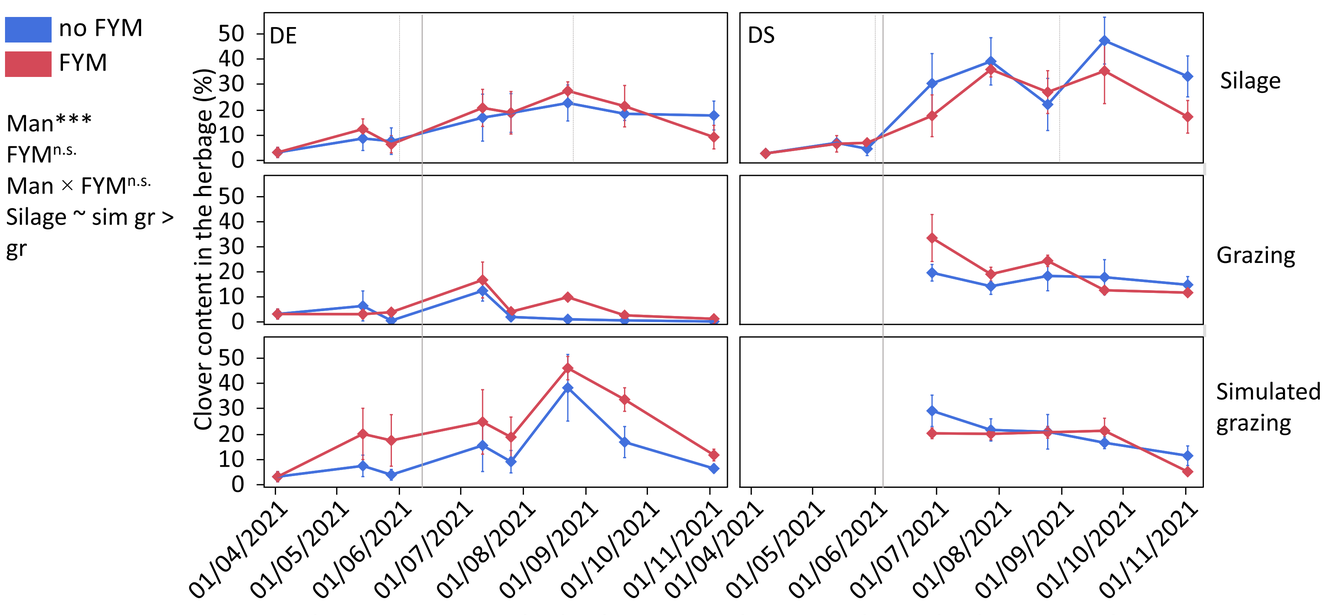



**Figure 4** Clover content in the herbage mass (mean and standard error, *n*=3).
Vertical dotted lines: cutting periods, vertical full line: FYM application

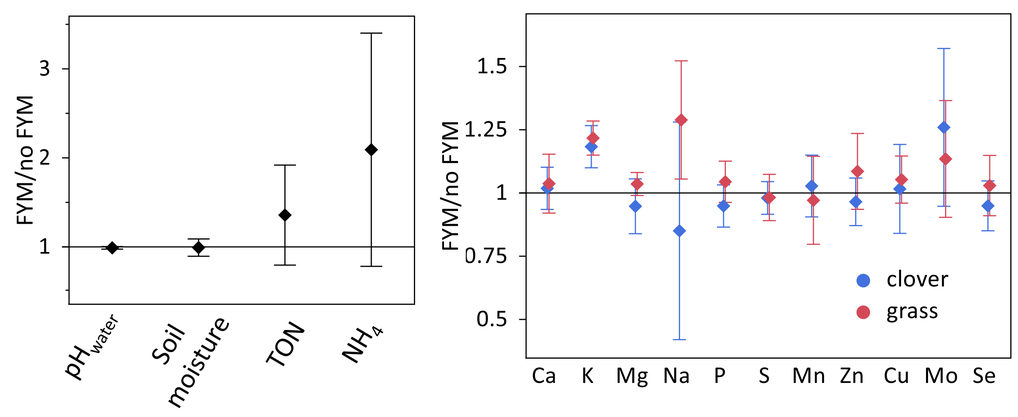



**Figure 5** Response ratio of different variables to the FYM treatment investigated end of July. Mean response ratio's and standard deviation between the field × management combinations are presented (n=6).

Soil mineral N = sum of TON and $NH_4$

## Conclusions

The herbage mass production, clover content and biological nitrogen fixation of a white clover-grass pasture under set-stocking conditions was only affected by the management. The ability of the clover to fix $N_2$ from the atmosphere was not affected by management nor by the FYM addition, but also did not influence the total BNF of the white clover-grass pasture under the conditions tested. Although the FYM had an effect on mineral N, K and possibly also Mo concentration in the clover and grass plants, the addition of the dose generally used on the NWFP (14 ton/ha) did not affect the BNF nor the herbage mass of the white clover-grass pasture under set-stocking conditions.

ROTHAMSTED RESEARCH

**Acknowledgements:**
The North Wyke Farm Platform (NWFP (BBS/E/C/000J0100) and Soil to Nutrition (BBS/E/C/000I0320).
We are very grateful to the large team supporting the field and lab work, namely Morten, C., Dixon, L., Nightingale, S., Mugliston, S., Currie, T., Lawson, H., Le-Grice, J., Manley, A., Searle, D., Tandy, S., Darch, T., Roberts, W., Gregory, W. and Durenkamp, M.

Biotechnology and Biological Sciences Research Council

# THE BROADBALK WHEAT EXPERIMENT 1843 – 2023

Paul Poulton, David Powlson, Andy Gregory
Rothamsted Research

ROTHAMSTED RESEARCH

Broadbalk, 17th August 1925 prior to its division into 5 sections in 1926.

**Started by Lawes and Gilbert in autumn 1843, the Broadbalk Wheat Experiment is a remarkable example of sustainable cereal production. Its original purpose was to maximise the yield of winter wheat using inorganic fertilisers or organic manure. It is now used to study the long-term sustainability of crop yield and is a valuable resource for studying soil processes and their interaction with ground water and the atmosphere. Broadbalk, the accumulated data and the archive of crop and soil samples dating back to 1844, is a unique resource used by scientists from around the world.**

Broadbalk, 17th May 2018 after its division into 10 sections in 1968.

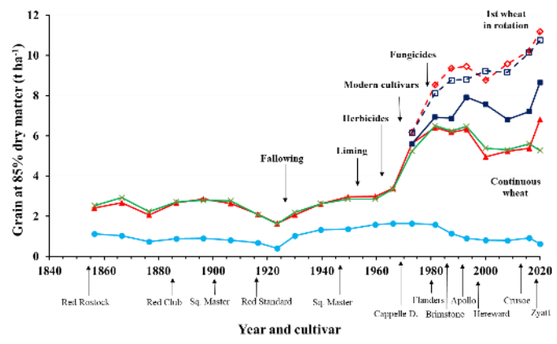



**Fig. 1. Broadbalk Wheat Experiment, 1852-2018.**

Mean yields of wheat grain, t ha$^{-1}$, on selected treatments, showing changes in cultivar and management. Continuous wheat (mean of Sections 1 and 9 after division into 10 sections): ●, Nil; x, (P)KMg+144 kg N ha$^{-1}$; ■, largest yield with (P)KMg+N (max. 288 kg N ha$^{-1}$); ▲, FYM. 1st wheat in rotation: □, largest yield with (P)KMg+N (max. 288 kg N ha$^{-1}$; ◊, FYM+96 kg N ha$^{-1}$ (+144 kg N ha$^{-1}$ since 2005). Updated from Rothamsted Research (2017).

To ensure its continuation and relevance to modern agriculture and environmental science, changes have been necessary. These changes have been made without losing the long-term integrity of the experiment and have included:-

- Rotational fallowing to control weeds from the 1920s until herbicides were introduced in the 1950s.
- Chalk applications since 1953 to maintain soil pH.
- A change from long-strawed to short-strawed cultivars in the 1960s which allowed larger rates of fertiliser N to be tested.
- The use of fungicides since 1979 which meant that we could exploit the potential of higher yielding cultivars.
- Rotations on some sections allows us to compare yields of continuous wheat with those of wheat grown in rotation; the influence of soil-borne diseases can be assessed.

The change from long- to short-straw cultivars doubled grain yield where sufficient nutrients were applied. Wheat grown as a 1st crop after a 2-year disease break resulted in larger yields as did the use of fungicides, larger amounts of N and newer cultivars. The best yields of wheat now exceed 12 t ha$^{-1}$ in some years.

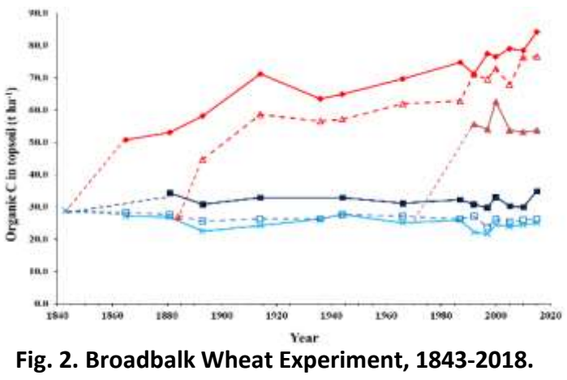



**Fig. 2. Broadbalk Wheat Experiment, 1843-2018.**

Long-term changes in the amount of soil organic carbon in topsoil, 0 – 23 cm, of sections in "continuous" wheat since 1843. x, Nil; □, (P)KMg; ■, N3(P)KMg; ♦, FYM; Δ, FYM N3; ▲, (FYM)N4. Data are adjusted for changes in bulk density. Starting values for 1843, 1884 and 1968 are estimated. From Rothamsted Research (2021).

Larger crops with fertiliser N leave more organic residues which increases soil organic matter (SOM) to a new equilibrium. With 35 t FYM ha$^{-1}$ yr$^{-1}$ the increase is greater. Soil organic C and $^{14}C$ data were used to develop and validate the Rothamsted Carbon Model, RothC which is used world-wide.

Soil and crop samples have been archived since the first harvest in 1844. They have been used extensively to investigate changes, some of which may take decades to become apparent. Examples include the build-up and/or decline of pollutants in the crop or soil, changes in the mineral components of the crop, changes in SOM and nutrient availability in the soil.

**Information can be accessed through the electronic Rothamsted Archive:**
**http://www.era.rothamsted.ac.uk**

Scan the QR code to find out more.

Lawes Agricultural Trust

Poulton, et al. 2023. The Broadbalk Wheat Experiment, Rothamsted, UK. *Advances in Agronomy* (In press)
Rothamsted Research. 2017. Dataset: Broadbalk mean long-term winter wheat yields. Electronic Rothamsted Archive, Rothamsted Research. https://doi.org/10.23637/KeyRefOABKyields
Rothamsted Research. 2021. Dataset: Broadbalk soil organic carbon content 1843-2015. Electronic Rothamsted Archive, Rothamsted Research. https://doi.org/10.23637/KeyRefOABKsoc-02
We thank the Lawes Agricultural Trust and Rothamsted Research. The Rothamsted Long-term Experiments-National Bioscience Research Infrastructure is funded by the UK Biotechnology and Biological Sciences Research Council (BB/CCG2280/1).

UKRI Biotechnology and Biological Sciences Research Council

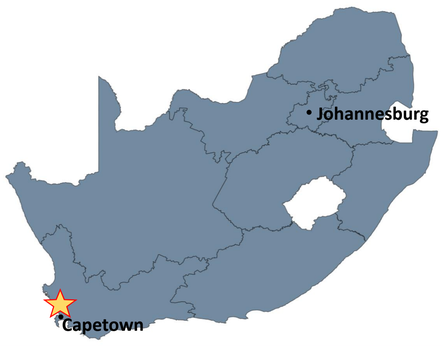
# Long-term effects of tillage on soil carbon and crop production within a diverse crop rotation

Louis Daneel du Preez (dupreez.daneel@gmail.com), Pieter Swanepoel (Stellenbosch University), Francis Rayns (Coventry University), James Bennett (Coventry University), Johan Labuschagne (Stellenbosch University), Annemarie van der Merwe (Wester Cape Department of Agriculture)

## INTRODUCTION

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 of critical significance for local farmers.

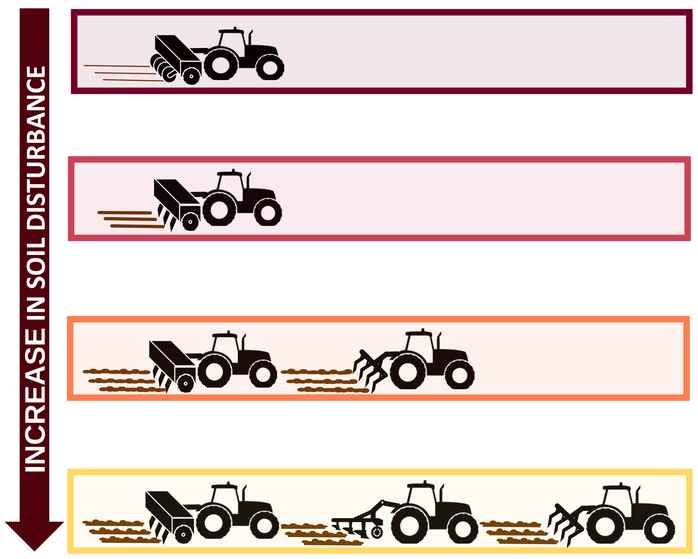
**South Africa**
Langgewens Research Farm




A long-term study was established 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 albus L.*).

## METHOLOGY

### TILLAGE → SPLIT PLOT DESIGN ← CROP ROTATION

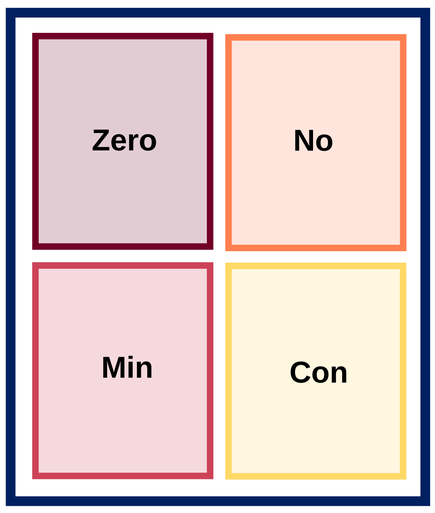



**Zero tillage (Zero)**
Planted with a disc planter.

**No tillage (No)**
Planted with a tine planter.

**Minimum tillage (Min)**
Cultivated with a tine implement and planted with a tine.

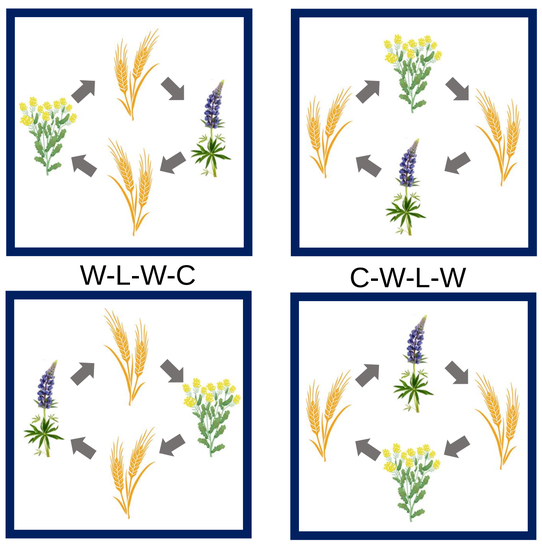
**Conventional tillage (Con)**
Cultivated with a tine implement, followed by a plough and planted with a tine.




Crop sequence represented as the main plot, with tillage systems as sub plots.

**Crops in rotation:**
Wheat (W)
Canola (C)
Lupin (L)

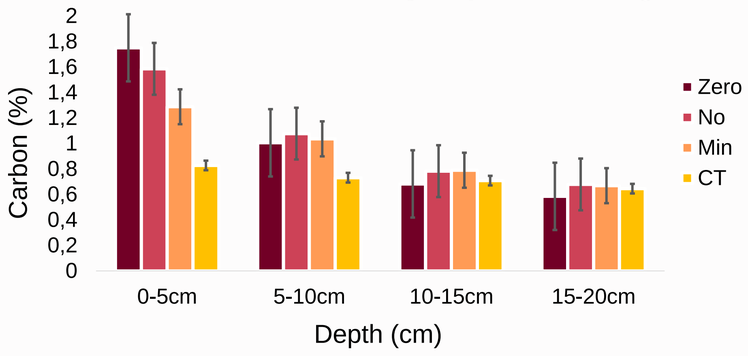
The system consist of a 4-year crop rotation with every crop present each year. Resulting in 4 cropping sequences as seen in the diagrams to the right.




## RESULTS AND DISCUSSION

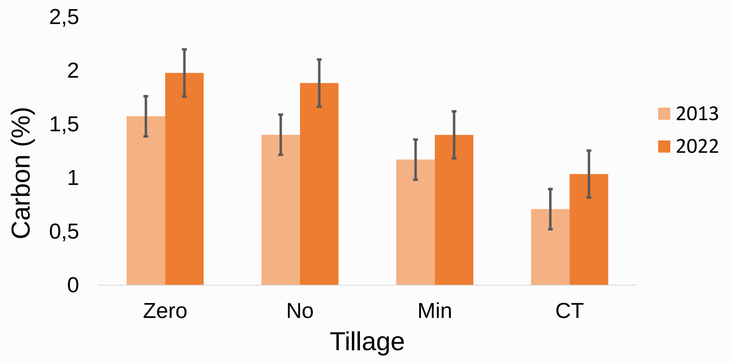
### Soil carbon (%)

**Mean carbon content by depth and tillage**




Less aggressive tillage treatments with lower soil disturbance resulted in higher levels of carbon sequestration in the upper 10cm of the soil.

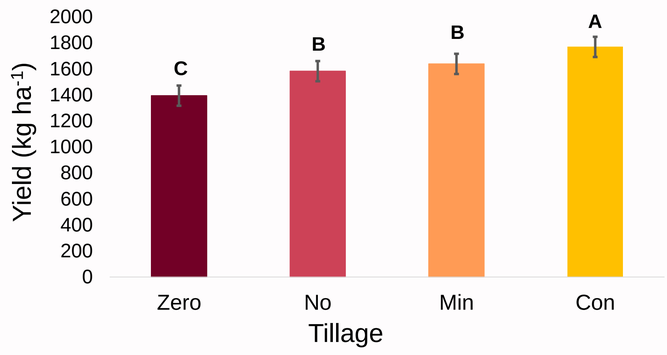
**Mean soil carbon increase**




Over a 9-year time period the combined depth mean amount of carbon sequestration increased for all tillage treatments. The highest mean obtained by zero till, decreasing with more aggressive tillage treatments.

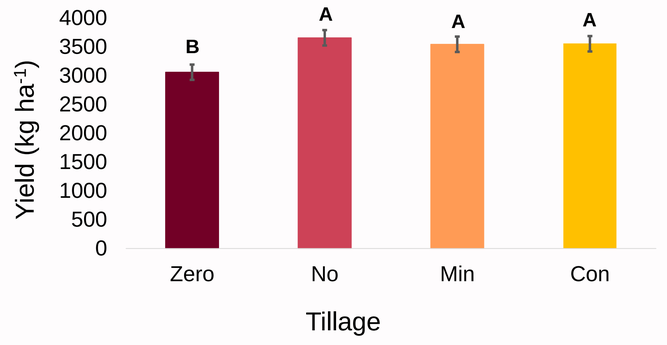
### Yield (kg ha$^{-1}$)

**Canola mean yield over 16 years**




Aggressive tillage treatments produced higher yields, decreasing significantly with less aggressive treatments.

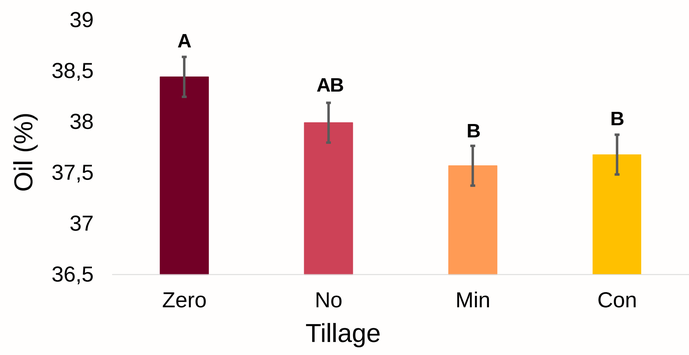
**Wheat mean yield over 16 years**




Mean grain yields within tillage treatments varied mostly insignificantly, with only zero till producing significantly less than that the rest of the treatments.

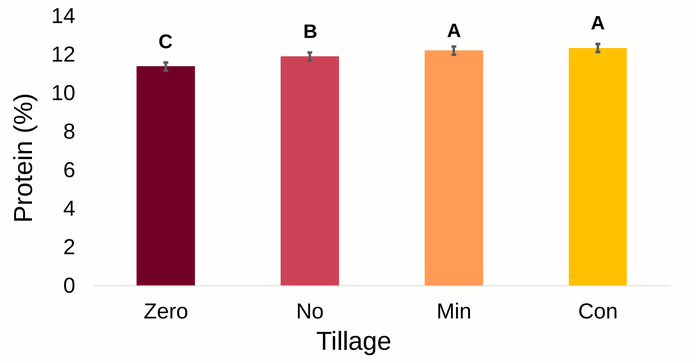
### Oil and protein content

**Canola mean oil over 16 years**




Canola seed oil quality (presented as oil %) produced highest percentages at less aggressive treatments decreasing significantly with more aggressive tillage treatments.

**Wheat mean protein over 16 years**




Wheat quality (presented as protein %) produced highest percentages at more aggressive treatments decreasing significantly with less aggressive tillage treatments.

## CONCLUSION

Special thanks to the Western Cape Department of Agriculture for permission to use the trial data.

The long-term trials have clearly shown an overall increase of soil carbon sequestration throughout the 16-year trial period. Less aggressive tillage practices had the largest effect on carbon sequestration at shallower soil depth intervals. Even though an increase in carbon sequestration is beneficial for improving soil structure, decreasing erosion and mitigating global warming, the effect didn't result into significant increases in yield and protein. The no tillage treatments had a positive effect on carbon sequestration without drastically lowering yields, oil and protein content and may prove to be the best choice for the Swartland district. The future of sustainable farming will require trade-offs, and it will be up to the farming and science community to determine where sustainability and profitability meets.

Thanks to the South African Winter Cereal Industry trust for financing the research trials.

Western Cape Government FOR YOU

SAWCIT

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT

Research Centre Agroecology, Water and Resilience

Coventry University

WAGENINGEN
UNIVERSITY & RESEARCH

# BASIS, long-term reduced tillage in a conventional and organic farming system on a sandy loam soil

Authors | Derk van Balen, Maria-Franca Dekkers, Wiepie Haagsma and others

## Background

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. Whereas reduced tillage has a positive effect on biodiversity and resilience. There is limited data on the effect of reduced tillage with arable crops on sandy loam soil.

## Objective

Is it possible to have a comparable yield with reduced tillage compared to deep inversion tillage in a conventional and organic crop totation containing potato, sugar beet, carrot and onion?

## Introduction

The BASIS experiment was set up in 2009 on a sandy loam soil in Lelystad, NL(Figure 2a&2b). There is a four year conventional and a six year organic crop rotation (Figure 1). Soil consists of 61% sand, 22% silt and 17% clay and an average organic matter content of 3,5%. Crops are grown in a Controlled Traffic farming system with 3.15m strips (Figure 3a&3b)

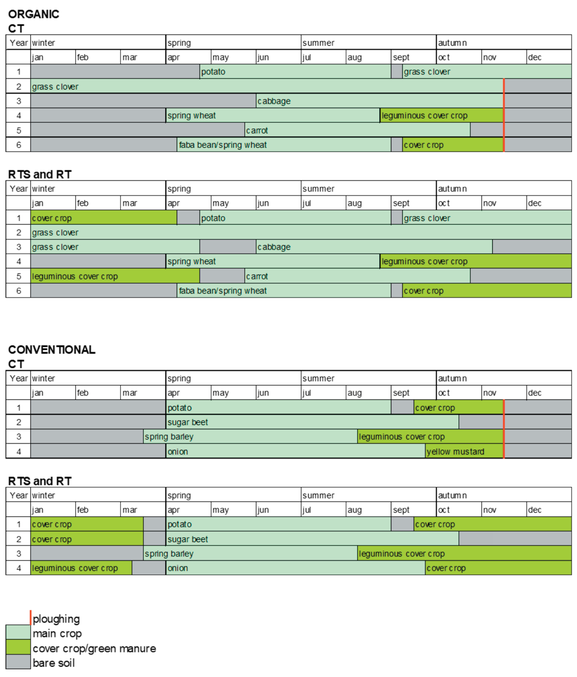



***Figure 1|*** *Soil cover, crop rotation and cover crop scheme for each farming system*

## Result in Yield

The marketable yield of 12 (RTS) and 11(RT) of the 13 crops grown in reduced tillage was similar or even higher over a 10 year period, compared to conventional (CT) tillage (Figure 4). Reduced tillage increased aggregate stability (Crittenden, 2015).

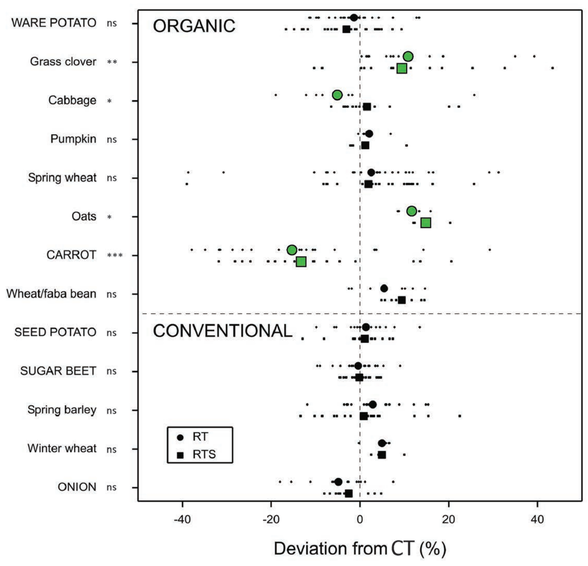



***Figure 4|*** *Relative marketable crop yields in RT (reduced tillage) and RTS (reduced tillage with subsoiling) compared to CT (conventional tillage = 100%). The large symbols represent marketable yields in RT (circles) and RTS (squares) relative to CT. (van Balen et al, 2023)*

## Results: soil quality

When reduced tillage is compared with conventional tillage we find:

- Total higher biomass of earthworm. Increase in total biomass of earthworm in the conventional system. But decrease of total earthworm abundance in organic system (Crittenden, 2015).
- Increase in aggregate stability
- Increase of fungal and bacterial biomass, labile carbon and nitrogen (Figure 5).
- Higher shannon index beetle population (Figure 6).
- Increase of C in toplayer (0-15). Increase of C in organic (Figure 7)

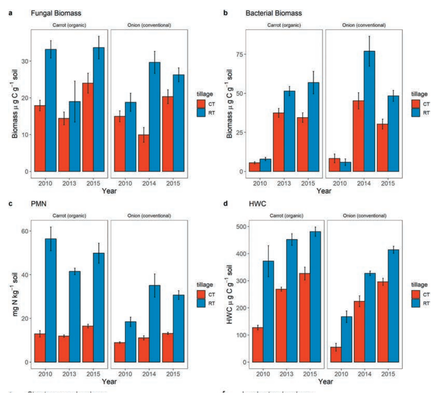



***Figure 5|*** *Fungal and bacterial biomass, PMN and HWC (Kurm et al, 2023).*

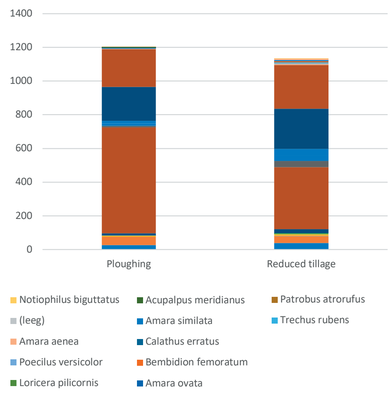



***Figure 6|*** *Number of beetle per species per soil tillage system (Stef Grolleman, 2022)*

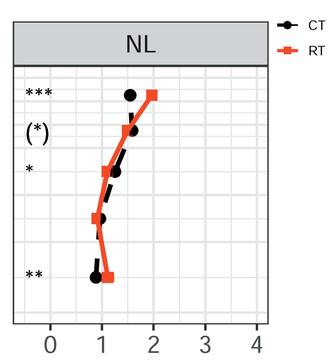



***Figure 7|*** Profile distribution of absolute SOC stocks (Mg $ha^{-1}$ $cm^{-1}$) c of the respective soil layer per tillage system (CT = mouldboard ploughing, RT = reduced tillage) (Krauss et al, 2022)

***Figure 3a|*** *CTF tractor*

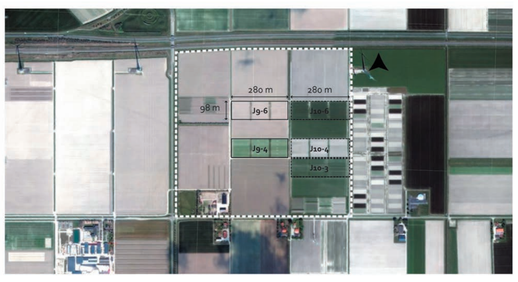


***Figure 2a|*** *Aerial view of the Wageningen University experimental farm and BASIS experiment*

***Figure 3b|*** *CTF combine harvester*

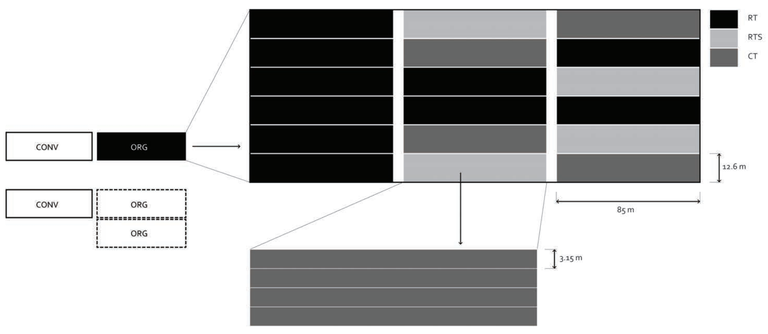



***Figure 2b|*** *Figure 2b. Layout of the trial fields of the BASIS experiment*

## Conclusions

- Crop yield in reduced tillage is comparable for most crops.
- Increase in biodiversity (number of species)
- More stable soil aggregates.
- This farm-scale experiment makes it possible to test the practical feasibility of measures.
- LTE's make it possible to deal with issues in the long and short term. Interested in this experiment? Contact: derk.vanbalen@wur.nl

## Acknowledgements

This work was supported by the Dutch Ministry of Agriculture, Nature and Food Quality and private institutes through the Public Private Partnership (PPP) 'Beter Bodem Beheer'.

Wageningen University & Research
P.O. Box 123, 6700 AB Wageningen
Contact | ***derk.vanbalen@wur.nl***
T| +31 (0)320 29 13 43 M| +31 (0)6 30 36 31 18

WAGENINGEN
UNIVERSITY & RESEARCH

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

**JenYu Chang[1, a], Chia-Chen Pan[2], Dah-Jing Liao[1], Rei-Chang Wang[2], Jenn-Kuo Tsai[1], Chi-Ling Chen [1, b]**

[1] Taiwan Agricultural Research Institute, Council of Agriculture, Executive Yuan

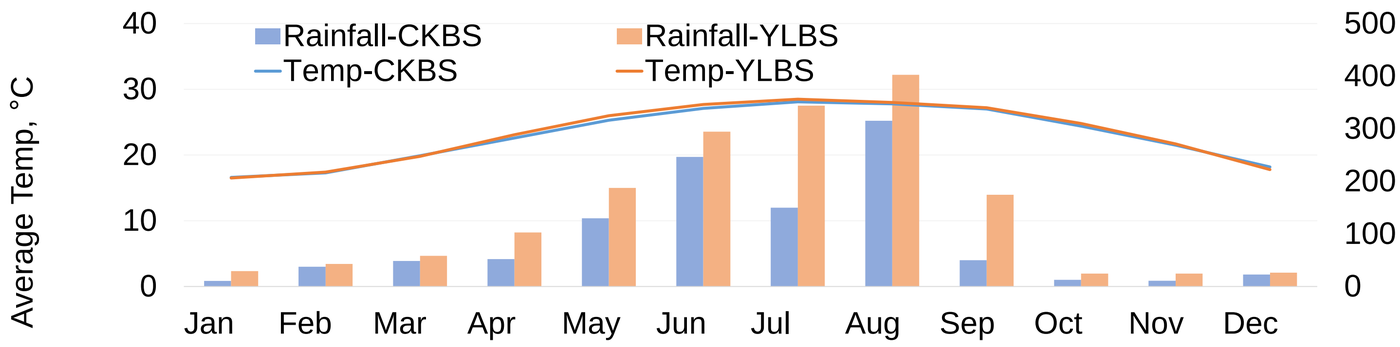
[2] Tainan District Agricultural Research and Extension Station, Council of Agriculture, Executive Yuan

[a] https://www.researchgate.net/profile/Jenyu-Chang; e-mail: jychang@tari.gov.tw

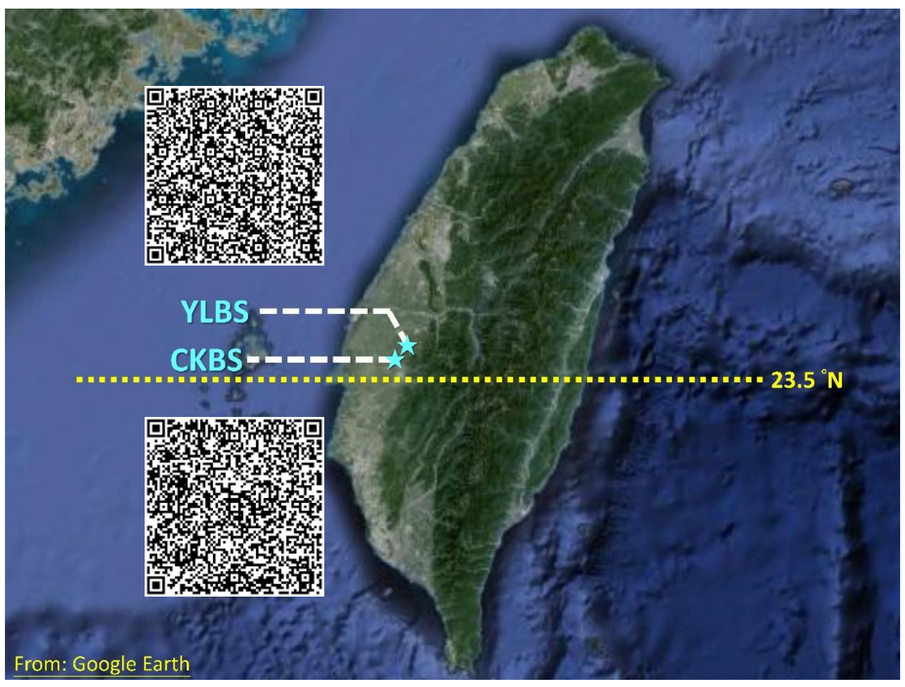
[b] corresponding author: chiling@tari.gov.tw

## Introduction

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.




| site | altitude | topsoil texture | fertilizer input (N input, kg/ha) |
|---|---|---|---|
| CKBS since 2006 | 16 m | Silt loam to loam | CA: 120-180; SA: 80-100 |
| YLBS since 2009 | 37 m | Sandy loam | CA: 160-180; SA: 100 |

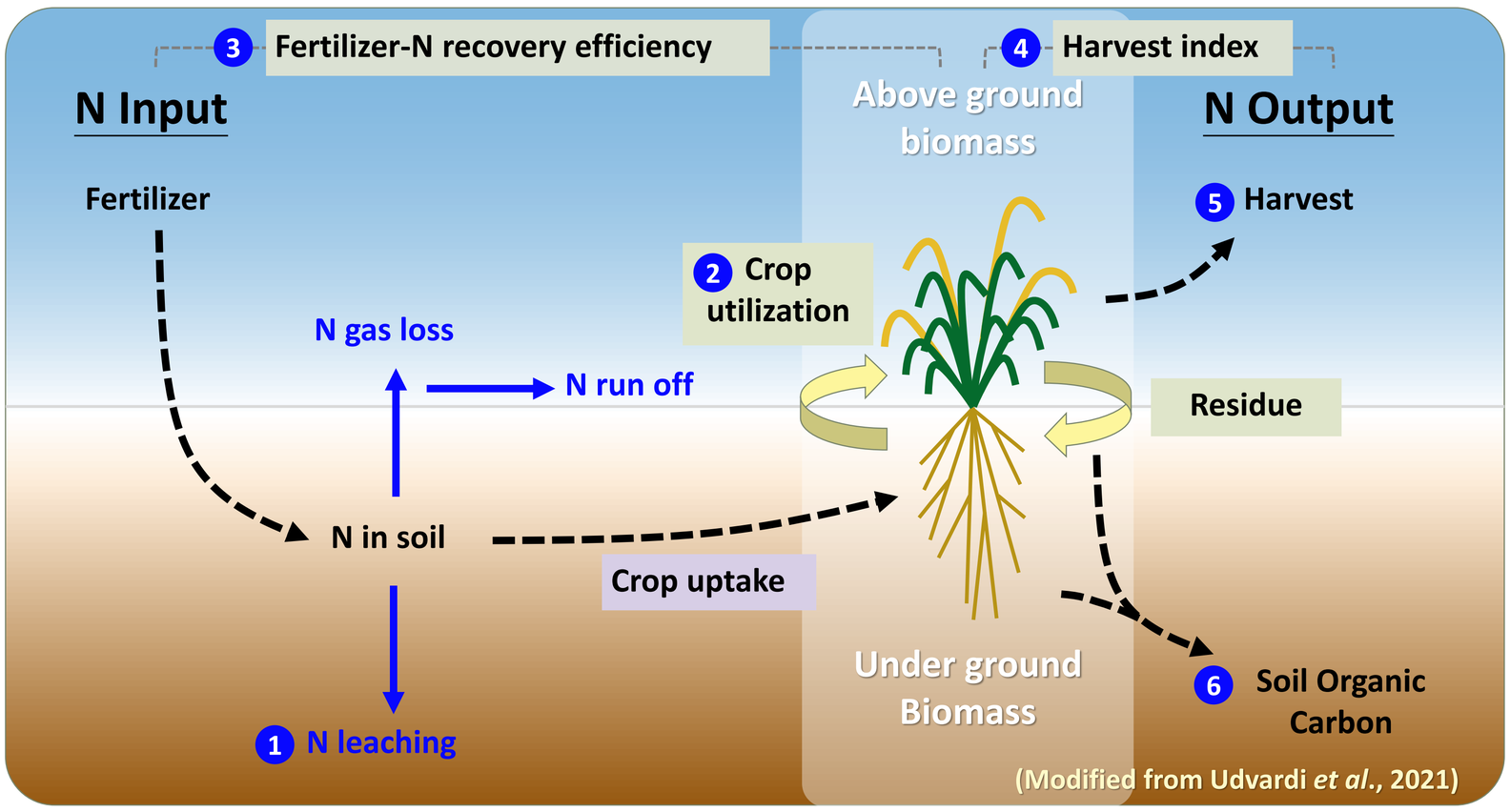


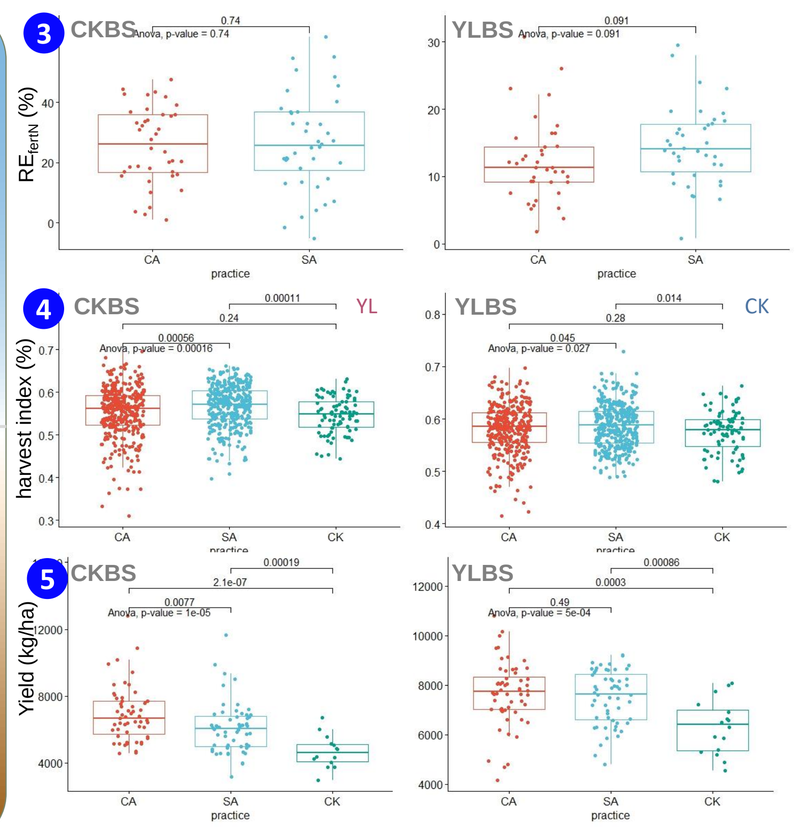

## Materials and Methods

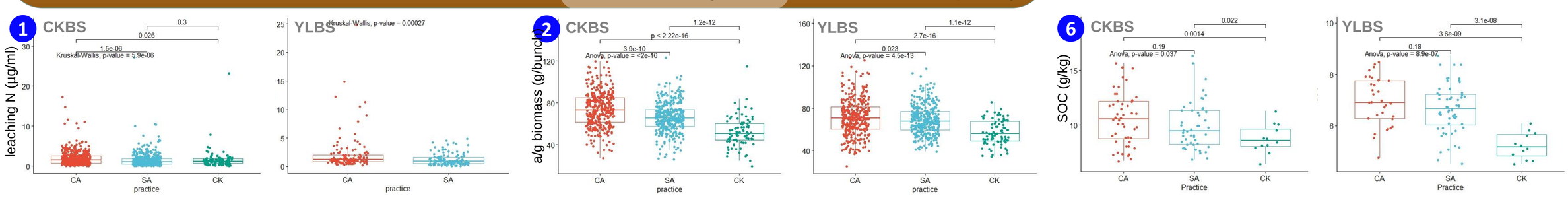
The long-term experiment of different nitrogen inputs to monocropping paddy rice 'Tainan No. 11' was conducted in Chi-Kuo branch station (CKBS, code in DEIMS: LTER-EAP-TW-8) and Yuin Lin branch station (YLBS, code in DEIMS: LTER-EAP-TW-7). Six variables including nitrogen content in leaching water, nitrogen use efficiency (fertilizer-N recovery efficiency, $RE_{fertN}$ was calculated as the indicator), above ground dry matters (a/g biomass), harvest index (HI) investigated yield, and soil organic carbon (SOC) were compared between high nitrogen inputs (CA, 120 to 180 kg/ha in CKBS and 160 to 200 kg/ha in YLBS), moderate nitrogen inputs (80 to 100 kg/ha in CKBS and 100 kg/ha in YLBS), and without nitrogen inputs (CK).

## Results and Discussion

High nitrogen inputs (CA) resulted in more above-ground dry matter and yield compared with moderate nitrogen inputs (SA). However, the harvest index 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 (28.3% and 72.9% increase 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.



UNIVERSITY OF DEBRECEN

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

Vivien PÁL[1], László ZSOMBIK[1]

[1]*University of Debrecen, Institutes for Agricultural Research and Educational Farm, Research Institute of Nyíregyháza, Westsik Vilmos út 4-6, Nyíregyháza, Hungary*

## *Introductions*

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. With the right choice of forecrops and green manure crops in crop rotations, we can make a sustainable contribution to increasing the yield of cash crops.

## *Materials and methods*

The experiment was set up in Hungary, University of Debrecen Research Institute of Nyíregyháza in 2019 (*Figure 2*), 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 (*Figure 3*) in which green-manure, fertilizer (80 kg ha$^{-1}$ N), and control treatments were applied in a randomized block design. The datas of the precipitation during the examined crop seasons are shown in *Figure 1*.

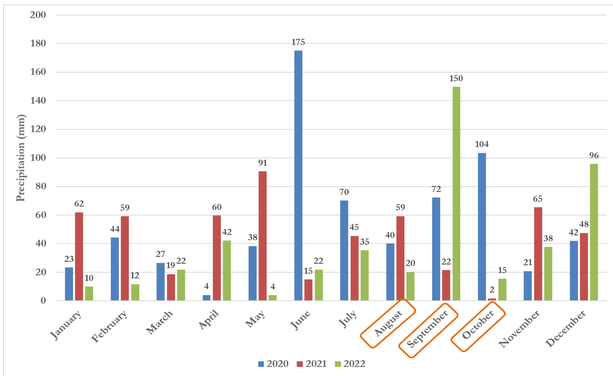



*Figure 1. Monthly amount of precipitation in 2020, 2021 and 2022 in Nyíregyháza*

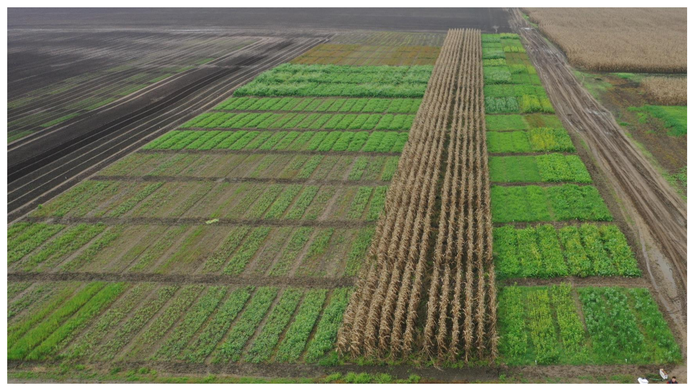


*Figure 2. Experimental area*

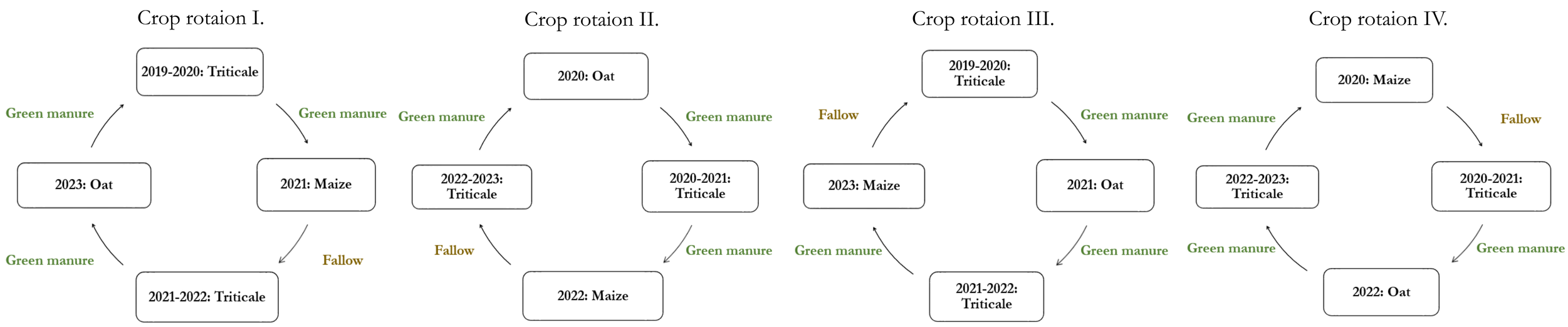



*Figure 3. Flow diagram of the studied crop rotation systems*

## *Results and conclusion*

We found higher soil moisture content levels in May-July after green manure treatments (*Figure 4 and 5*). 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 (*Figure 9*). For oats yield, in the case of wet autumn period, the results of the common vetch green manure treatment significantly exceeded the effect of the other treatments (*Figure 8*). In maize, in a regular cropyear (2021), the effect of leguminous green manure plants proved to be equivalent to the fertilized treatment (*Figure 6*), however, in an extremely dry season (2022), in the case of plots treated with leguminous green manure plants the maize yield significantly exceeded the values of the control and fertilized areas (*Figure 7*).

Based on these results, we have justified reasons to use green manures in our crop rotations as a nutrient supply method. It has a positive effect on the soil's moisture content, furthermore the input requirement, and the carbon footprint of the cultivation can be reduced.

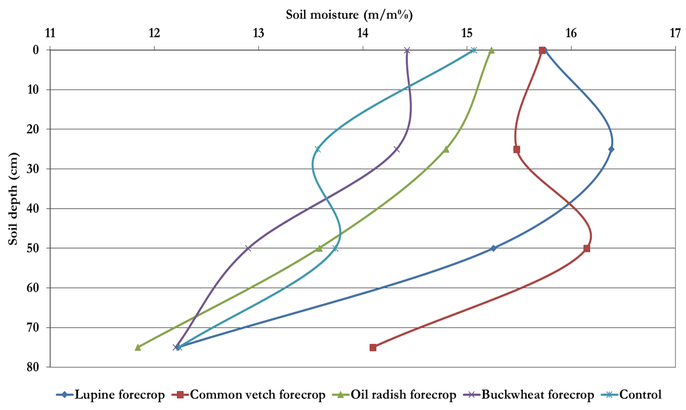



*Figure 4. Soil moisture content in maize in case of green manure and control treatments (2021. 05. 19)*

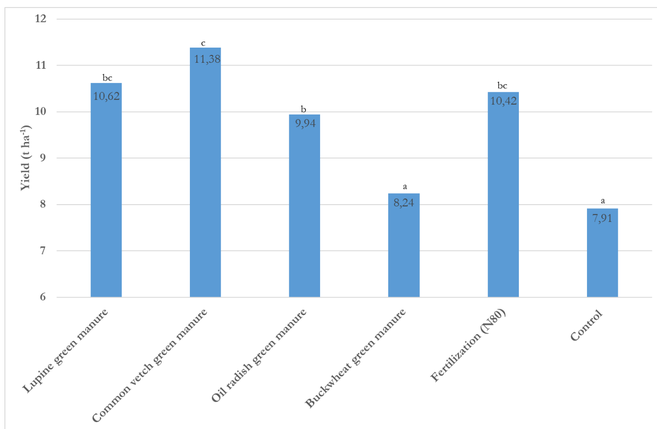



*Figure 6. Effect of different green manure, fertilizer, and control treatments on maize yield in 2021*

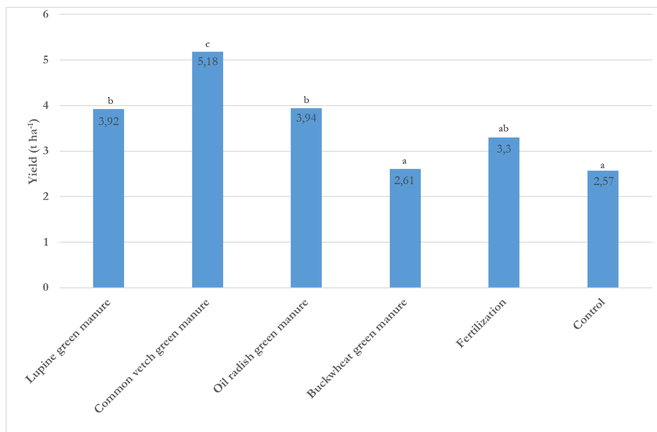



*Figure 8. Effect of different green manure, fertilizer, and control treatments on oat yield in 2021*

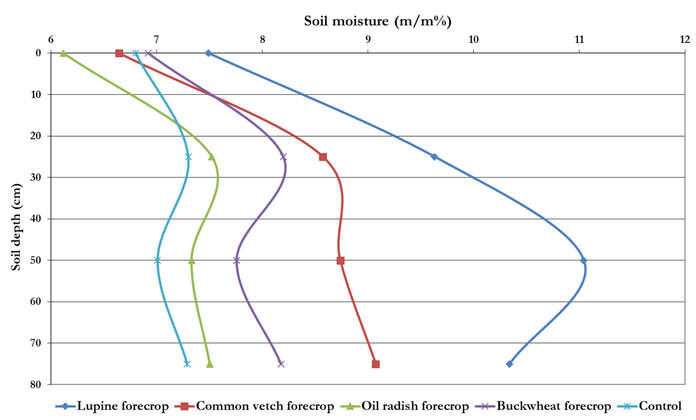



*Figure 5. Soil moisture content in triticale in case of green manure and control treatments (2021. 07. 01)*

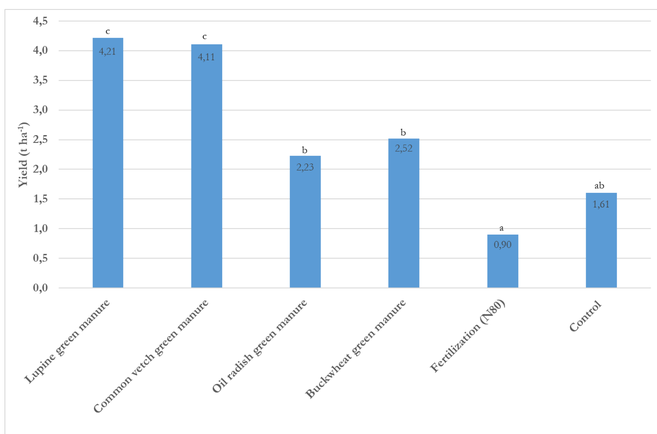



*Figure 7. Effect of different green manure, fertilizer, and control treatments on maize yield in 2022*

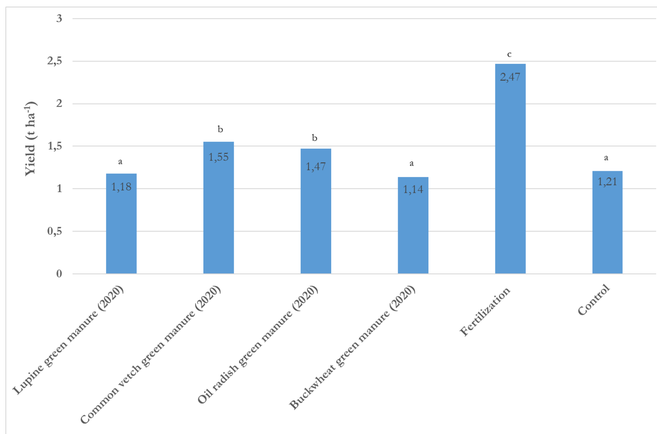



*Figure 9. Effect of different green manure, fertilizer, and control treatments on triticale yield in 2022*

*Project no. [1020024] has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the [KDP-2020] funding scheme.*

Contact: pal.vivien@agr.unideb.hu

# Long-term effect of rotation on wheat production and selected soil nutrients in the Mediterranean region of South Africa

A van der Merwe[1*], J Labuschagne[2] & M Booyse[3]

[1]Directorate: Plant Sciences, Western Cape Department of Agriculture, South Africa
[2]Department of Agronomy, University of Stellenbosch, South Africa
[3] Agricultural Research Council Biometry, South Africa

*Corresponding author: Annemarie.vanderMerwe@westerncape.gov.za

## INTRODUCTION

The adoption of Conservation Agriculture (CA) in the Western Cape province of South Africa and climate change brings a new dimension to the importance of gathering information from long-term experiments (LTE). The aim is not the highest yield, but rather a more sustainable optimum yield, especially during unfavourable growing seasons.

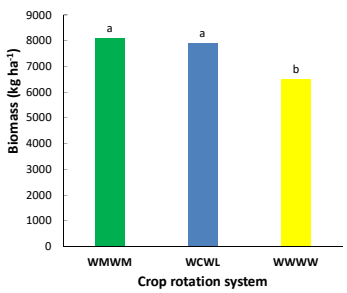
## OBJECTIVE

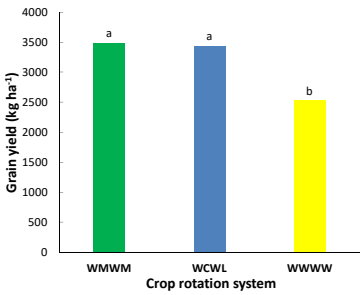
Wheat biomass production, yield and grain protein content are an indication of each rotation system's productivity. The soil organic carbon (SOC), phosphorus(P) and potassium(K) content were used as an indicator of soil fertility within each system.

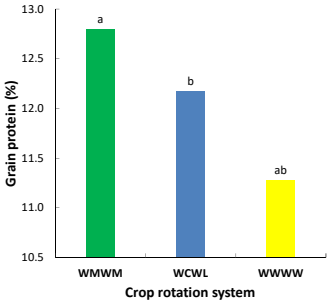
## MATERIAL & METHODS

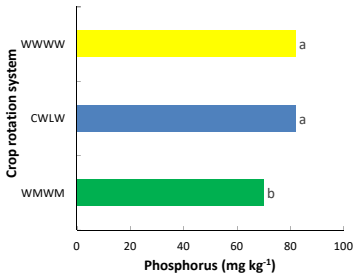
The LTE was established in 2007 at Langgewens Research Farm (33°17'0.78'' S, 18°42'28.09'' E). The experiment consists of 3 crop **rotation systems**- medics/wheat **(MWMW**), canola/wheat/lupine/wheat **(CWLW**) and wheat monoculture (**WWWW).** The average biomass, grain yield and protein content of the last 10 years (2013-2022) were used. Soil samples were taken for the depth of 0-15 cm after 14 years and compared to the average initial P (89 mg $kg^{-1}$), K (199 mg $kg^{-1}$) and C (1.02%) values.

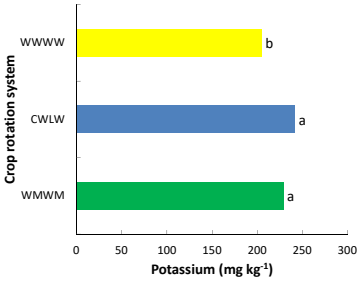
## RESULTS

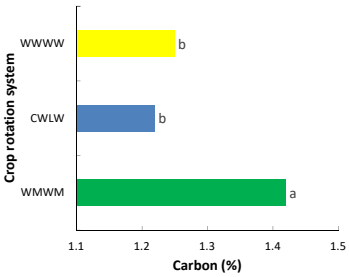




## DISCUSSION

The mean biomass and wheat yield was significantly higher in the WMWM and CWLW systems in comparison to the WWWW. The protein content of the WCWL system was significantly higher than the other two rotational systems. The inclusion of legumes into a cropping system increases N availability for greater biomass production. Due to the grading system of wheat, a premium is paid for higher protein content. WMWM had a significantly higher SOC than the other 2 systems. This may be explained by less soil disturbance as medics are self-regenerative. Medics have a very fibrous root system, in comparison to canola and lupines contributing to the SOC.

## CONCLUSION

The wheat monoculture system is not sustainable. The inclusion of legumes enhances sustainability. Even though the SOC in the CWLW and WWWW system was significantly lower than MWMW, the biomass and yield of only the WWWW were significantly lower.

## ACKNOWLEDGEMENT

Winter Cereal Trust and South African Winter Cereal Industry Trust

# Organic cropping systems maintain yields but fail in yield levels and yield stability

**Jochen Mayer*, Paul Mäder and Samuel Knapp**
Agroscope, 8046 Zurich, Switzerland; www.agroscope.ch

**Summary**

- Organic and conventional systems showed similar 40 year temporal yield trends.
- Organic yields were significantly reduced only in non-legumes (13% to 34%).
- Applied mineral N forms determined yield levels mainly in winter wheat and potatoes.
- Similar absolute stability, but better relative stability in conventional systems.
- Fertilisation level determined yield potential, crop protection yield stability.

## Introduction

- 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 non-renewable resources require new solutions for future cropping systems beyond existing management practices.

We analysed 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.

## Long-term experiment and methodology

- The experiment has a seven-year rotation, where bio*organic* and bio*dynamic* systems are compared with *conventional mixed* and *sole mineral* fertilised systems, at reduced half and regular fertilisation level.
- Yield data comprises winter wheat, potatoes, grass-clover, maize, and soybean.

**Treatments**

| | |
|---|---|
| NOFERT | unfertilised control |
| BIODYN 1 / 2 | bio-dynamic system at half / regular fertilisation |
| BIOORG 1 / 2 | bio-organic system at half / regular fertilisation |
| CONFYM 1 / 2 | conv. mixed system at half / regular fertilisation |
| CONMIN 2 | conv. mineral system at regular fertilisation |

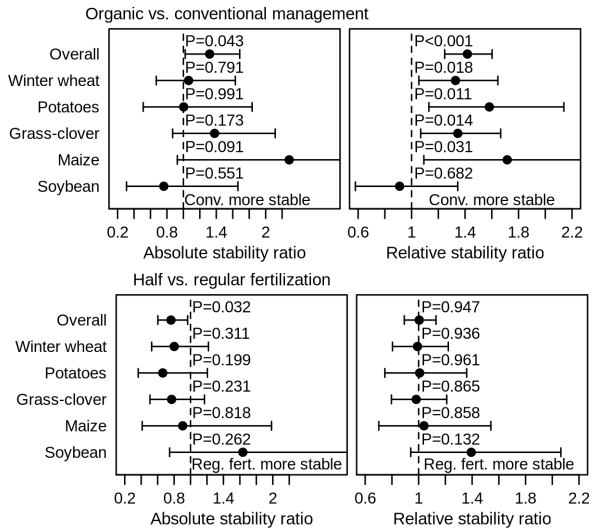



Fig. 2: Absolute (variance) and relative (CV) stability of organic and conventional cropping systems and half and regular fertilisation

## Results

- Yields were significantly reduced in organic systems in non-legumes between 13% and 34 (Fig. 1).
- No yield reduction was observed in soybean and only 10% in grass-clover ley.
- Half fertilization reduced yields by around 10%.
- Applied mineral N forms determined yields mainly in winter wheat and potatoes.
- Temporal yield trends were not different between organic and conventional systems, nor between half and regular fertilisation.

- 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 fertilisation. This suggests that the variation in relative stability between organic and conventional management might be more related to plant protection than to fertilization intensity.

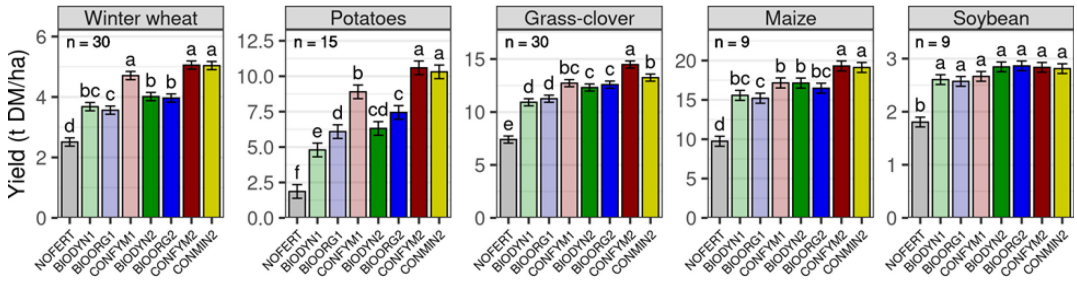



Fig. 1:
Crop yields over 40 years in in organic and conventional cropping systems at half and regular fertilisation

*jochen.mayer@agroscope.admin.ch

FiBL

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
Agroscope

Agroscope good food, healthy environment

# Long-term grassland experiments in Norway.

## Grassland yields and botanical succession at Fureneset.

Kvifte, Å.M., Øpstad, S.L. and Sturite, I.

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

## Location and history of experiments

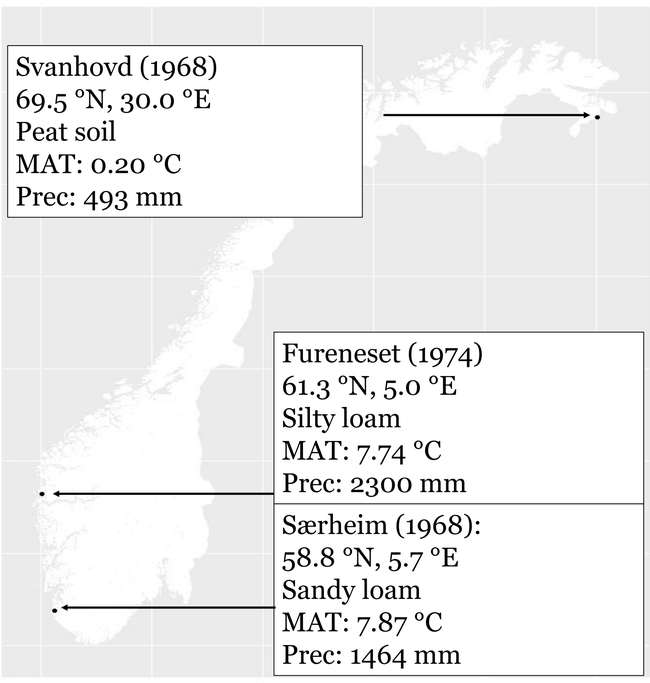
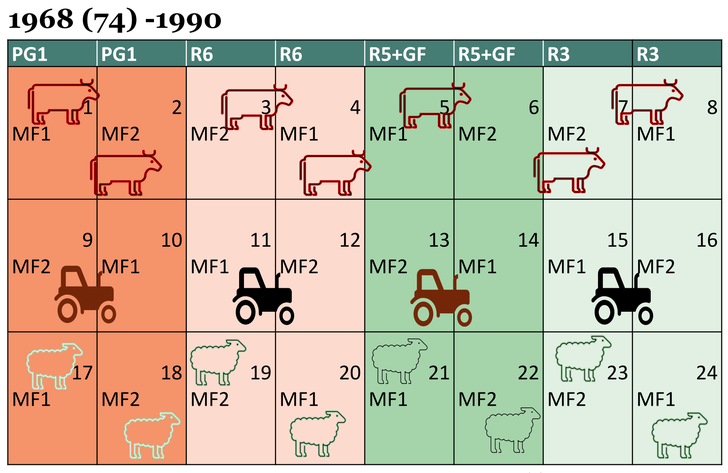



Figure 1: Locations of the experiments, soil type and mean annual temperature (MAT) and precipitation (Prec) (1991 – 2020)

## Experimental design over time

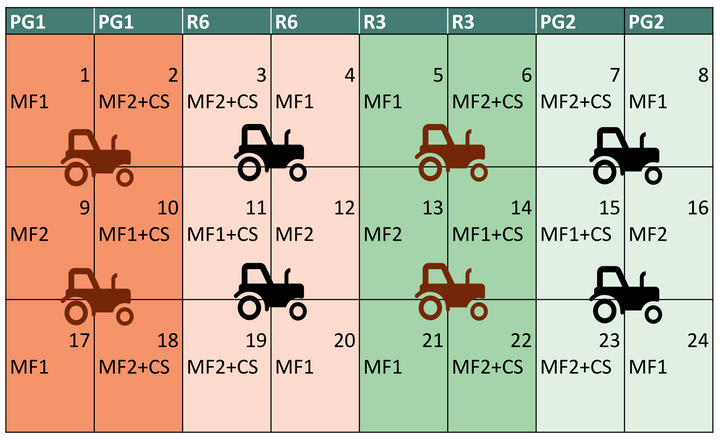
**1968 (74) -1990**




PG1 –permanent grassland
R3 – renewed every 3rd year
R5+GF – 5 years ley and one year green fodder
R6 – renewed every 6th year
MF1 – mineral fertiliser, relevant rate
MF2 – 50% more than MF1

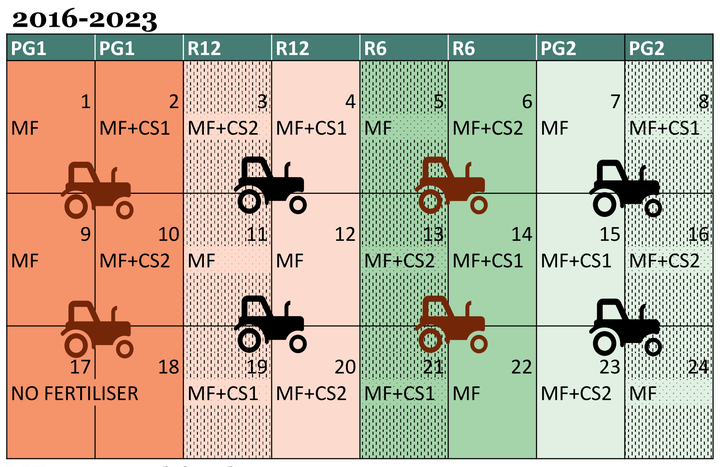
2 harvests + autumn grazed
2-3 harvests
2 harvests + spring and autumn grazed

**1991-2011**




PG2 – permanent grassland since 1991
+CS – cattle slurry

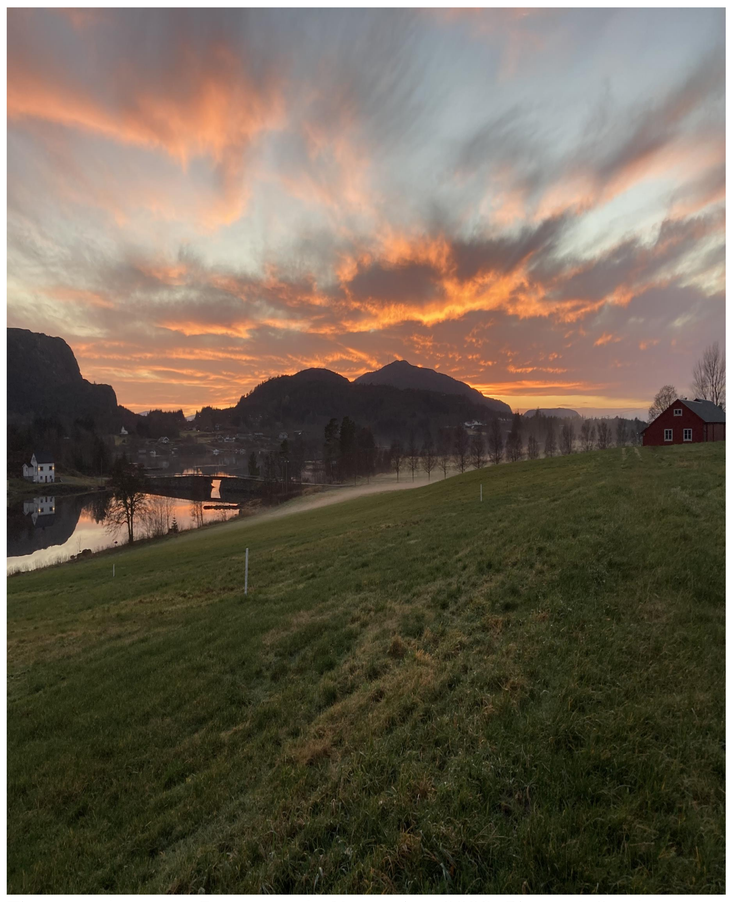
**2016-2023**




MF – mineral fertiliser
+CS1 – cattle slurry 30Tha$^{-1}$
+CS2 – cattle slurry 60Tha$^{-1}$
R12 – renewal evey 12th year

Sod-seeding every third year

Figure 2: Experimental setups for long-term grassland experiments in Norway.



The experiment at Fureneset in November 2022. Photo: I. Sturite

## Factors investigated and measurements taken

The experiments were established at several locations (fig 1) to investigate optimal renewal rates of grassland, and how often the grassland should be cut and/or grazed. The design has changed over time (fig 2) to remain agronomically relevant and economically feasible. The permanent grassland from 1991 was renewed in 2016 at the start of the 3rd experimental period. There are three replicates(blocks)per location. Yield, forage quality and visually determined botanical composition are registered throughout the decades. Soil analyses are carried out unfrequently.

At present, the following factors are investigated:

- Fertilizer types and application rates
- Renewal frequency
- With and without sod-seeding
- Seed mixtures (linked to renewal frequency and sod-seeding)

**Results** from the last period at Fureneset 2016-2022 show:

- Dry matter yield (fig 3)
- Soil organic matter (SOM)content in 2019(fig 4)
- Botanical composition of the first cut in 2022 (fig 5)

Other measurements during this period are soil physical and chemical properties and forage quality (results are not shown).

## Some conclusions

- Renewal of grassland causes yield increase, however, too-frequent renewals may risk yield loss in the year of renewal and this can be larger than the yield gain attained subsequent years.
- Distribution of SOM down to 29 cm depth seems to be more affected by renewal strategy than total amount of SOM.
- Fertilisation regime affects botanical composition.

## Results since 2017

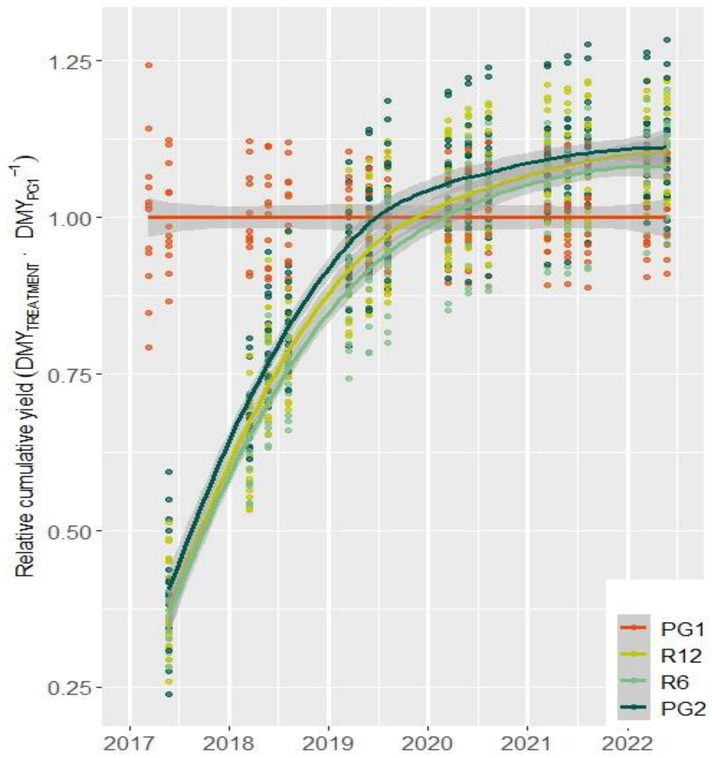



Figure 3: Dry matter yield on renewed relative to permanent grassland (PG1) Dots represent individual plots and cuts. With an average annual PG1 yield of 8.7 tonnes per ha dry matter, and 0.17 tonnes increase in the renewed treatments, it takes 5 years before all treatments significantly overyield PG1.

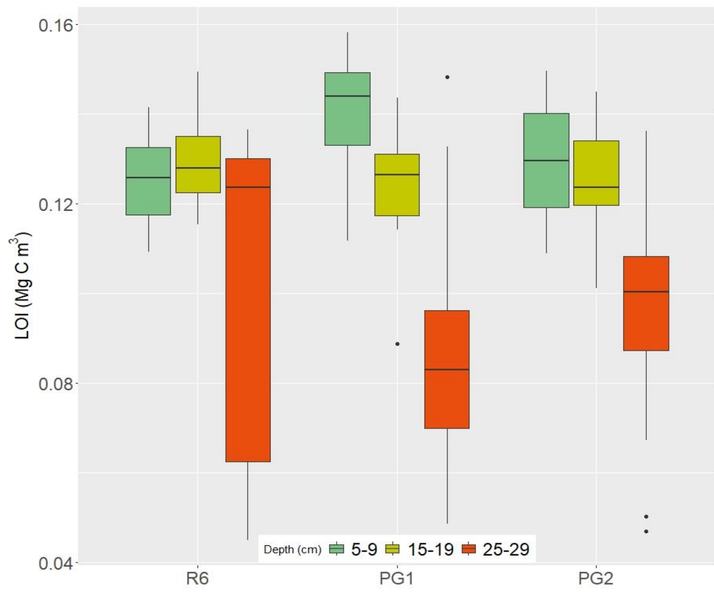



Figure 4: Organic matter content in 2019 of different treatments. There is a difference in distribution of organic matter, but we haven't found a difference in total amounts. LOI is used as a proxy for organic matter and carbon content. This is likely valid as the clay content is low.

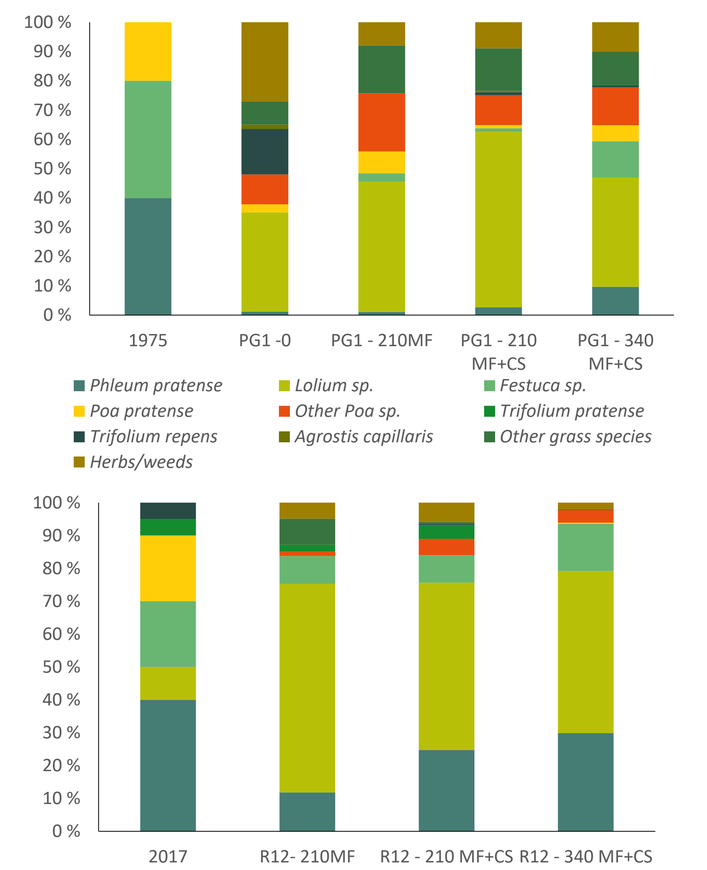
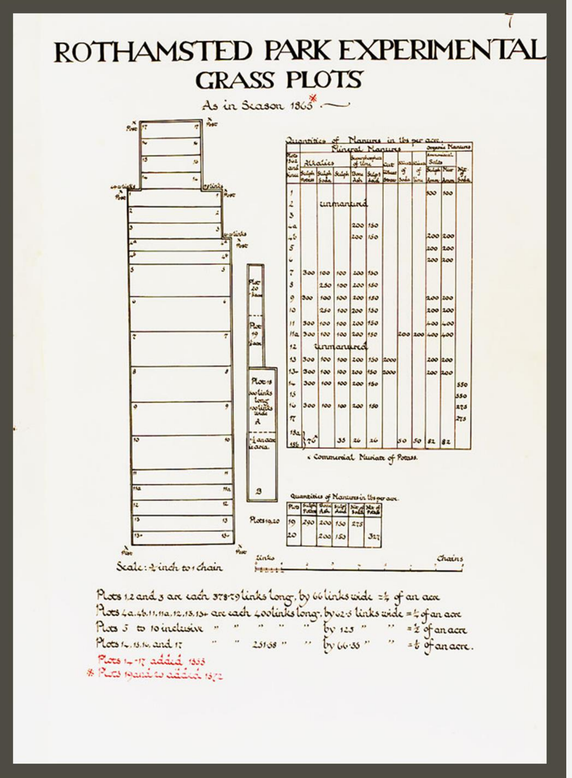



Figure 5: Species botanical composition (% of dry biomass) in the permanent grassland in 1975 and in 2022 (A) and in renewed grassland in 2017 and in 2022 (B) at Fureneset.

Contact info: Ievina Sturite: Ievina.Sturite@nibio.no Åsmund M. Kvifte: Asmund.Kvifte@nibio.no

nibio.no

PO Box 115, N-1431 Ås, Norway
+47 406 04 100




# PARK GRASS OVER 160 YEARS: CARRYING CAPACITY AND NUTRITIONAL COMPOSITION ARE DRIVEN BY FERTILISER APPLICATION

**AUTHORS**: Andrew S Cooke[1], Jon Storkey[2], Michael RF Lee[3] and **M. Jordana Rivero[2]**

[1]University of Lincoln, [2]*Rothamsted Research*, [3]*Harper Adams University*

jordana.rivero-viera@rothamsted.ac.uk

## INTRODUCTION

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. The LTE experiment investigates herbage yields in response to varying soil fertiliser and liming treatments. In this study we estimated the carrying capacity and their nutritional quality as a feed for ruminant livestock of a set of plots.

## METHODS

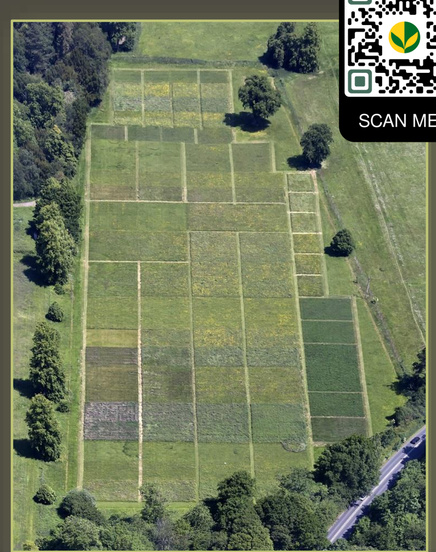
Samples were taken from the Park Grass' Archive at 10-year intervals, from 1860 to 2020, representing a range of treatments (Table 1) including:

- ✓ No fertiliser (Nill)
- ✓ Organic fertiliser (Or)
- ✓ Sodium nitrate (SN) and ammonium sulphate (AS) at varying applications rates (48, 96, and 144 kg N/ha)
- ✓ Liming (with + or without -)
- ✓ Mineral application: K, Mg, Na, and P (all or none, + or -).

Samples underwent proximate analysis for herbage fibre fraction, total N and minerals content which, combined with yield data, were used to estimate pasture's carrying capacity (CC). General linear models (GLM) were applied.

**Table 1.** Summary of the Park Grass plots' treatments used in this study.

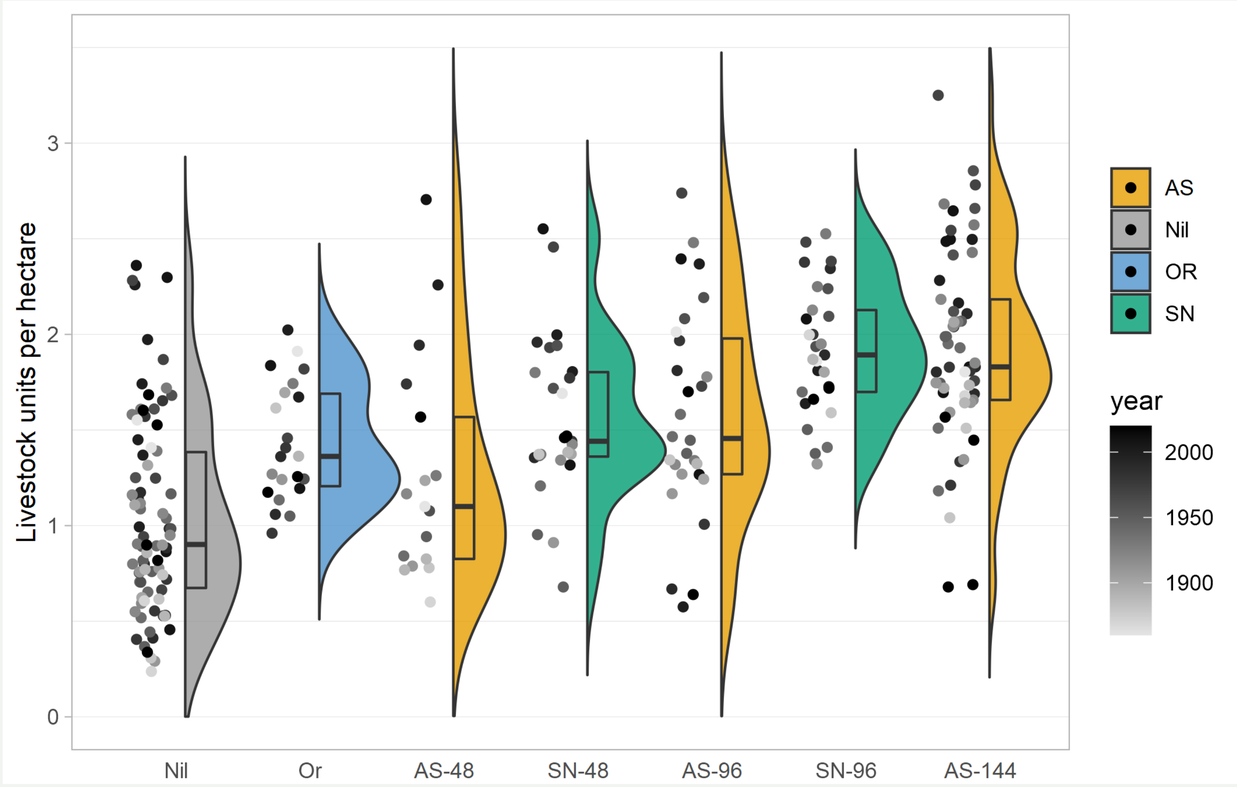
| Plot | Sub-plot | N-form | N (kg ha$^{-1}$) | Minerals | Lime |
|---|---|---|---|---|---|
| 3 | B | - | - | - | + |
| | D | - | - | - | - |
| 6 | B | AS | 48 | + | + |
| 7 | B | - | - | + | + |
| | D | - | - | + | - |
| 9 | B | AS | 96 | + | + |
| | D | AS | 96 | + | - |
| 11 | B | AS | 144 | + | + |
| | D | AS | 144 | + | - |
| 13 | B | OR | - | - | + |
| | U | OR | - | - | - |
| 14 | L | SN | 96 | + | + |
| | U | SN | 96 | + | - |
| 15 | L | - | - | + | + |
| | U | - | - | + | - |
| 16 | L | SN | 48 | + | + |
| | U | SN | 48 | + | - |



SCAN ME

## RESULTS & DISCUSSION

- ✓ Fertilisers application and liming increased carrying capacity (Figure 1 and 2).
- ✓ Increased in carrying capacity were driven by yield increases.
- ✓ Fertiliser applications tended to reduce the nutritional quality of the grass, leading to decreases in crude protein and increases in cellulose and hemicellulose (Table 2) – possibly as grass became more 'stemmy' as it became longer.
- ✓ Increased growth also appeared to have a dilution effect on some essential minerals, particularly Ca, Mg, Mn, and P (Table 3).



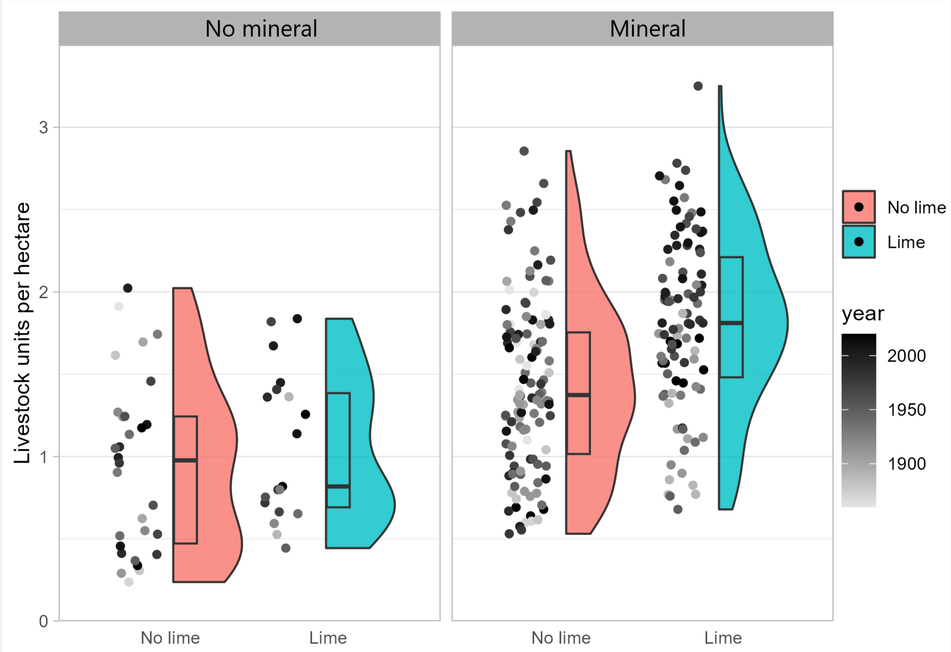




Figure 1. Plot showing the carrying capacity (livestock units per ha) of different N fertiliser (above) and liming or mineral (left) treatments. Nil = no fertiliser, Or = organic manure applied, AS = ammonium sulphate, SN = sodium nitrate. Numbers afterwards signify N application rate (kg ha$^{-1}$). Semi-violins show distribution with medians and quartiles 1 and 3 inside. Individual points are plotted to the left of those with darkness signifying year.

The **effect of time was observed throughout the experiment**, which included fluctuations resulting in high and low carrying capacity years. This **highlights the importance of long-term data sets** in discerning patterns beyond mere noise and **capturing long-term effects**.

**Table 2.** GLM results summarising the impact of different plot treatments, year on primary macronutrients. Table values are *t*-values and thus a positive/negative value is associated with a positive/negative impact on the independent variable on the dependent variable. Superscripts signify level of statistical significance: 0 '***' 0.001 '**' 0.01 '*' 0.05 '^' 0.1 ' ' 1.

| Component | AS | SN | OR | Mineral | Lime | Year |
|---|---|---|---|---|---|---|
| Ash | 0.27 | -4.17$^{***}$ | 2.85$^{**}$ | 3.45$^{***}$ | -1.08 | -1.92$^{\wedge}$ |
| Crude protein | 0.76 | -4.66$^{***}$ | -4.66$^{***}$ | -1.34 | -3.16$^{**}$ | -0.94 |
| Cellulose | 1.66$^{\wedge}$ | 5.36$^{***}$ | 8.01$^{***}$ | 7.10$^{***}$ | 2.70$^{**}$ | 0.50 |
| Hemicellulose | 5.30$^{***}$ | 7.46$^{***}$ | 4.10$^{***}$ | 1.42 | 0.49 | 1.36 |
| Lignin | -2.31$^{*}$ | -3.64$^{***}$ | 1.85$^{\wedge}$ | 2.83$^{**}$ | 0.59 | -3.45$^{***}$ |

**Table 3.** GLM results summarising the impact of different plot treatments, year on essential minerals. Table values are t-values and thus a positive/negative value is associated with a positive/negative impact on the independent variable on the dependent variable. Superscripts signify level of statistical significance: 0 '***' 0.001 '**' 0.01 '*' 0.05 '^' 0.1 ' ' 1.

| Factor | Ca | Cl | Cr | Co | Cu | Fe | Mg | Mn | Mo | Na | Ni | P | K | S | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AS | -6.39$^{***}$ | 1.54 | 1.09 | 0.08 | -0.57 | 0.33 | -2.02$^{*}$ | -2.55$^{*}$ | 0.14 | 3.36$^{***}$ | -2.44$^{*}$ | -2.18$^{*}$ | 0.09 | 2.48$^{*}$ | -0.89 |
| SN | -10.11$^{***}$ | -0.5 | -0.62 | 0.73 | -1.06 | -0.76 | -3.52$^{***}$ | -7.63$^{***}$ | -0.43 | -0.9 | -2.88$^{**}$ | -4.90$^{***}$ | -2.45$^{*}$ | -2.63$^{**}$ | -1.35 |
| OR | -7.58$^{***}$ | 1.02 | 3.14$^{**}$ | -0.81 | -0.51 | 3.23$^{**}$ | -4.43$^{***}$ | 2.90$^{**}$ | 3.95$^{***}$ | 1.68$^{\wedge}$ | -2.06$^{*}$ | 8.04$^{***}$ | 4.57$^{***}$ | -5.07$^{***}$ | -0.33 |
| Mineral | -8.20$^{***}$ | -0.94 | 1.97$^{\wedge}$ | -1.3 | -0.22 | -0.35 | -6.47$^{***}$ | 5.18$^{***}$ | 1.82$^{\wedge}$ | -0.29$^{\wedge}$ | -1.16 | 14.48$^{***}$ | 12.17$^{***}$ | -2.56$^{*}$ | -0.81 |
| Lime | 1.4 | -1.22 | -0.85 | 1.3 | -0.94 | -1.19 | 1.29 | -6.81$^{***}$ | 0.87 | -3.07$^{**}$ | 1.76 | -0.26 | -0.19 | -2.10$^{*}$ | -2.22$^{*}$ |
| Year | -4.14$^{***}$ | -6.73$^{***}$ | 0.08 | 1.08 | -1.48 | -0.46 | -5.53$^{***}$ | -0.99 | -0.25 | -4.04$^{***}$ | 1.24 | -2.05$^{*}$ | -0.76 | -0.45 | 2.52$^{*}$ |

ROTHAMSTED RESEARCH

Biotechnology and Biological Sciences Research Council

Global Long-Term Agricultural Experiment Network

**Acknowledgements**

This research was supported by the Biotechnology and Biological Sciences Research Council (BBSRC) Institute Strategic Programme (ISP) grant "Soils to Nutrition" (S2N) (BBS/E/C/000I0320).

# The Yield Enhancement Network: *10 years in*

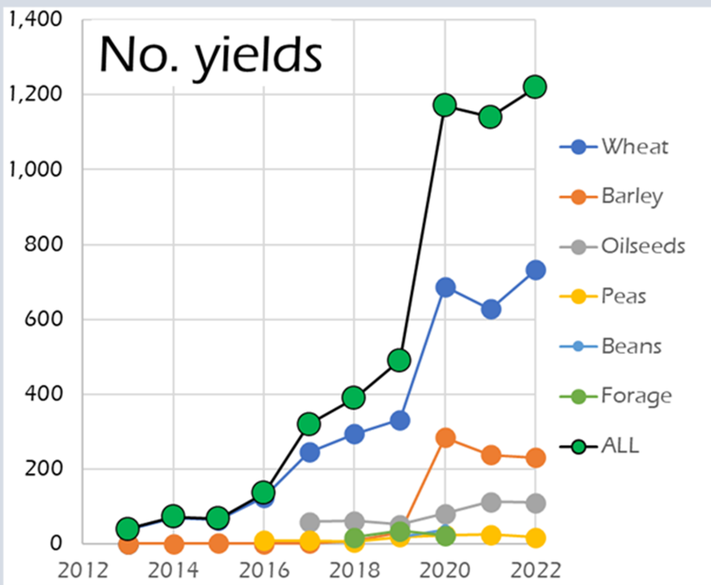
E. Guest, R. Sylvester-Bradley, S. Clarke, S. Kendall, D. Patel, P. Berry

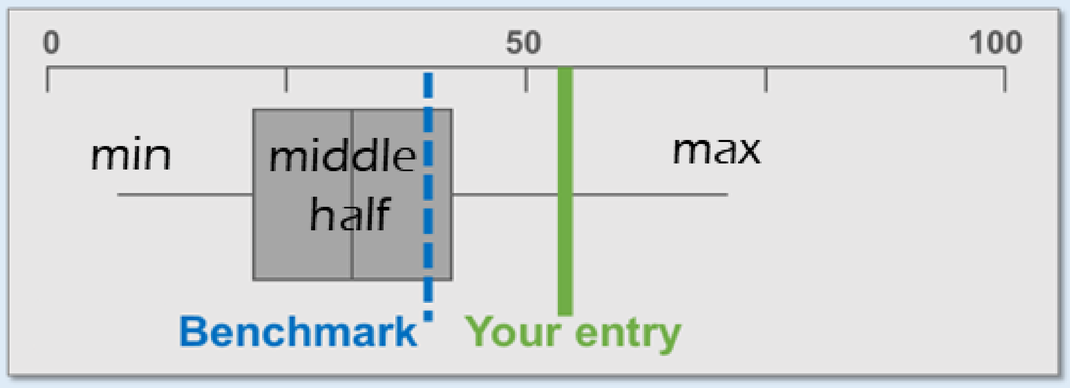
yen@adas.co.uk @adasYEN

ADAS developed the Yield Enhancement Network, 'YEN', in 2012 with the aim to help growers understand yields and form communities to help farmers in their innovation.

Understanding crops is based on knowledge e.g. in the Growth Guides, and is done through the measurement of metrics…

Our database can be analysed to understand yield formation and enhancements. Through this, we have identified the importance of the 'Farm Factor', beyond what is explicable by soil, season, weather or husbandry.

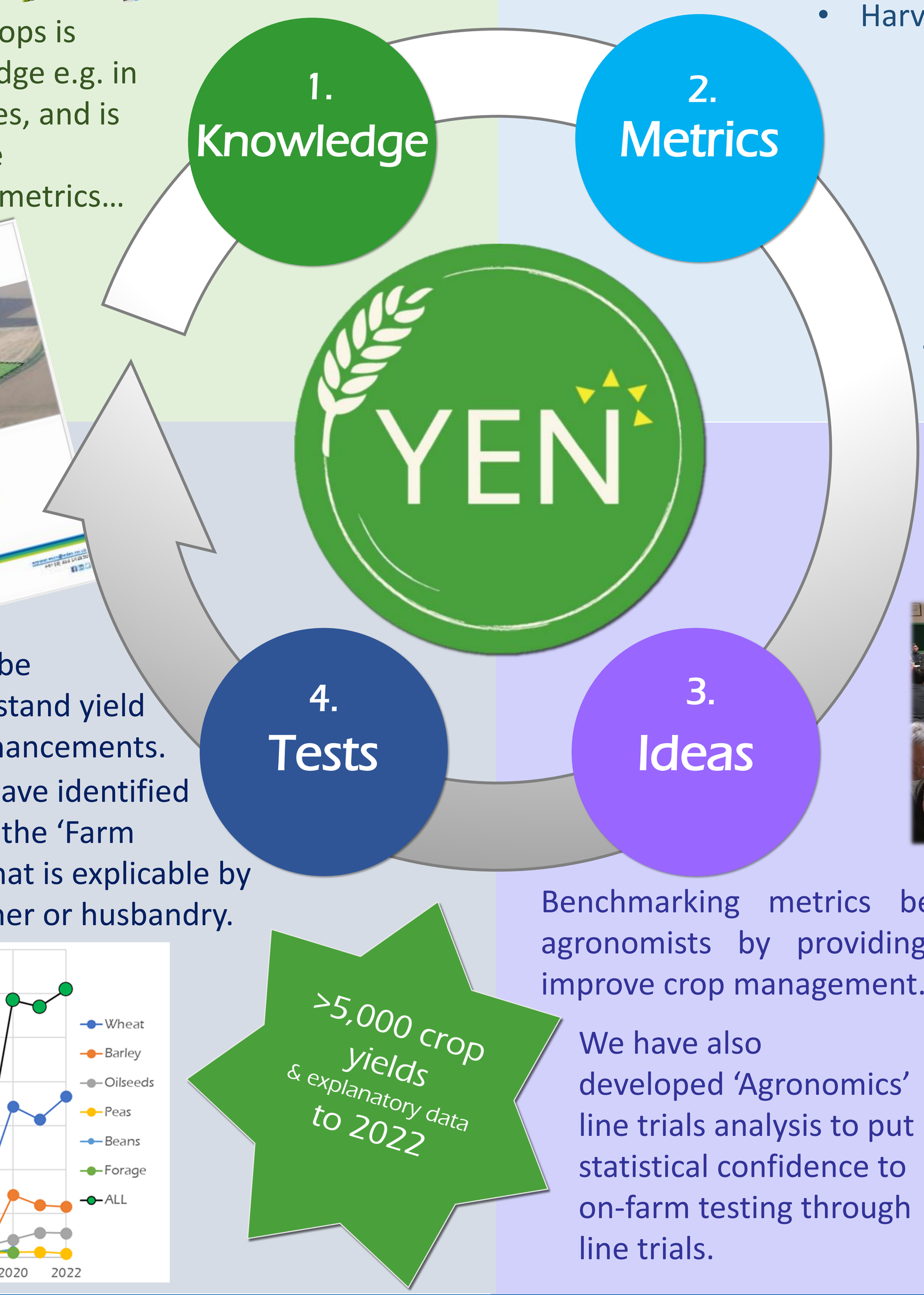



Metrics are collected throughout the season for multiple crops including:

- Physical and nutritional analysis at harvest
- Soil description and analysis
- Harvested area and weight
- Agronomy details
- Leaf nutrients
- Weather

These metrics are benchmarked against all entrants and AHDB guidelines in a 'benchmarking report'.




We have built Farming Innovation Groups to share and develop ideas.

Benchmarking metrics benefits farmers and agronomists by providing ideas on how to improve crop management.

>5,000 crop yields & explanatory data to 2022

We have also developed 'Agronomics' line trials analysis to put statistical confidence to on-farm testing through line trials.

With thanks to our YEN 2023 sponsors:
ROTHAMSTED RESEARCH, Lancrop Laboratories, SRUC, syngenta, United Oilseeds THE LEADING BREAK CROP SPECIALIST, SOYL SWEDEN, BASF We create chemistry, YARA, A&B pulses ltd, TFF The Farming Forum, PREMIUMCROPS LEADERS IN PREMIUM & SPECIALIST CROPS, NFU, Agrii, DTN, NIAB TAG, DE SANGOSSE, John Innes Centre, LSPB COMBINING EXCELLENCE, DSV, UK FLOUR MILLERS, PGRO, RAGT SEEDS, HUTCHINSONS Crop Production Specialists, dalton seeds, senova

# Use efficiency of different nitrogen sources applied to wheat fields

Abdul Wakeel, Abdul Qadeer, Zunaira Bano, Aysha Kiran and Muhammad Sanaullah, Tariq Aziz
University of Agriculture Faisalabad-38000, Pakistan

## Rational

Nitrogen (N) is an essential nutrient for plant growth, but its excessive use can have negative environmental impacts, such as nitrate leaching, ammonia volatilization and nitrous oxide emissions. Site specific right dose of N using optimal source of N can contribute to enhanced N use efficiency by crops. This study investigate the effects of different N fertilizer management practices on crop yield and N use efficiency.

## Objectives

The current study aimed to:

- assess the impact of various sources and rates of N fertilizers on crop yield, nitrogen use efficiency, soil health indicators (enzyme activity and microbial biomass) and $NO_3^-$ leaching.
- the impact of tillage depth on yield, N use efficiency and $NO_3^-$ leaching

## Methodology

**Duration of field Experiment**

Long term field experiment has been set up and the data of first two years have been presented here

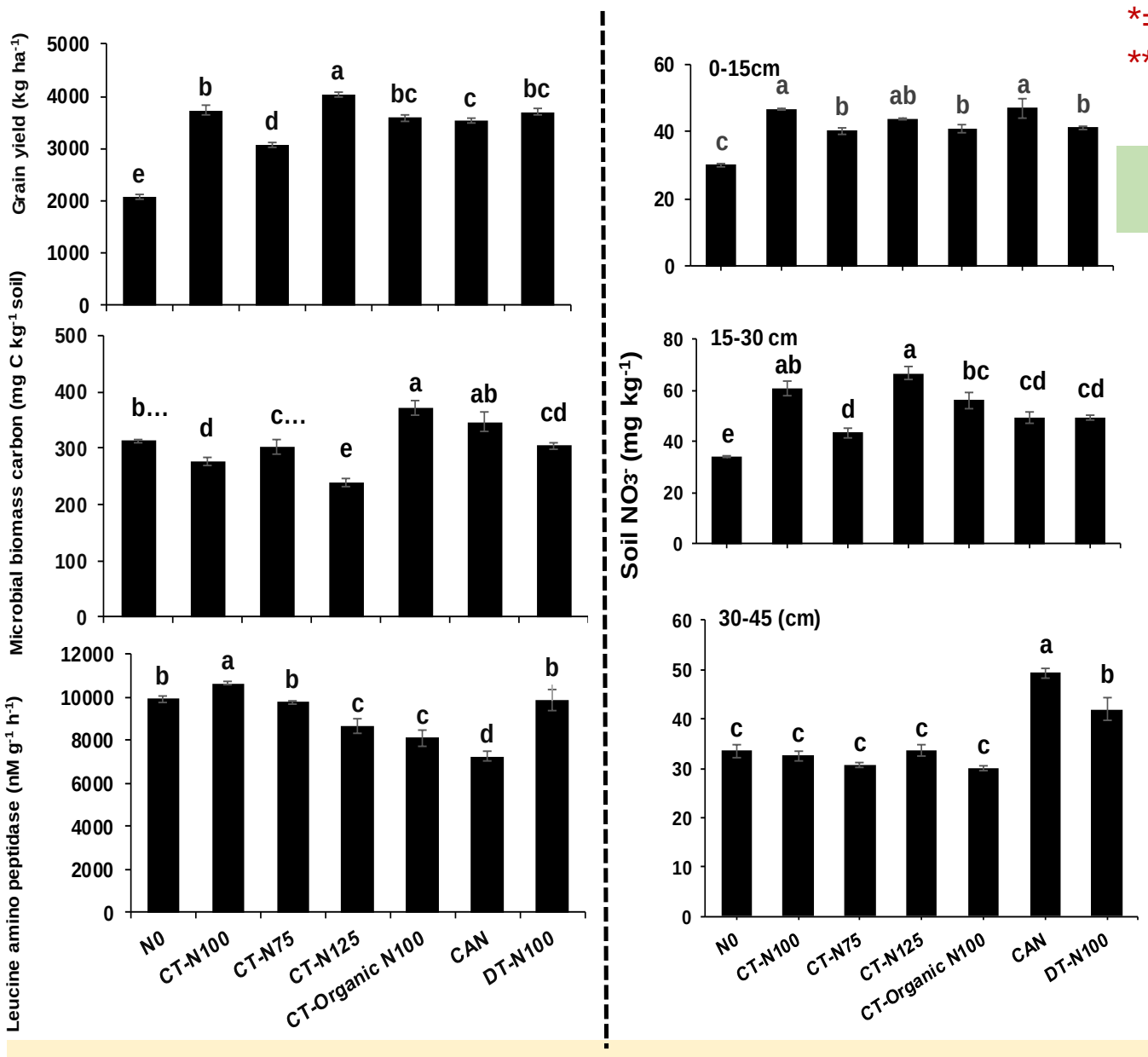
**Treatments**

1. Control with no N fertilizer (N0)
2. 100% recommended N fertilizer rate (CT-N100)*,
3. 125% recommended N fertilizer rate (CT-N125)*
4. 75% recommended N fertilizer rate (CT-N75)*
5. Animal manure (CT-Organic N 100)**
6. 100% recommended N using CAN fertilizer (CAN)
7. 100% recommended N deep tillage (DT-N 100)*

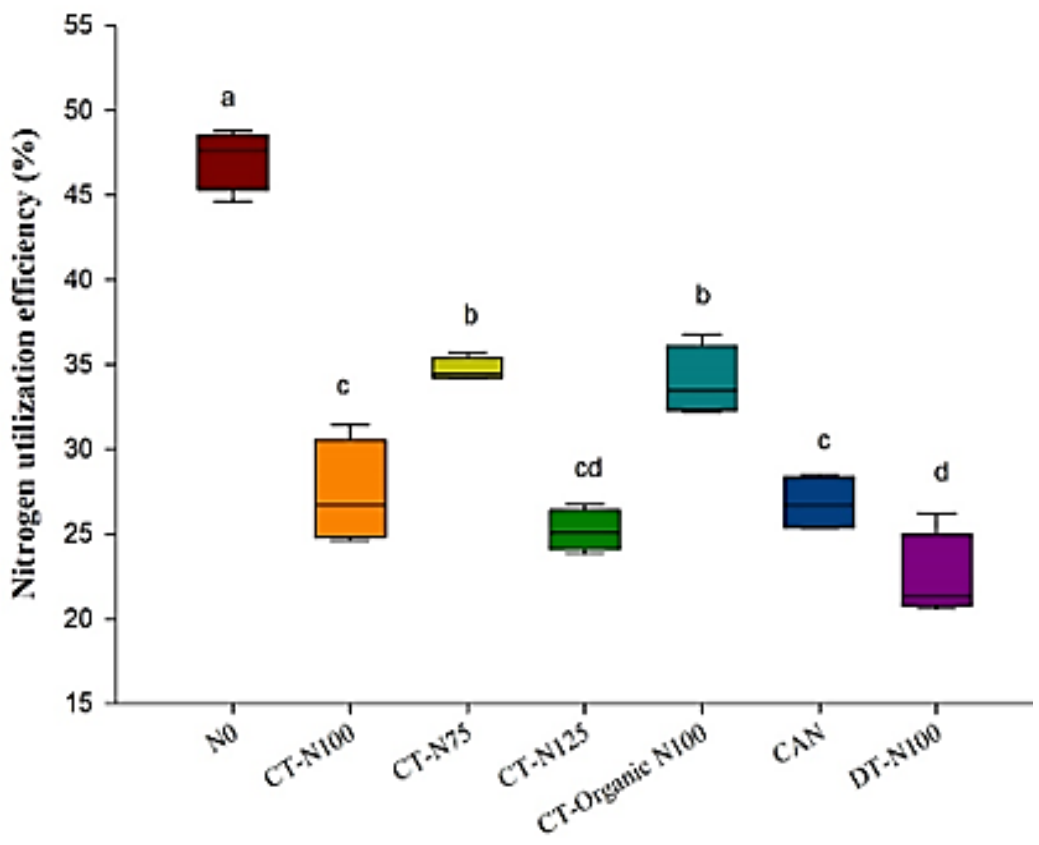
*= urea was the source of N

**= animal manure equivalent to 100 recommended N.

## Yield, Soil Health and Residual Nitrate




## Nitrogen Use Efficiency




## Conclusion

This study showed that excessive N fertilizer use can lead to N losses with low N use efficiency. Deep tillage and reduced N fertilizer rates can help to improve N use efficiency and reduce environmental impacts with very low compromise on yield.

## References

Shahzad A N, Qureshi M K, Wakeel A, Misselbrook T, 2019. Nature Sustainability 2: 1106–1114.
Anas, M., F. Liao, K.K. Verma, M.A. Sarwar, A. Mahmood, Z. L. Chen, Q. Li, X. P. Zeng, Y. Liu and Y.R. Li. 2020.. Biol. Res. 53:1-20.

UKRI GCRF South Asian Nitrogen Hub

# Nitrogen use efficiency of integrated crop-livestock systems in the 'Palo a Pique' long-term experiment

Pereyra-Goday, F.[1] ; Castillo, J.[1]; Rovira, P[1].; Ayala, W.[1]; Rivero, M.J.[2]

[1]Instituto Nacional de Investigación Agropecuaria (INIA), Treinta y Tres, 33000, Uruguay
[2] Net Zero and Resilient Farming, Rothamsted Research, North Wyke, Okehampton, Devon, EX20 2SB, UK

## INTRODUCTION

Developing metrics that allow for the evaluation of sustainability in food production systems has become an important tool for achieving sustainable intensification. Nitrogen (N) use efficiency (NUE) is a crucial indicator of efficiency used in crop and livestock systems. Therefore, the objective of this study was to **quantify and compare the NUE of four pasture crop rotations** (**Figure 1**) with different levels of soil intensity use and different livestock strategy over a period of three years (2019-2022) at system and at the component level (crop and livestock).

## MATERIALS & METHODS

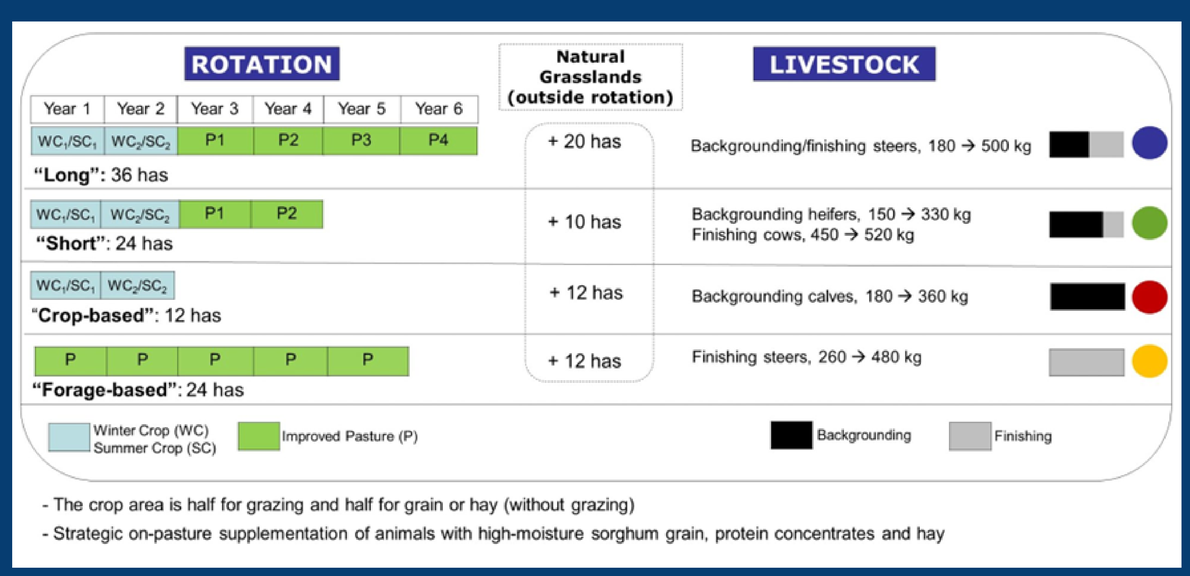



**Figure 1**. Pasture-crop rotation at the 'Palo a Pique' long-term experiment, Treinta y Tres, Uruguay.

- Crop component was defined as the area where exclusively grain is produced, pasture phase was not included in crop component.
- Livestock component included the total grazing area.
- NUE was calculated as N in food outputs relative to N inputs.
- Inputs were fertilizers, biological N fixation, atmospheric deposition and feed to animals in livestock component.
- Outputs were soybean, oats, wheat and liveweight.

## RESULTS & DISCUSSION

⇒ Differences ($p<0.0001$) were detected in the livestock component; the highest NUE was observed in CC, and the lowest was observed in FR (**Figure 2**).

⇒ At crop component, differences were not detected ($p=0.0725$), with an average value of 74.6% (**Figure 3**).

⇒ At system level, differences were detected ($p=0.0001$); NUE average values were 43.4, 28.1, 29.3 and 5.5% for CC, SR, LR and FR, respectively.

⇒ Our findings reveal differences between components and indicate the necessity of implementing distinct strategies to enhance NUE, particularly in the livestock component. This consideration is vital for the development of sustainable food production systems.

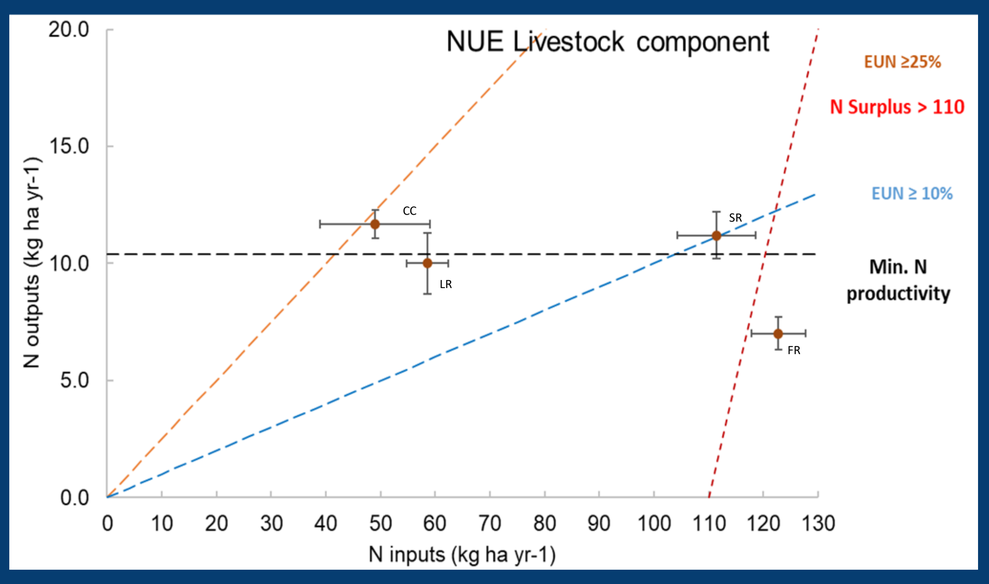



**Figure 2**. NUE at livestock component (3 years average) at the 'Palo a Pique' long term experiment, Treinta y Tres, Uruguay.

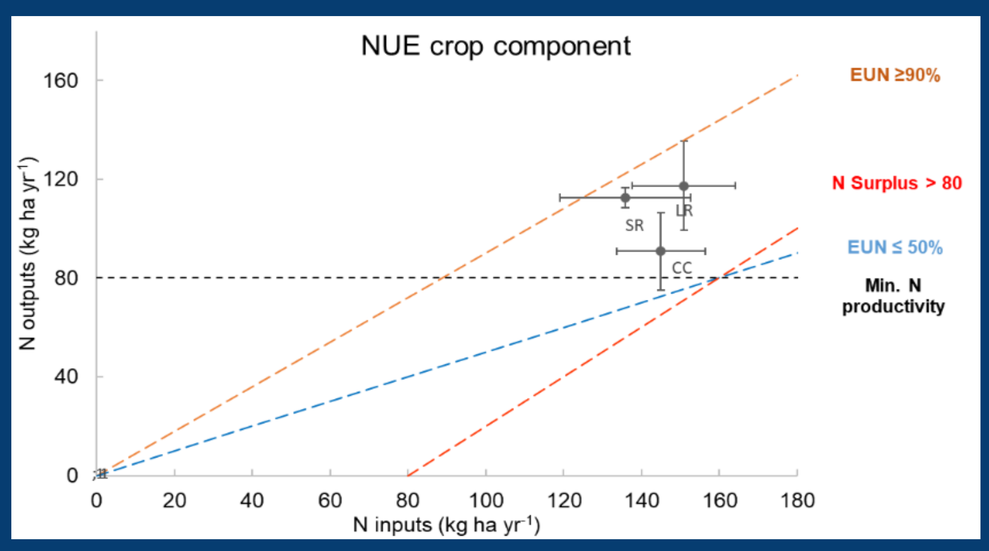



**Figure 3.** NUE at crop component (3 years average) at the 'Palo a Pique' long term experiment, Treinta y Tres, Uruguay.

This research was funded by: Long Term Experimental Platforms project (INIA), F.P-G was funded by posgraduate fellowship INIA and ANII code MOV_CA_2021_1_171482. RRes receives funding from the BBSRC of the UK. Support in the work was received by BBSRC through the program Soil to Nutrition (S2N; BBS/E/C/000I0320) and Growing Health (BB/X010953/1) at RRes. Contributions by MJR were funded by the Natural Environment Research Council (NERC) under research Programme NE/W005050/1 AgZero+: Towards sustainable, climate-neutral farming. AgZero+ is an initiative jointly supported by NERC and BBSRC.

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

**Nele Verhulst[a], Christian Thierfelder[a], ML Jat[b], Johan Labuschagne[c,d], Mahesh K. Gathala[a], Chloe MacLaren[a,d,e]**

[a]International Maize and Wheat Improvement Center (CIMMYT), El Batán, Texcoco, Mexico
[b]International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India
[c]Western Cape Department of Agriculture, Elsenburg, South Africa
[d]Department of Agronomy, Stellenbosch University, Stellenbosch, South Africa
[e]Rothamsted Research, Harpenden, UK

**Correspondence: Nele Verhulst (n.verhulst@cgiar.org)**

## Introduction

Conservation agriculture (CA) – a system based on minimum soil disturbance, permanent soil cover and crop diversification – has been proposed to sustainably improve the productivity of cereal-based systems, 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. Therefore, this study uses 15 long-term experiments (LTEs) to investigate the effects of CA on cereal yields in 7 countries in Africa, South Asia and Latin America.

## Material and methods

This study analyses data from 15 LTEs that tested CA practices in India, Malawi, Mexico, Mozambique, South Africa, Zambia, and Zimbabwe (Fig. 1). 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 the main crops in the experiments were maize (*Zea mays* L.), wheat (*Triticum aestivum* L. and *Triticum durum* L.) and rice (*Oryza sativa* L.).

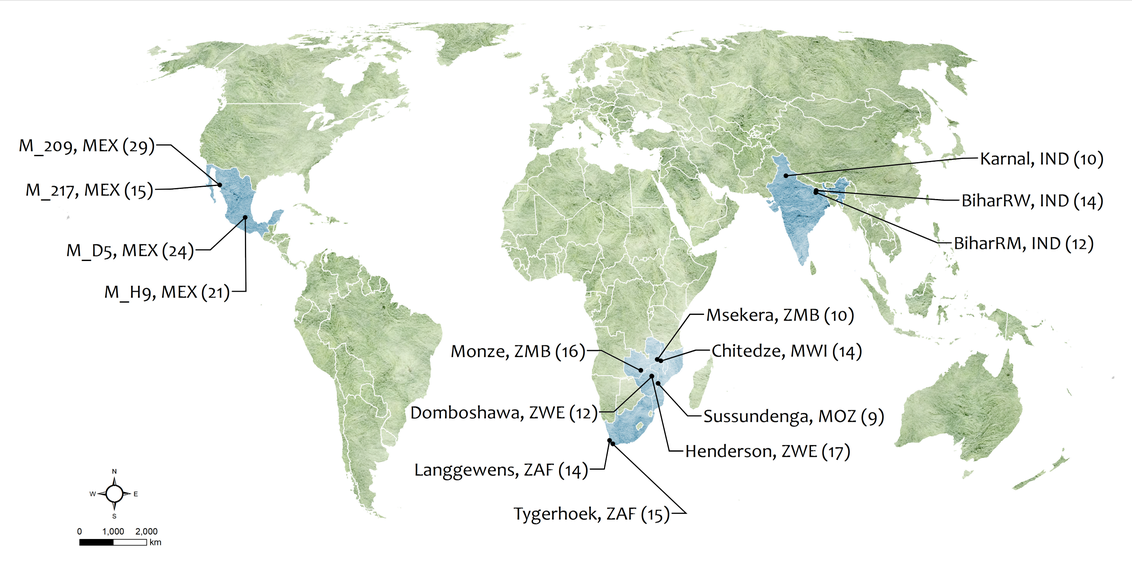



**Fig. 1.** Map indicating location of long-term experiments included in the study and duration of dataset in parenthesis. Country codes: MEX=Mexico, IND=India, ZAF=South Africa, MWI=Malawi, MOZ=Mozambique, ZMB=Zambia.

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. The differences between the control treatment and comparison treatments consisting of different combinations of CA practices (Fig. 2) were investigated using a meta-analysis procedure (MacLaren et al., 2022) that drew on the raw data from each experiment. The effects of experiment duration and rainfall on these differences were also explored.

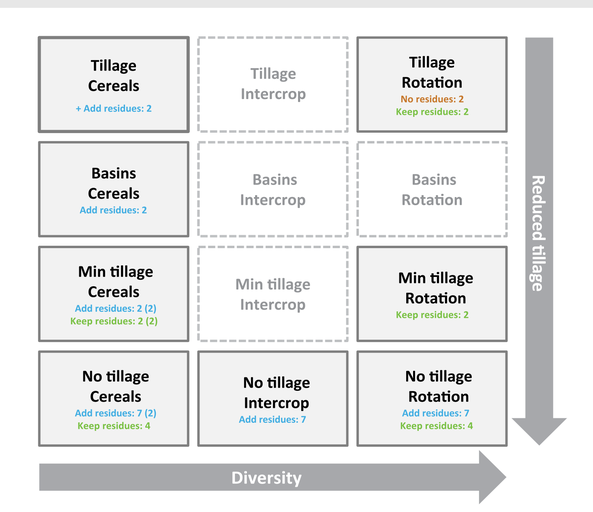



**Fig. 2.** Schematic summarizing comparisons made in the meta-analysis model, indicating the number of LTEs providing data to each comparison in Figure 3. All comparisons include a 'tillage with cereals' control, and are made within residue categories (coloured text) and irrigation categories (numbers with no parentheses = rainfed, numbers in parentheses = irrigated). A comparison was also made within 'tillage with cereals', between that treatment with and without residue retention. Treatments where comparisons could not be made are faded.

## Results

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 (Fig. 3). 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.

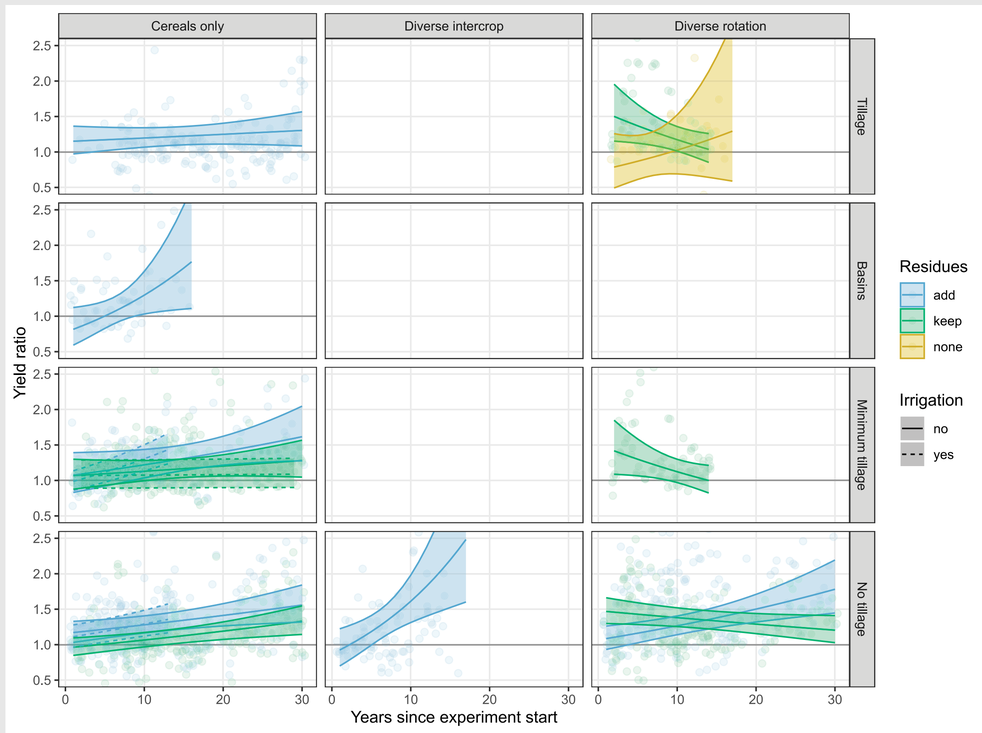



**Fig. 3.** Estimates for the effect of time on the yield ratio between a conventionally tilled monoculture and different CA practices or combinations thereof, averaged over the effect of rainfall. The grey line indicates a yield ratio of 1, or no difference between treatments.

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 – marked in blue in Fig. 3) than for similar treatment pairs where both the control and comparison treatment had the same residue treatment (either retained – marked in green – or removed – marked in yellow).

Crop rotation also tended to increase the mean benefit of CA, but this effect varied in interaction with experiment duration, irrigation, and residues.

The benefit of CA practices generally increased over time, illustrating the need for LTEs to adequately evaluate these practices.

## Conclusions

Crop rotation and especially residue retention increased the mean benefit of CA, while tillage did not significantly affect the yield ratio between the control and comparison treatments. Additionally, the LTEs serve as reference sites to monitor the effects of climate change on cereal production in the regions.

## References

MacLaren, C., Mead, A., van Balen, D., et al., 2022. Long-term evidence for ecological intensification as a pathway to sustainable agriculture. Nature Sustainability 5, 770–779. https://doi.org/10.1038/s41893-022-00911-x

Stellenbosch University Iyunivesithi Universiteit · Rothamsted Research · ICRISAT International Crops Research Institute for the Semi-Arid Tropics · CGIAR · CIMMYT International Maize and Wheat Improvement Center · EIA Excellence in Agronomy Adapt Intensify Grow · Western Cape Government For You

# Nutrient Management Through Organic and Inorganic Sources in Pearl Millet in Western Rajasthan of India

MANOJ KUMAR[1]*, P. S. SHEKHAWAT[2], MOOLA RAM[1], R. C. MEENA[1], SUPRIYA[1], JAGDISH PRASAD BISHNOI[1], VIKAS KHANDELWAL[1] AND C. TARA SATYAVATHI[1]

[1]*ICAR-All India Coordinated Research Project on Pearl Millet, PC Unit, Agriculture University, Jodhpur*
[2]*All India Coordinated Research Project on Pearl Millet, ARS, SKRAU, Bikaner*
*Corresponding author: mkagro86@gmail.com

**Pearl millet (*Pennisetum glaucum* (L.) R. Br.)**

- **An important annual millet crop and used as a smart food**
- **Used traditionally as a human food, cattle fodder and as a climate resilient crop**
- **It is known as nutri-cereals due to its high nutritional quality**

An attempt was made to enhance productivity and improve quality of pearl millet through organic nutrient sources compared with conventional inorganic nutrient source at two locations i.e. Jodhpur and Bikaner of western Rajasthan.

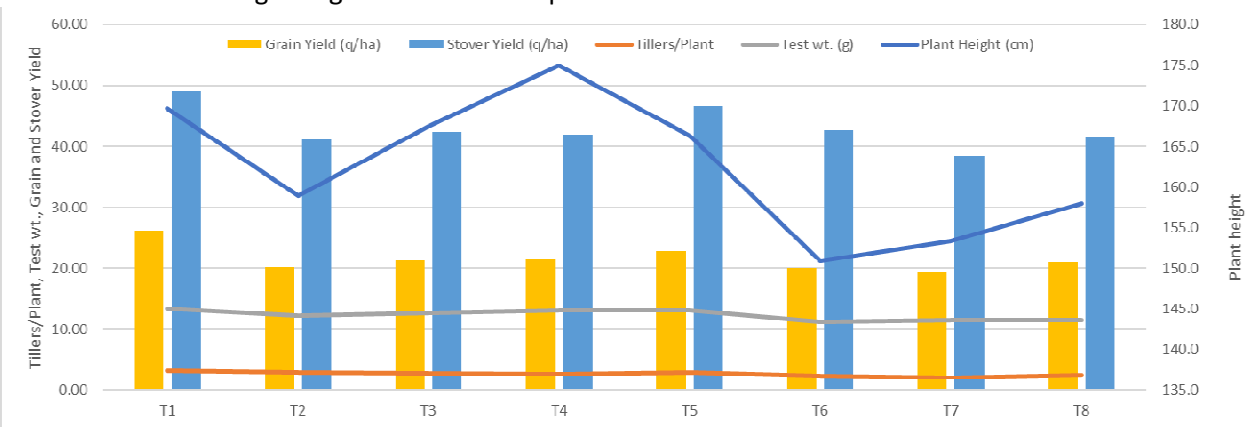
## Method

The experiment was conducted for three years (2018, 2019 & 2020). 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.

## Results

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) 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). 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.

Fig. 1: Agronomic traits of pearl millet under different treatments




## Conclusion

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.

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

MANOJ KUMAR[1], UMMED SINGH[2], REKHA CHOUHAN[3], RAJESH[4], JIVA RAM VERMA[2], MOOLA RAM[1] AND HANUMAN PRASAD PAREWA[5]

*[1]ICAR-All India Coordinated Research Project on Pearl Millet, PC Unit, Agriculture University, Jodhpur (Rajasthan), India*
*[2]College of Agriculture, Agriculture University, Jodhpur (Rajasthan), India*
*[3]Department of Botany, JNV University, Jodhpur (Rajasthan), India*
*[4]ICAR-Indian Agriculture Research Institute, Pusa campus, New Delhi, India*
*[5]College of Agriculture, Sumerpur, Pali (Rajasthan), India*
*Corresponding author: mkagro86@gmail.com

**Pearl millet (*Pennisetum glaucum* (L.) R. Br.)**

- **An important annual millet crop and used as a smart food**
- **Used traditionally as a human food, cattle fodder and as a climate resilient crop**
- **It is known as nutri-cereals due to its high nutritional quality, UN declared 2023 as the International Year of Millets**

## Methods

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 thrice.

## Results

Results reveals that application of customized fertilizer grade 6:6:2:1 ($N:P_2O_5:K_2O:Zn$) 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), 50% flowering (40.30, 50.96, 50.10 mg/kg) and at harvest (45.27, 46.54, 47.29 mg/kg), 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), manganese (15.13 mg/kg) and copper (18.31 mg/kg) concentrations in the pearl millet grain was also fetched by applying customized fertilizer. Moreover, customized fertilizer statistically enhanced grain (2010 kg/ha) and straw (3417 kg/ha) yields over control. Among pearl millet hybrids, 'HHB 67 Improved' recorded substantially higher Zn (61.97 mg/kg), Fe (43.98 mg/kg) and Mn (15.46 mg/kg) concentration in grain and Cu (25.09 mg/kg) concentration in straw. Albeit, 'HHB 173' noticed significantly higher Cu (19.60 mg/kg) concentration in grain. Further, among hybrids, 'MPMH 17' out yielded (1958 kg/ha) followed by 'RHB 173' (1795 kg/ha). In terms of straw yield, 'MPMH 17' recorded 3466 kg/ha straw followed by 'RHB 173' (3170 kg/ha), which was significantly superior over rest of the hybrids.

Table 1: Effect of fertilizers and hybrids on nutrient concentration in pearl millet (Pooled data)

| Treatments | Nutrient concentration in grain (mg/kg) | | | | Nutrient concentration in straw (mg/kg) | | | |
|---|---|---|---|---|---|---|---|---|
| | Zn | Fe | Mn | Cu | Zn | Fe | Mn | Cu |
| Control | 53.69 | 36.68 | 12.02 | 16.14 | 27.49 | 68.31 | 39.24 | 22.16 |
| Straight fertilizer | 55.83 | 39.00 | 14.44 | 17.87 | 29.53 | 68.80 | 39.25 | 22.12 |
| Customized fertilizer | 56.42 | 39.50 | 15.13 | 18.31 | 30.03 | 69.07 | 39.93 | 24.90 |
| SEm± | 0.09 | 0.06 | 0.05 | 0.08 | 0.06 | 0.06 | 0.08 | 0.06 |
| CD (P=0.05) | 0.26 | 0.18 | 0.14 | 0.24 | 0.18 | 0.18 | 0.24 | 0.18 |

## Conclusion

Application of customized fertilizer (6:6:2:1) to pearl millet gave substantially higher grain yield and straw yield and also improved Zn and Fe concentrations in different plant parts. Thus, micronutrient fortification (Zn, Fe, Mn and Cu) of grain and straw can be achieved with the application of customized fertilizers.

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

Nazish Annum[1,2], Teun Munnik[3], Moddassir Ahmed[1,2], Mark Tester[4] and Nasir A. Saeed[1,2]

[1]National Institute for Biotechnology and Genetic Engineering College, [2]Pakistan Institute of Engineering and Applied Sciences, Islamabad, Pakistan,

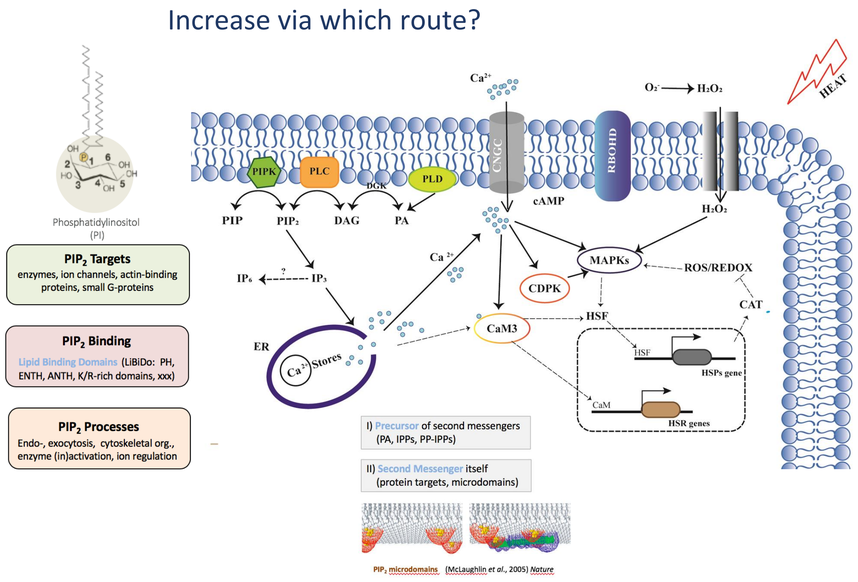
[3]Section of Plant Cell Biology, Swammerdam Institute for Life Sciences, University of Amsterdam, Amsterdam, Netherlands,

[4]Center for Desert Agriculture (CDA), King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia

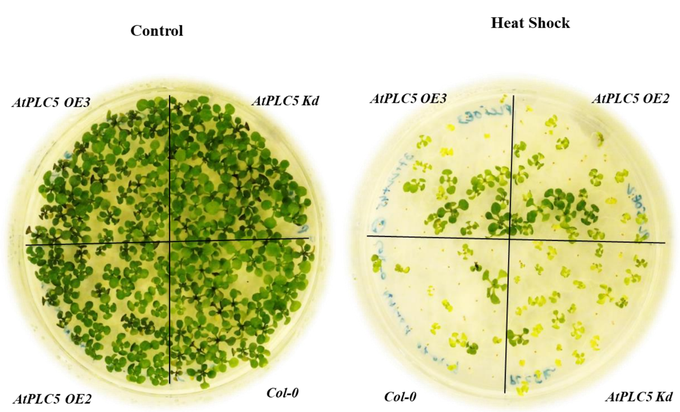
**Introduction**: The supervening heat stress drastically affects wheat plant growth and development, consequently compromising its grain yield. It is estimated that every 1°C rise in temperature results in 6% yield losses in wheat crop. There are some receptors present on the plant cell membrane that perceive stress (abiotic/biotic) signals and transduce this information downstream for the activation of certain stress responsive genes. Although heat shock proteins have received the most intense scrutiny, there is a growing appreciation that membrane lipids play key roles, not only in terms of structural adjustments to fatty acyl chains but importantly, through rapidly induced phospholipid-based signaling. Phosphoinositide-specific phospholipase C (PI-PLC) hydrolyzes Phosphatidylinositol 4,5-bisphosphate ($PIP_2$) to generate Inositol 1,4,5 trisphosphate ($IP_3$) and Diacylglycerol (DAG) which further phosphorylated into phosphatidic acid (PA) that acts as a second messenger and is involved in multiple processes under heat stress. In current study, *AtPLC5* gene was tested and isolated from *Arabidopsis thaliana*, cloned under two constitutive promoters (*CaMV35S* and *pUBQ10*) and has been transformed in locally adapted elite wheat cv. *Faisalabad-08* by employing *Agrobacterium*-mediated transformation technique. Transgenic and wild-type wheat plants were evaluated for their physiological and agronomic traits at pre-anthesis and post-anthesis stages under heat treatment at 40°C.

What does an increase in $PIP_2$ mean???

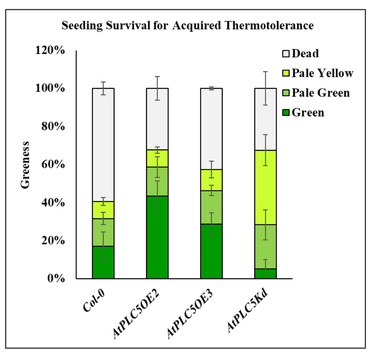
Increase via which route?



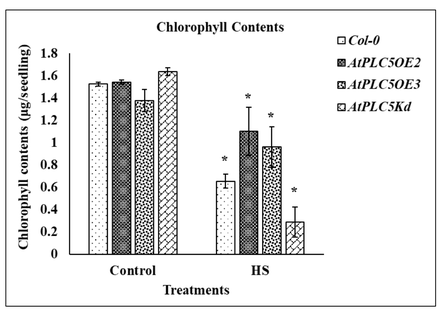

## Characterization of *AtPLC5* Gene for Thermotolerance in *Arabidopsis thaliana*



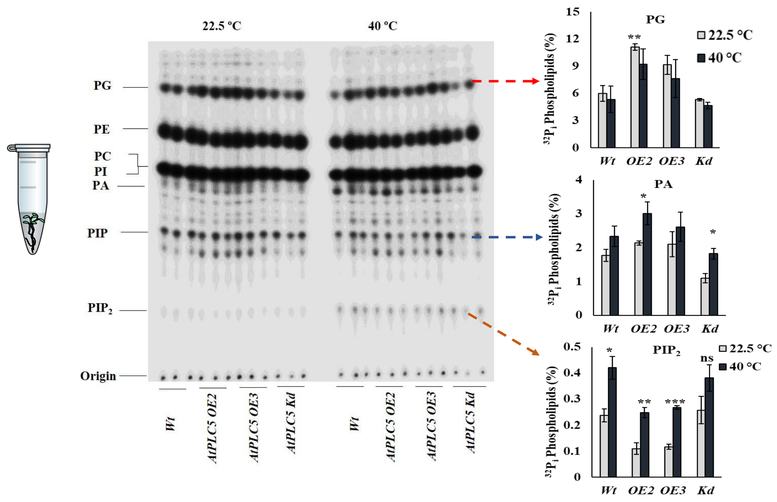

Three days old seedlings were prior acclimatized by subjecting to heat stress at 37 °C for 1 h, at 22 °C for 2 h (for recovery), and then exposed to 45 °C for 0 h (control) and 2.5 h (heat shock). Seedlings of mutants were daily monitored for 15 days after treatment.




Survival was observed and scored based on seedling leaves color.

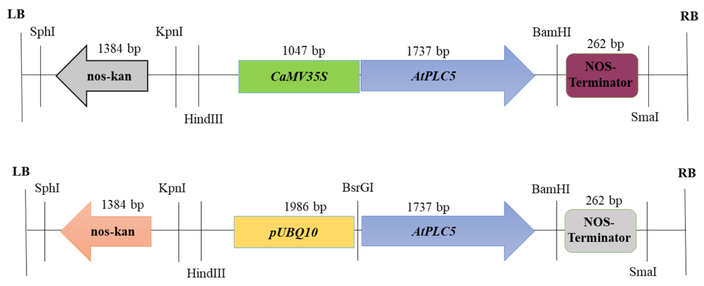



Chlorophyll contents (µg/seedling) were determined after 15 days of acquired thermotolerance treatment.

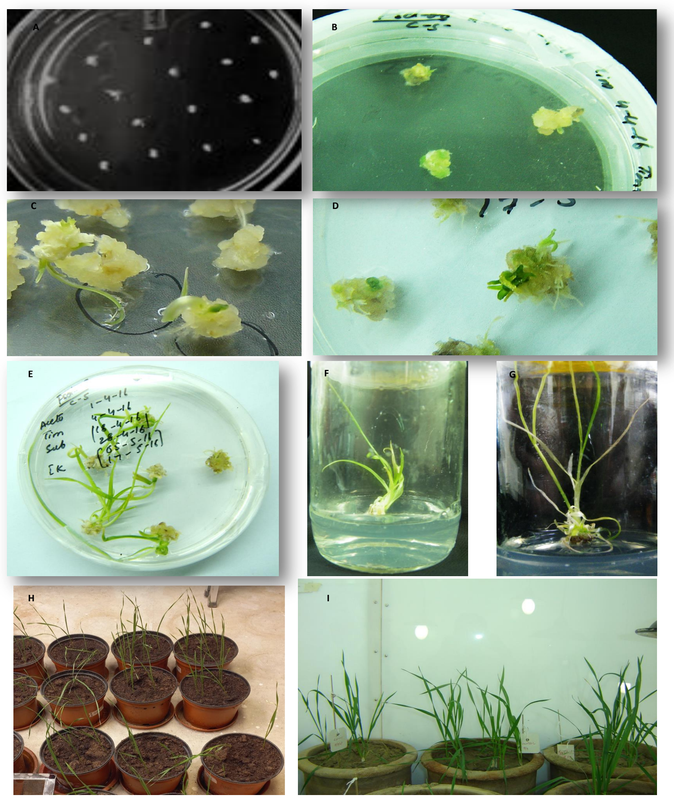



**$^{32}P_i$ lipid profiling of PLC5 mutants under heat stress.** Five days old seedlings were radioactively labeled O/N and treated for 30 min at high temperature (40 °C) using heat block. Lipids were then extracted, analyzed and quantified by phosphoimaging.

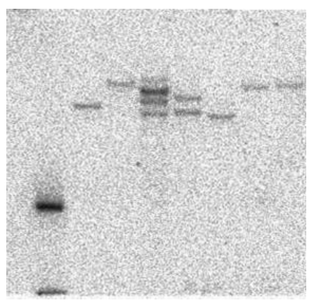
## Cloning Strategy of *AtPLC5* Gene for Plant Expression Vector *pGreenoo29JV*



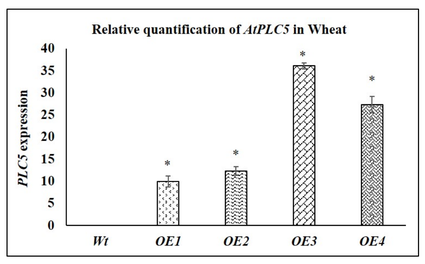

## *Agrobacterium*-mediated Transformation of Wheat



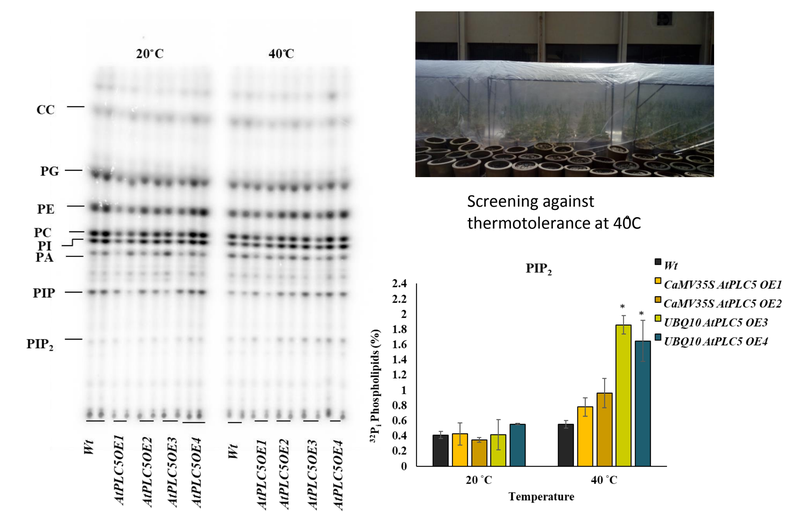
Transgenic wheat development stages. (A) Immature embryo excision and cultivation on callus induction media. (B) Callus proliferation and regeneration of transformed calli on IK4 media supplemented with 100 mg/L Kanamycin. (C, D) Prolific regeneration from transformed calli. (E) Plantlet regeneration from calli. (F) Plantlets on antibiotic selection media. (G) Plantlets on roots induction media. (H, I) Acclimatization of putative transgenic wheat plants in pots under control conditions.



Southern blot of putative transgenic wheat plants for validation of *AtPLC5* gene insertion and integration

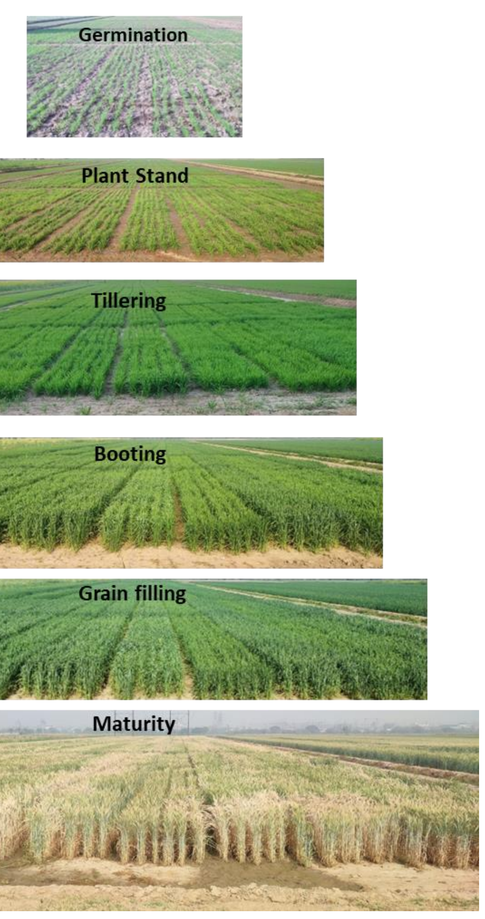


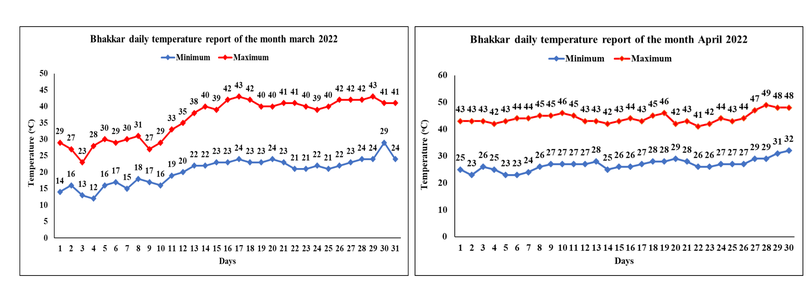

Relative expression of *AtPLC5* gene in wheat with respect to actin (housekeeping gene).



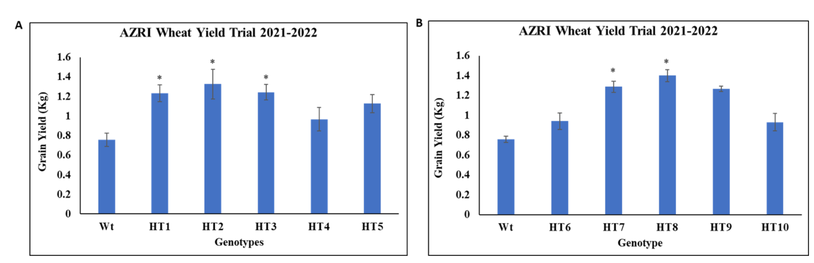

**Heat stress increases the production of $PIP_2$ at the anthesis stage.** Leaf disc of wheat plants were labeled *In vivo* O/N with $^{32}P_i$ radioactive isotop and treated for 30 min at 20°C and 40°C using heat block the following day.

## Evaluation of Transgenic Wheat Lines Under Field Conditions of Arid Zone Research Institute (AZRI) Bhakkar During Crop Season 2021-2022




Daily Temperature Record for the Month of March-April 2022




In 2022, Pakistan experienced a sudden heat wave in March-April (36 °C ± 3 °C – 44.1 °C ± 4 °C), which is considered the critical months for the wheat reproductive and grain-filling phases. Interestingly, all transgenic wheat lines performed exceptionally better than *Wt* (Non-transformed control) in the field at AZRI. A significant increase of ~1.85-fold in grain yield was observed in transgenic wheat line HT8.

**Publications:**

1. **Annum N**, Ahmed M, Tester M, Mukhtar Z and Saeed NA (2023). Physiological responses induced by phospholipase C isoform 5 upon heat stress in *Arabidopsis thaliana*. Front. Plant Sci. 14:1076331. http://doi:10.3389/fpls.2023.1076331
2. **Annum N,** Ahmed M, Imtiaz K, Mansoor S, Tester M and Saeed NA (2022). 32Pi Labeled Transgenic Wheat Shows the Accumulation of Phosphatidylinositol 4,5-bisphosphate and Phosphatidic Acid Under Heat and Osmotic Stress. Front. Plant Sci. 13:881188. https://doi.org/10.3389/fpls.2022.881188

**Conclusion:** The seedling survival assay of *PLC5* over-expressing lines of *Arabidopsis thaliana* appeared to be more thermotolerant than *PLC5* knockdown mutant and *Col-0*, indicating the involvement of *PLC5* gene in high temperature tolerance. The chlorophyll analysis and radioactive lipid profiling further support the results of this study. Furthermore, a significant increase in $PIP_2$ has been witnessed when subjected to heat stress (40 °C) in *PLC5* over-expressed lines of *Arabidopsis* and Wheat as compared to *wild-type* (non-transgene). Thus, we assume over-expression of *PLC5* increase the thermotolerance and this is caused by the increase in hydrolysis of $PIP_2$.

# Improving biodiversity within upland permanent pastures: lessons from the Brignant long-term plots

*Mariecia Fraser, Pwllpeiran Upland Research Centre, Aberystwyth University, UK*
*Rocio Rosa Garcia, SERIDA, Spain*
*Vilém Pavlů, Technical University of Liberec, Czechia*

**The Brignant plots were established in 1994 to test the effectiveness of extensification managements when applied to upland-fringe pasture.**

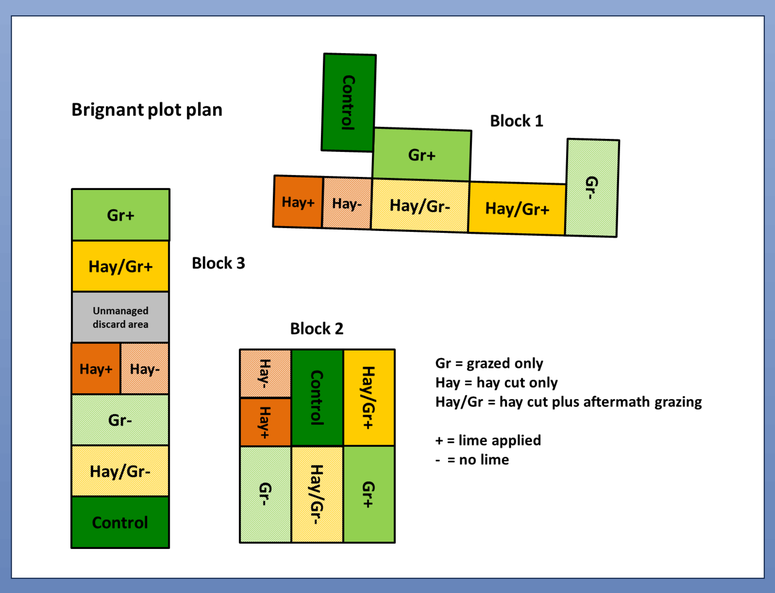
The plots are located 15 miles inland from Aberystwyth, Wales on the edge of the Cambrian Mountains.

They were established on *Lolium perenne*-dominant pasture that had been reseeded in 1973, and which had received regular inputs of fertiliser and lime.

The initial 12 years of funding came from MAFF/Defra (UK government)

More recent small grant/researcher support received from Natural Resources Wales, Stapledon Memorial Trust, and the Ecological Continuity Trust.

- Altitude: 310 m a.s.l.
- Free-draining brown podzolic soils
- Annual rainfall ~1850 mm
- Randomised block design
- 7 treatments
- Plot size: 0.15 ha grazed; 0.08 ha hay cut only
- Control treatment = 60 kg N/ha/yr plus P, K and lime as required
- Grazed by sheep
- Single hay cut after third week of July.



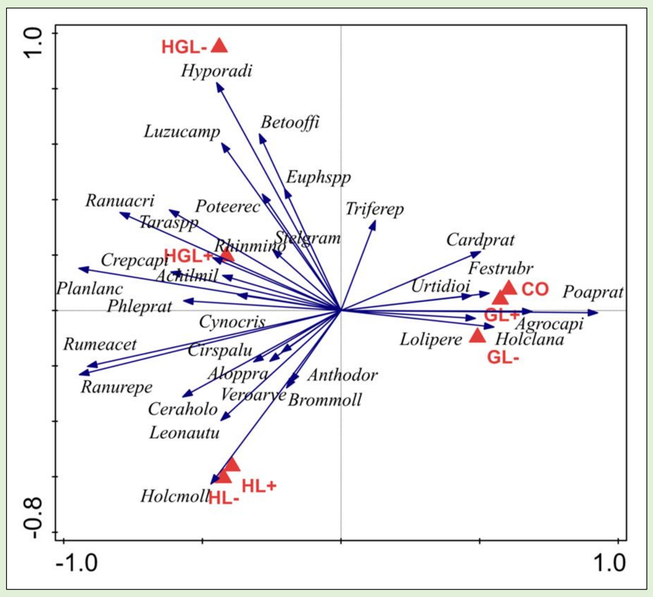

## Impact on vegetation

Full botanical survey conducted in 2012.

Although former lime and NPK applications were still detectable in the soil, their effect on botanical composition was small.

The main effect on plant species composition was via the management treatment applied.

A higher species richness with a higher proportion of forbs was observed on treatments which incorporated cutting.




*Pavlu et al., Sci Total Envir, 2021*

Most recent survey conducted in 2023.

Early data analysis indicates the sward composition was similar to that in 2012 and treatment effects are now relatively stable.

## Additional measures

Herbage biomass and chemical composition

Managements incorporating cutting resulted in higher forage quality

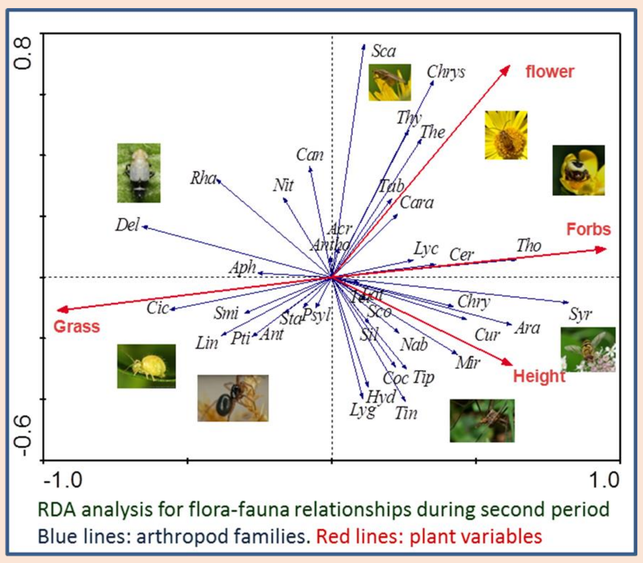
*Kajzrov et al., Grass & Forage Sci, 2022*

## Impact on invertebrates

Arthropod abundance and diversity surveyed in 2013 in using sweep nets.

Sward height, flower numbers plus percentage of forbs and grasses also recorded.

Arthropod communities were more commonly linked to taller, flower rich areas with higher percentage of forbs, although certain groups were associated with grass dominated areas.




RDA analysis for flora-fauna relationships during second period
Blue lines: arthropod families. Red lines: plant variables

*Garcia and Fraser, Sci Reports, 2020*

**Summary**

We have found postponing first defoliation to the middle of the growing season enables forbs to reach seed production, and is thus an effective restoration management option for upland grassland

Arthropod communities is more abundant and diverse in flower-rich and forb-dominated plots managed by hay cutting

Postponing the timing of the first defoliation need not result in a deterioration in forage quality relative to continual extensive sheep grazing

**Its age and the extent of the treatments effects at the site make Brignant a unique experimental resource, and the plots are available to all scientists for the study of processes and interactions within managed grassland ecosystems**

# 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[1], LUCIE BÜCHI[2], RAPHAEL CHARLES[3], THOMAS GUILLAUME[1], MARIO FONTANA[1]**

[1]Agroscope, Nyon, Switzerland; [2]University of Greenwich, United Kingdom; [3]FiBL, Lausanne, Switzerland

## 1. Introduction

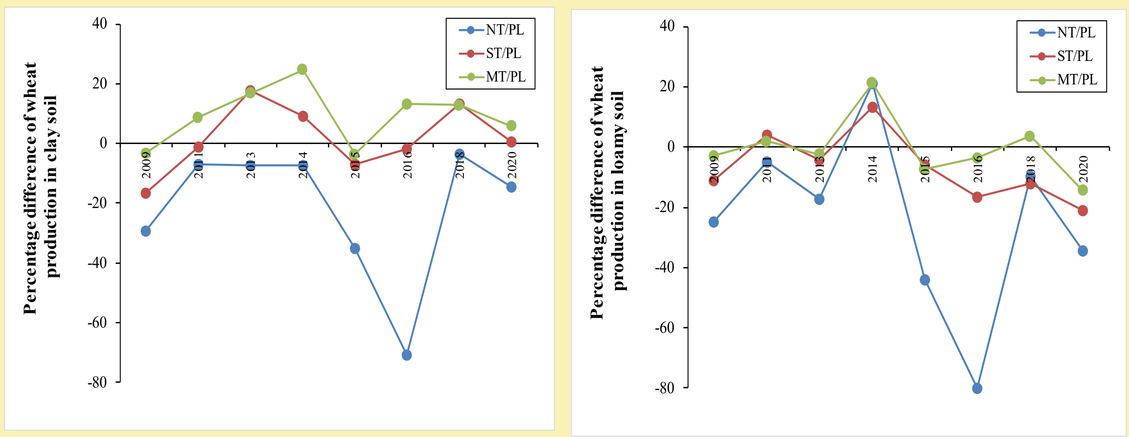
A major challenge of current agriculture is to preserve the quality of soil while assuring food production. A practice to improve or preserve soil quality is reducing the frequency and intensity of tillage. Practices reducing or stopping (= no-till) tillage have been introduced relatively recently in agriculture so that it is not completely clear when, where and how such practices are as much as or even more profitable than conventional tillage. Indeed, there are indications that reducing the intensity of tillage (= conservational tillage) or using tillage less frequently (= occasional tillage) could be more sustainable than no-till. Long-term studies are then necessary to clarify the effects of a transition from conventional tillage to no-till. These data are still more helpful if obtained from different soil types and under various climate conditions. In order to fill this gap, in this study we compare the effect of four different tillage treatments, i.e., conventional plough (PL = 25 cm), shallow tillage (ST = 12 cm), and minimum tillage (MT = 8 cm) that have been all applied since 1969 plus a no-till (NT) treatment that started in 2007 on: 1) grain yield and grain quality of winter wheat, and 2) a set of soil properties in a clay and in a loamy soil from western Switzerland.

## 2. Materials and Methods

The average total annual precipitation is 999 mm and the mean temperature 10.2 °C. The soil of the experimental field is a Cambisol, divided into two parts presenting different textures, a clay (48% clay-37% silt) and a loam (25% clay-44% silt) soil. The crop rotation is winter wheat (*Triticum aestivum*), winter rapeseed (*Brassica napus*), winter wheat, grain maize (*Zea mays*). Since 2007, residues of all crops are left on the field. The main tillage implements used for the different treatments are a mouldboard plough (PL), and a rototiller (MT, ST). The no till treatment (NT) involves a direct seeder developed for experimentation purposes. Soil properties were measured in samples collected at four depths (0-5, 5-10, 10-20 and 20-50 cm) in 2020. Grain nutrient concentrations refer to the winter wheat harvested in 2019.

## 3. Grain yield

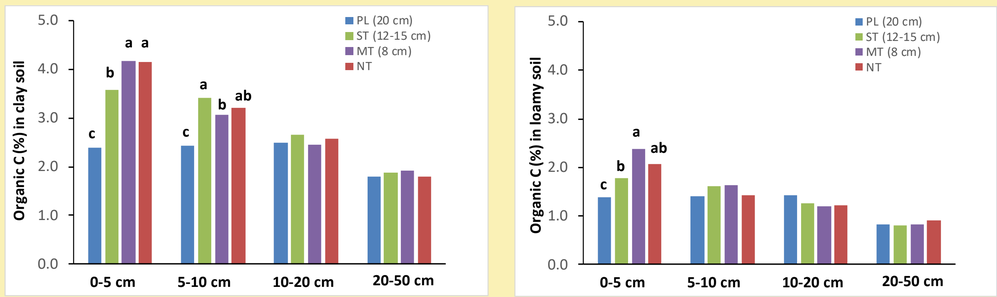
During the period 2009-2020, the mean annual yield of winter wheat was, respectively for the clay and the loamy soil, 3.9 and 3.5 t/ha in the plough tillage, 3.9 and 3.2 t/ha in the shallow tillage, 4.2 and 3.4 t/ha in the minimum tillage, and 3.1 and 2.5 t/ha for the no-till. No significant differences in the mean annual yield between the tillage treatments ($p > 0.35$) were found for both the clay and the loam soil. Similarly, no significant differences in mean annual yield were detected ($p > 0.18$) between the two soil types for the same tillage treatment. It is interesting to note that the strongest decline (up to -80%) of the relative yield in the no-till treatment took place in 2016 after four years of wheat monoculture.




**Temporal pattern of wheat grain production in the clay (right panel) and loam (left panel) soil as percentage difference compared to the conventional plough (PL) for the shallow tillage (ST), minimum tillage (MT) and the no-till (NT) treatment.**

## 4. Soil organic carbon (SOC)

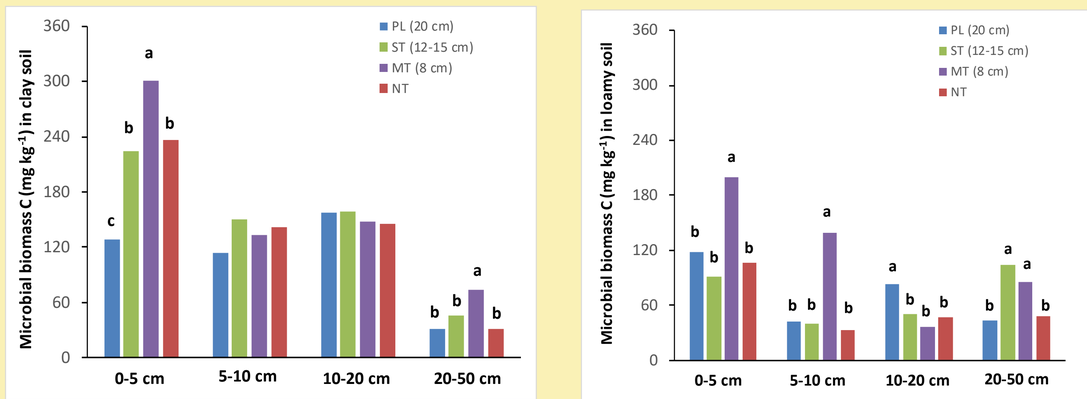
The soil organic carbon concentration is about the double in the clay soil compared to the loamy soil with highest values in the no-till and in the minimum tillage, particularly in the upper soil layer. Differences in SOC concentration among the four different tillage treatments are mainly visible in the upper 10 cm of soil depth.




**Mean soil organic carbon (C) concentration at different soil depth intervals in the two soil types (clay and loamy) in response to tillage intenstity, i.e., conventional plough (PL), shallow tillage (ST), minimum tillage (MT) and the no-till (NT). Within each depth interval, significant differences ($p < 0.05$) are indicated by different superscripts. (No-superscripts = no significant differences).**

## 5. Microbial biomass carbon

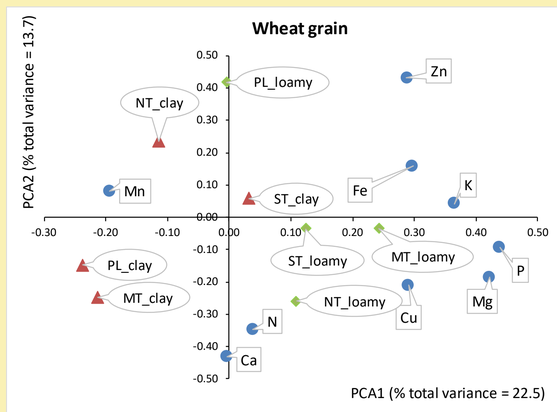
Microbial biomass C differed in response to soil type, soil depth and tillage intensity. Overall, we observed higher microbial biomass C in the clay soil (c. 139 mgC $kg^{-1}$) than in the loam soil (c. 79 mgC $kg^{-1}$) with a clear stratification along the soil depth so that higher values of microbial biomass C were found in the in the first 5 cm of depth. Within each soil type, the tillage intensity had different effects on microbial biomass C with the no-till and the minimum tillage showing the highest value of microbial biomass C.




**Mean microbial biomass carbon (C) at different soil depth intervals in the two soil types (clay and loamy) in response to tillage intensity. Within each depth interval, significant differences ($p < 0.05$) are indicated by different superscripts. (No-superscripts = no significant differences).**

## 6. Macro- and micro-nutrients in wheat grains

Factorial ANOVA showed that micro- and macro-nutrient concentrations in wheat grain (harvest of 2019) were significantly affected by soil type ($F = 4.3$, $p = 0.011$) and soil tillage ($F = 2.2$, $p = 0.012$). Overall, wheat grains from the loam soil were characterized by higher P, K, Mg, Fe and Zn concentration, whereas wheat grains from the clay soil were distinguished by higher Mn concentration.




**Principal component analysis (PCA) of macro- and micro-nutrient concentration in wheat grains harvested in 2019 in relation to soil tillage depth from loam and sandy soil.**

Agroscope good food, healthy environment

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
**Agroscope**

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

Kihara J., Kinyua M., Bolo P., and Sila A.
a.sila@cgiar.org

## Abstract

Increasing and/or maintaining crop productivity requires management practices that perform well under variable environments presented by climate change. Three aspects of crop performance are of key importance from a farmer's perspective :

- High yields
- Income
- Yield stability (i.e. low risk).

Reduced cultivation has twin benefits of lowering production cost and increased buildup of soil organic carbon.

Combining conservation agriculture (CA) with other agronomic activities led to increased yield compared with conventional agriculture (CT).
The best performances was observed in:

- CA + continuous maize + 60N + 60P
- CA + continuous maize + 90N + 60P
- CA + maize-soybean rotation + 60N + 60P
- CT + continuous maize + 60N + 60P

## Background

Conservation agriculture contributes to long-term productivity of crops by making better use of agricultural resources through the integrated management of available soil, water and biological resources combined with limited or no external inputs.
Adoption of conservation agriculture at the farm level is associated with lower labor and farm-power inputs, more stable yields and improved soil nutrient exchange capacity.
In contrast , conventional agriculture regularly use ploughs to enable a deep tilling the soil . The conventional farmer believes that tilling soil will provide benefits to the farm and would increase tillage if economically possible

## Objectives

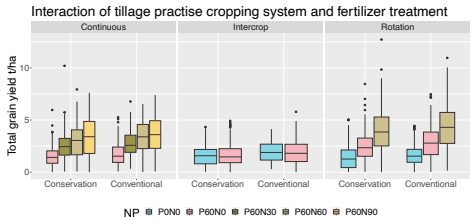
The goal is assess how yield stability and profits are affected by using the two different crop production systems : (1) Conservation agriculture, and (2) Conventional agriculture. Specifically this study aims to determine:

1. The overall yield trend from the production systems and whether they remain stable.
2. Profitability: identify which of the two crop production systems gives better income.

## Methods

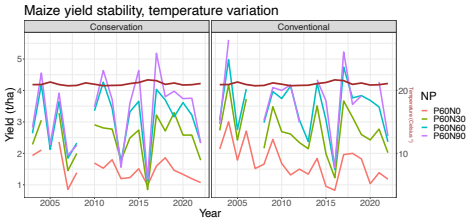
- The on-farm researcher managed trial was initiated and maintained by the International Center for Tropical Agriculture (CIAT) in 2003.
- The trial is laid out in a split-split-split plot design with four replicates. The plots measure 4.5 m x 7 m.
- Trial has two tillage systems – minimum tillage (0T) and conventional tillage (CT) – as main plots, and two residue (R) levels as sub-plots, one on which 2 t $ha^{-1}$ maize stovers are retained (R+) and the second one where all residues are removed after harvest (R-).
- M-M, M-S rotation and M-S intercrop

## Results




## Results

- Factors with significant effect on grain yield assessed with repeated measures are tilling practice, cropping system, fertilizer management, crop rotation and cropping system interaction with fertilizer management.
- At the same level of P application, Benefit Cost Ratio (BCR) increased with N application up to 60 kg N $ha^{-1}$ both under continuous M-M and M-S cropping systems.
- Annual yield averages for continuous M-M cropping fluctuated with temperatures patterns. As temperature rises in the year 2005 maize yield drop to ~ 1t/ha.




## Conclusion

- Not applying P fertilizer in maize and soy bean intercrop reduces input cost.
- Adopting crop rotation agronomic practice and using nitrogen fertilizer with N90 gives higher yields for both cropping systems.
- Using nitrogen based fertilizer during planting and top-dressing increases grain yield.
- Yield keeps fluctuating with changing temperatures.

## Future Direction

- Extend this analysis to cover all the seasons with data available
- Include in the BCR computation estimate for labor cost for managing stover.

Using LTEs and remote sensing to predict SOC variability at farm scale

# OPEN-SOURCE DATA PROVIDES A COST AND TIME-EFFECTIVE ESTIMATION OF SOIL ORGANIC CARBON


**C. Segura[1], A.L. Neal[1], L. Castro-Sardiña[2] and G. Irisarri[1]**

[1]Rothamsted Research North Wyke, EX20 2SB Okehampton, UK [2]IFEVA, FAUBA, CONICET, Buenos Aires Argentina

carmen.segura-quirante@rothamsted.ac.uk


## INTRODUCTION

**Monitoring, reporting, and verifying soil organic carbon (SOC)** levels are essential for implementing sustainable agricultural management policies, especially during land-use changes, but can be challenging, time-consuming and expensive

Combining **Long-Term Experiments (LTEs)** with **remote sensing** provides opportunities to evaluate changes in SOC

**Which are the most effective variables explaining SOC variability under dynamic land-use?**

## METHODOLOGY

### SOC predictors at North Wyke Farm Platform (2012-2021)

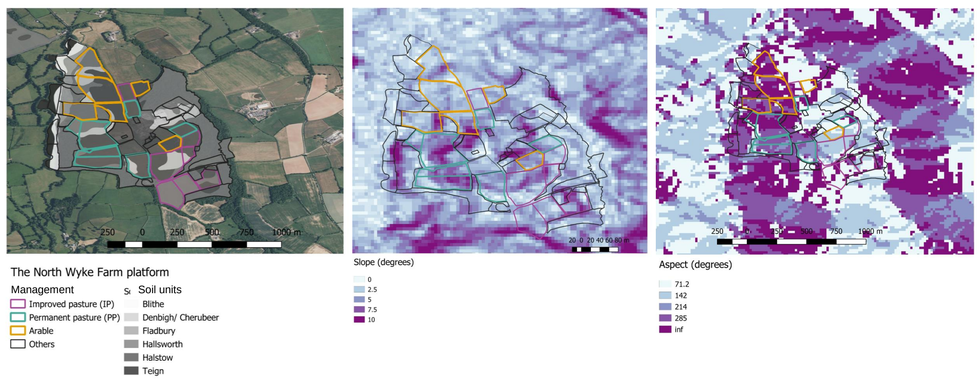



Fig 1. North Wyke Farm Platform (NWFP) fields included in the study and their management in 2021. The NWFP, established in 2010, is a large-scale research facility located in southwest England (UK)

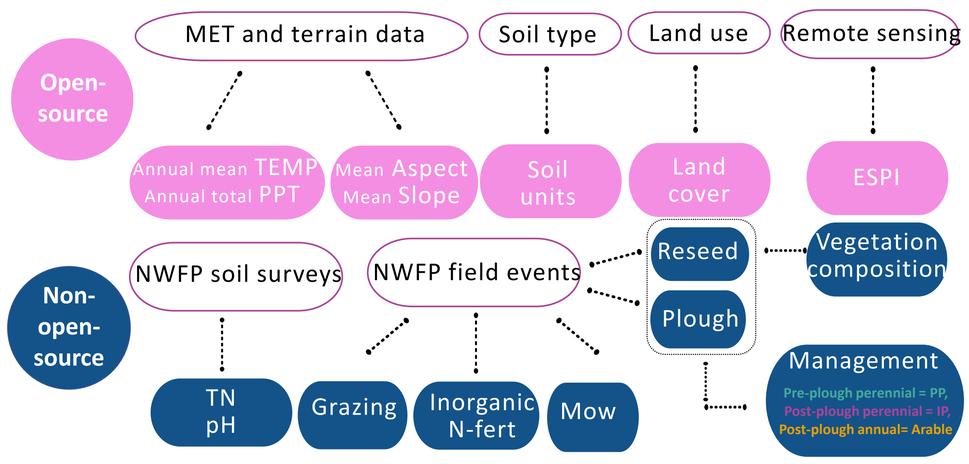



Fig 2. Variables included as candidate predictors for SOC (% w/w) in the top 10 cm. Farming practise predictors were interpreted annually from the NWFP field event records. ESPI (Ecosystem Services Provision Index), a C inputs proxy, was annually calculated from the incoming radiation absorbed by photosynthetically active green vegetation( APARg) from March to October. ESPI (MJ $m^{-2}$ $d^{-1}$ )= $APARg_{\mu}$ –$APARg_{\sigma}$

### Modelling

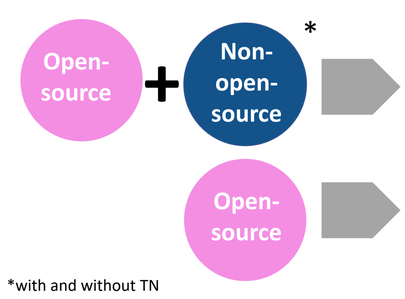



Fig 3. The most parsimonious model for each approach was selected using the Akaike Information Criterion. Model selection and validation included assessment of goodness of fit, model performance and cross-validation.

**Model selection and validation to fit best model for each approach**

| | |
|---|---|
| SOC and predictors have linear relationships? --> | Linear model (LM) |
| Effects of *Fields* on SOC? --> | Linear mixed model (LMM) |
| SOC and predictors have non-linear relationships? --> | Generalised additive model (GAM) |
| Effects of *Fields* on SOC? --> | Generalised additive mixed model (GAMM) |

## RESULTS

### SOC and ESPI decreased after conversion to arable at NWFP

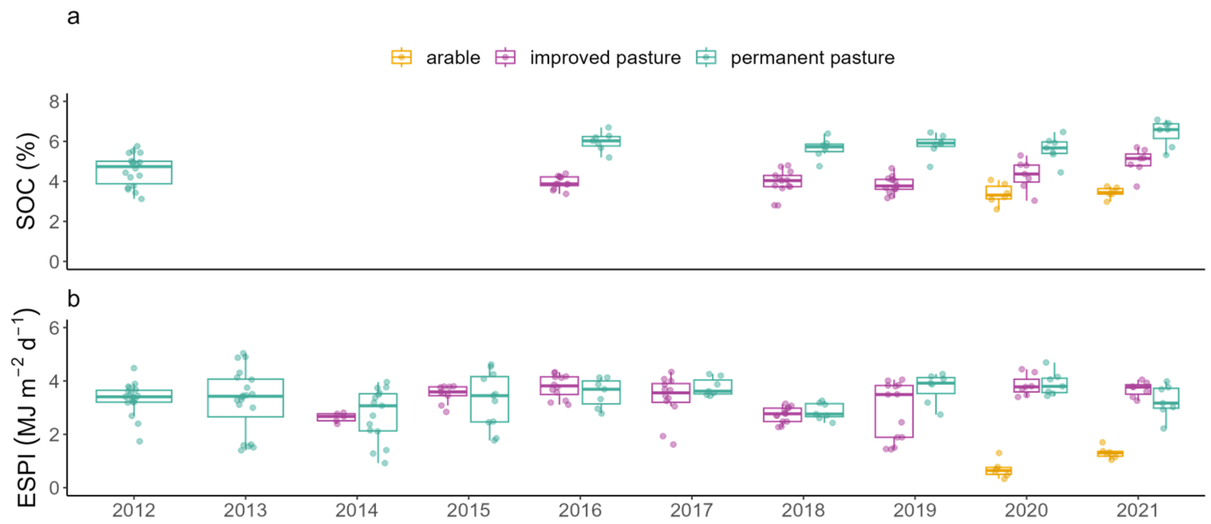



Fig 4. Dynamics of (a) SOC and (b) ESPI across the NWFP. Boxplots show median, 25th percentile, 75th percentile and range for the different management systems. Mean values in each field are represented as individual datapoints

Open-source + Non-open-source

### Best model: GAM explained 84.6% of deviance

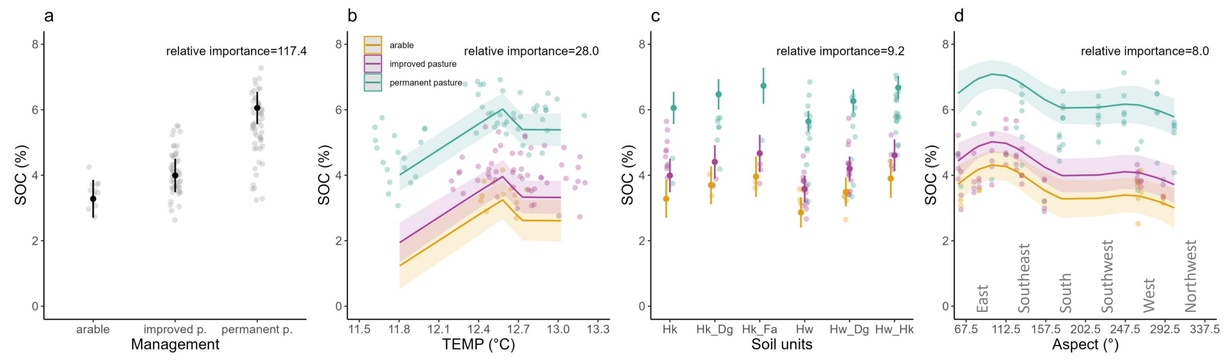



Fig 5. Response curves for the best model fitted with the open and non-open source sets of variables (excluding TN): SOC ~ management + soil.units + s(aspect) + s(TEMP); RMSE= 9.1%, i.e., 0.4% SOC w/w. The order of the terms is related to their F-statistic value, which can be used as a proxy for their relative importance in the model: (a) Management; (b) mean annual temperature (TEMP, °C); (c) Soil units (Fig 1); (d) fields mean aspect (°). When TN was included in the candidate set of predictors the best model also was a GAM (SOC ~ management + soil.units + ESPI + TN + s(TEMP), deviance of 98.5%, RMSE=2.9%, i.e., 0.1% SOC w/w). Curves provide the predicted values on the scale of the response and the shading represents the 95% confidence intervals on the estimated SOC based on model predictions

Open-source

### Best model: GAM explained 68.4% of deviance

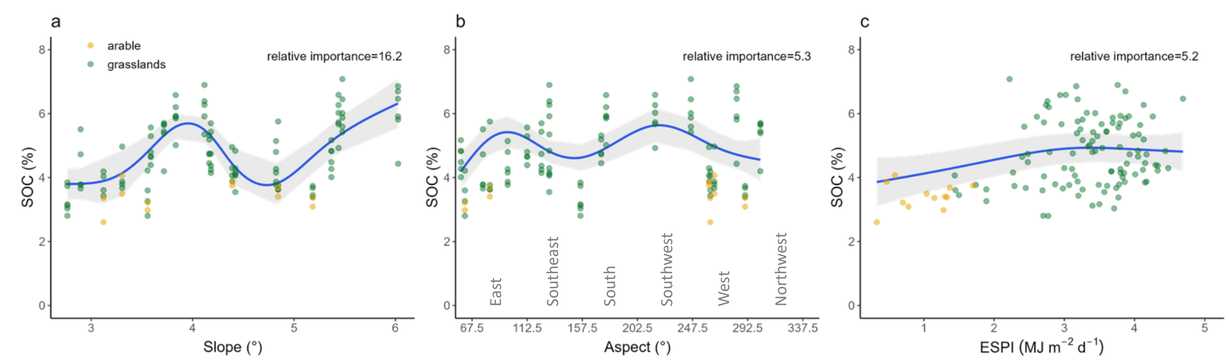



Fig 6. Response curves for the best model fitted with the open source set of variables: SOC ~ s(ESPI) + s(aspect) + s(slope); RMSE= 13.0%, i.e., 0.6% SOC w/w. The order of the terms is related to F-statistic value, which can be used as a proxy for their relative importance in the model: (a) fields mean slope (°); (b) fields mean aspect (°); (c) Ecosystem Services Provision Index (ESPI, MJ $m^{-2}$ $d^{-1}$)

## CONCLUSIONS

- ✓ In temperate grazing grasslands, conversion to arable land promotes SOC depletion and lower ESPI values, hence, lower C inputs to the soil
- ✓ Combining long-term data and flexible statistical modelling offers an opportunity to assess SOC variability at farm level
- ✓ Management is the most important predictor of SOC through losses from ploughing and reduced C inputs from annual crops
- ✓ Statistical modelling using open-source predictors for SOC can be an alternative and useful cost-effective methodology at the farm level


*References*

Evans et al. Eur J Soil Sci. 2022;73:e13145. doi: 10.1111/ejss.13145
Paruelo et al. Ecol. Indic. 2016; 71: 145–154. doi:j.ecolind.2016.06.054
Smith et al. Glob Change Biol. 2020;26:219–241. doi: 10.1111/gcb.14815



*Acknowledgements*

Work funded by *Soils to Nutrition* (WP1 BBS/ E/C/000I0320 and WP2 BBS/ E/C/000I0320), *AgZero+* (NE/W005050/1), *Growing Health* (BB/X010953/1) and *Resilient Farming Futures* (BB/X010961/1) programs. North Wyke Farm Platform data was provided by BSS/E/C/000J0100.


ROTHAMSTED RESEARCH

UKRI Biotechnology and Biological Sciences Research Council

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

ROTHAMSTED RESEARCH

Andrew Riche, March Castle, Parul Sehrawat, Andrew Gregory and Malcolm Hawkesford

Rothamsted Research, Harpenden, AL5 2JQ UK

**Figure 1**. The UAV with co-aligned hyperspectral sensors, LiDAR and high precision GNSS.

## INTRODUCTION

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) was used to collect reflectance data from the Broadbalk long-term field experiment at Rothamsted.

## METHODS

The UAV system was flown on seven occasions between 28th April and 23rd June 2022 to collect hyperspectral data from Broadbalk. The system includes lidar and a high accuracy GNSS system, and by combining the data accurate high resolution 3D geo-located ortho-rectified image mosaics were produced. To cover the whole field took two or three flights, each of around 13 minutes. The UAV was flown at 60m altitude and between 2.4 and 4m/s. From the data, sixteen growth indices were calculated for each plot; yield data was also collected at final harvest.

## RESULTS

The spectra show clear differentiation between the different N levels (Fig 3a) and between plots with the various nutrient restrictions (Fig 3b).
The spectra particularly separate in the short infrared wavebands.

The Green Normalised Difference Vegetation Index, GNDVI, showed the best correlation with grain yield at final harvest compared to the other indices calculated. Figure 4 shows the data collected from each flight; data collected on 15th June correlated the most closely with the grain yield.

**Figure 2**. Broadbalk field, March 2022. Section 9 is at the bottom of the image, with the FYM treatment the greenest, on the right.

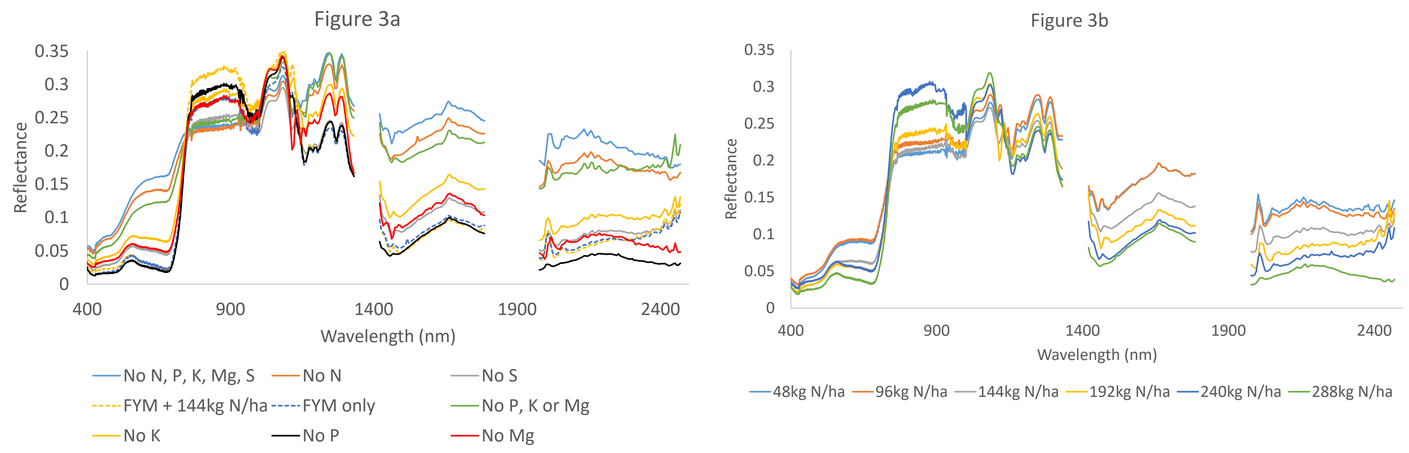



**Figure 3.** Reflectance spectra from wheat plots in section 9 of Broadbalk, receiving specific elemental restrictions (a) and different levels of N fertilization (b). Data collected 19/05/2022, gaps in the data correspond to regions of atmospheric water interference.

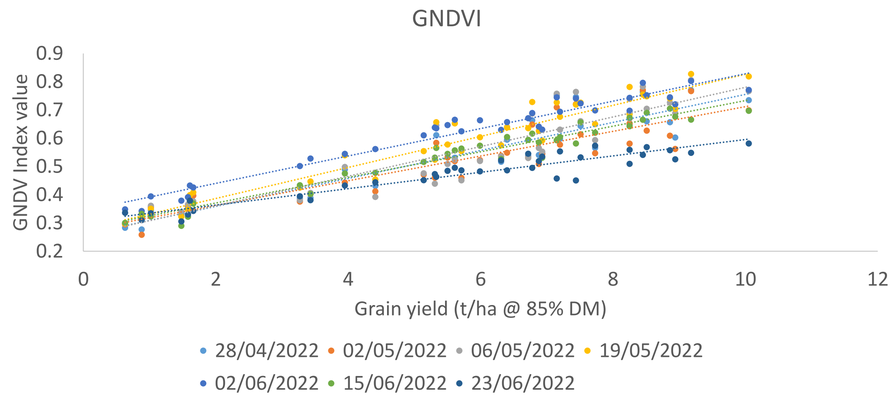



**Figure 4.** GNDVI, calculated for each date, plotted against grain yield at final harvest. The best fit was for 15/06/2022, with a regression coefficient of 0.9543.

## CONCLUSIONS

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**

Rothamsted Research receives strategic funding from the Biotechnology and Biological Sciences Research Council of the United Kingdom. We acknowledge support through the Designing Future Wheat (DFW) and Delivering Sustainable Wheat Strategic (DSW) Programmes (BB/P016855/1 & BB/X011003/1).

**References**

Holman, F. H.,Riche, A. B.,Michalski, A.,Castle, M.,Wooster, M. J.,Hawkesford, M. J. 2016.High throughput field phenotyping of wheat plant height and growth rate in field plot trials using UAV based remote sensing. Remote Sensing 8(12), pp.1031 doi: 10.3390/rs8121031

Holman, F. H., Riche, A. B., Castle, M., Wooster, M. J. and Hawkesford, M. J. 2019. Radiometric calibration of 'Commercial off the shelf' cameras for UAV-based high-resolution temporal phenotyping of reflectance and NDVI. Remote Sensing. 11 (14), p. 1657.

DSW DELIVERING SUSTAINABLE WHEAT

UKRI Biotechnology and Biological Sciences Research Council

# Long term field experiment on stockless organic farming

UNIKASSEL VERSITÄT | ORGANIC AGRICULTURAL SCIENCES

Möller M., Athmann M., Bruns C.
University of Kassel
Section of organic farming and cropping systems
morten.moeller@uni-kassel.de

## Background:

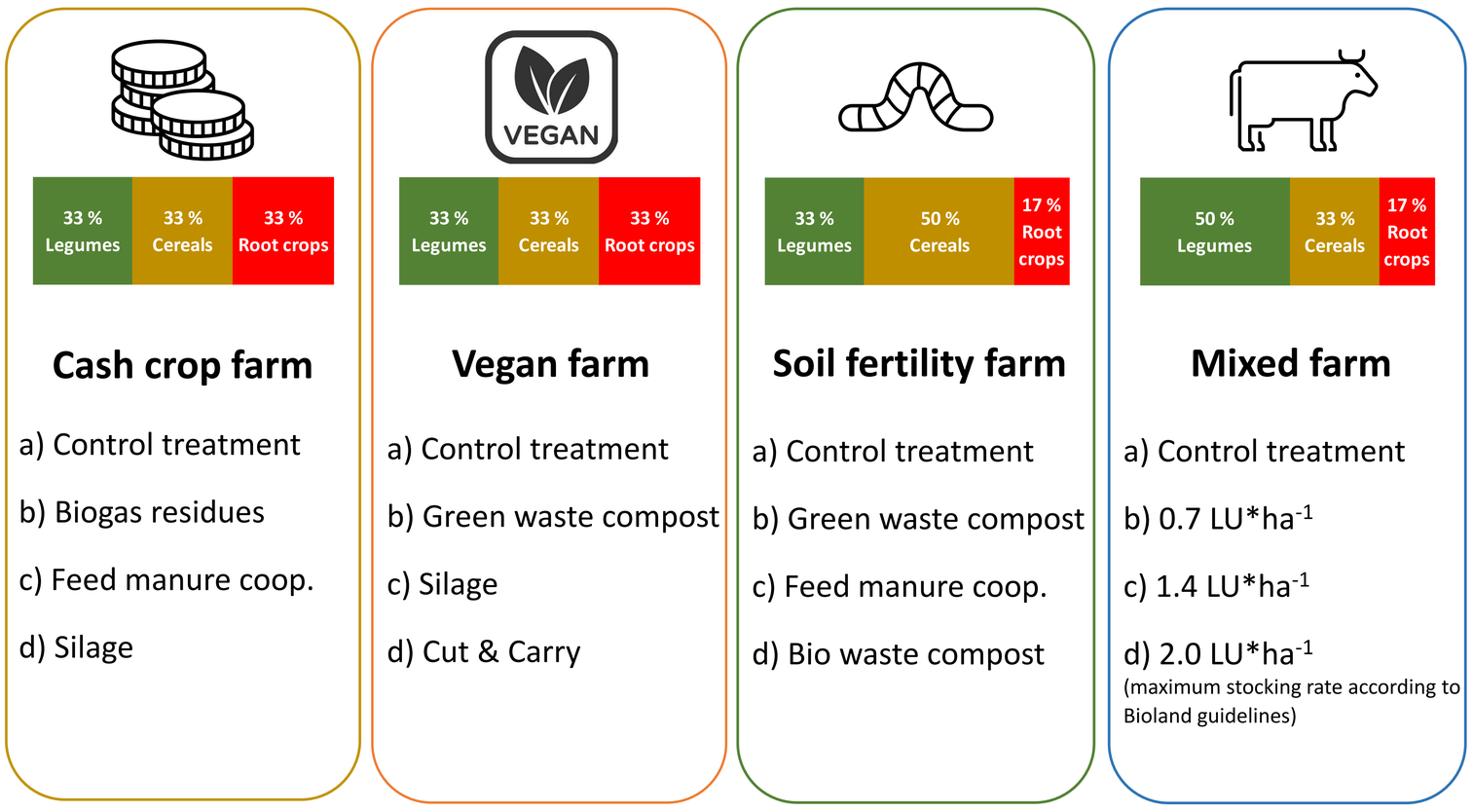
- Organic farming is sharply increasing in Germany
  - 14 % of all farms work under organic management
- Common practice for organic farms is to work in an almost closed nutrient cycle
- **As stockless organic farming is also increasing, the nutrient cycle needs to be questioned**
- Challenges in terms of nutrient management and soil fertility may occur due to missing utilization of legume-grass mixtures for animal feeding resulting in production of farm fertilizers

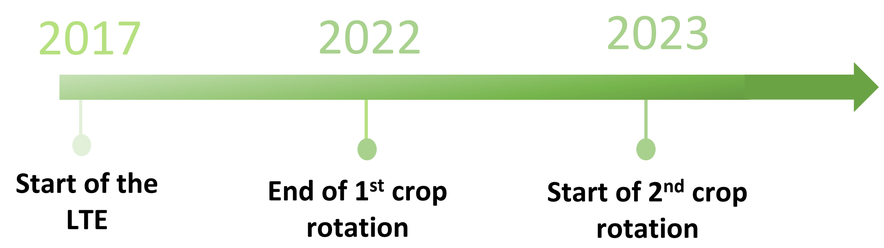
## Objectives:

- Data collection regarding different use options of fodder legumes in stockless farms
- Evaluation of fertilization concepts that include external fertilizers
- Development of soil health concepts which enhance productivity of legumes by using diversified crop rotations and SOM increasing fertilizers
- **Development of long-term sustainable cropping systems for stockless organic farms**

## Material and methods:

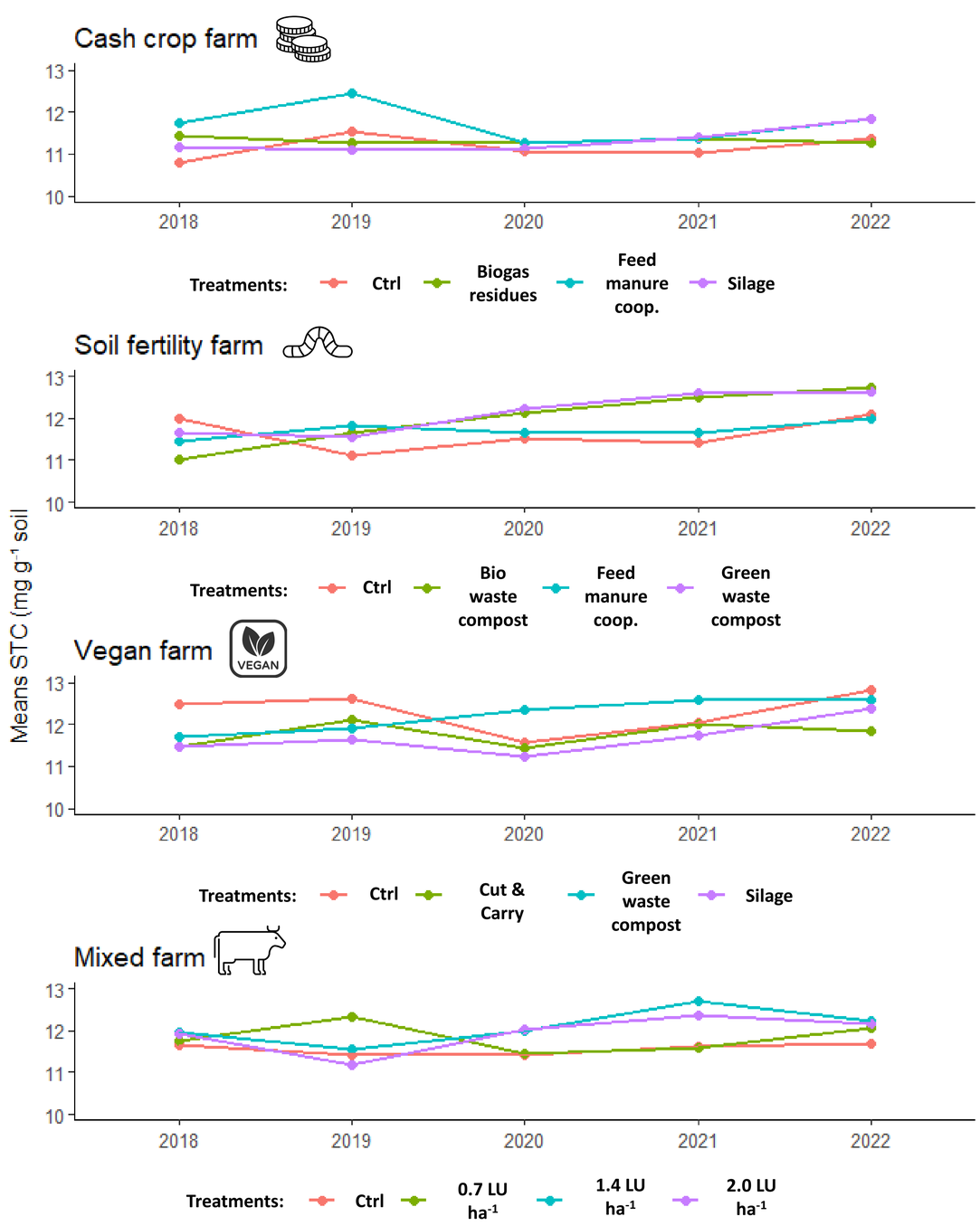
**Simulation of three stockless organic farms, each with a different focus and four different fertilization systems, compared to a traditional mixed farm.**



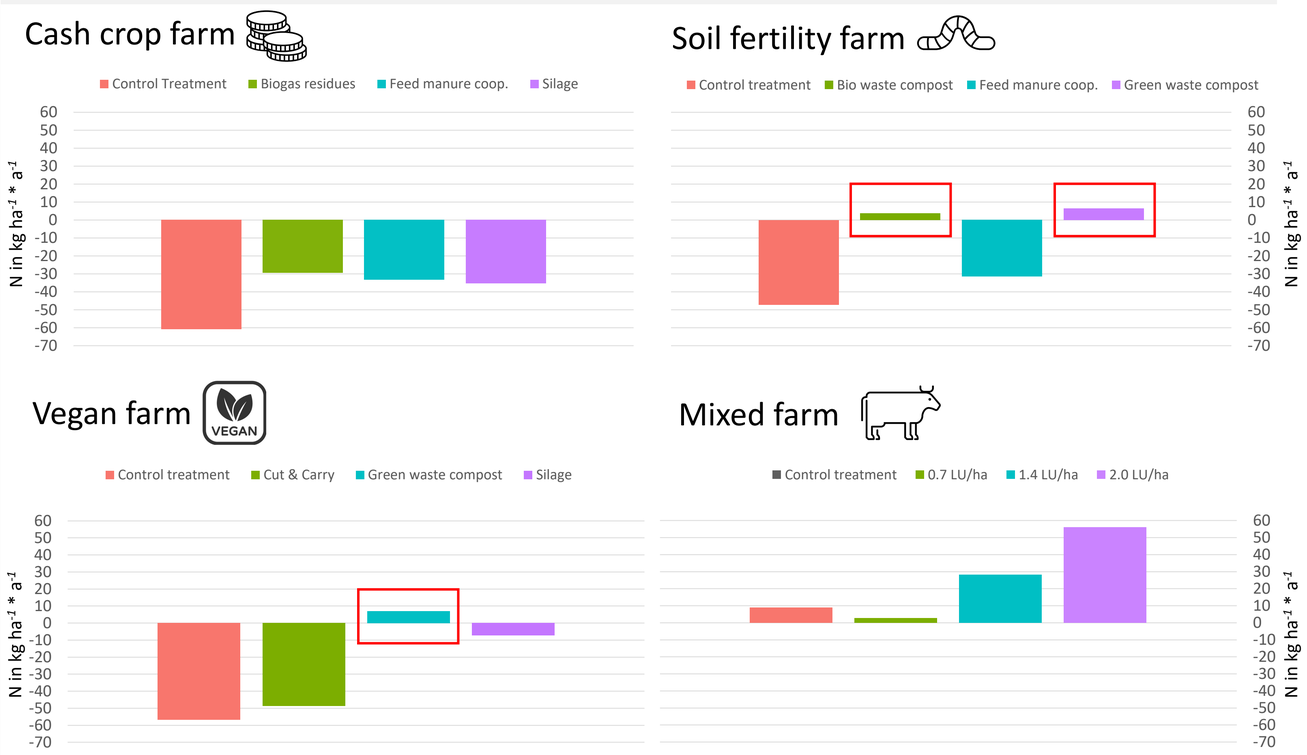

- **Location**: Germany, state Hesse
- **Soil type:** Haplic luvisol/ Colluvisol with loess layer
- **Experimental design:** Split plot design, 4 field repetitions
- **Measurements:** $C_t$, $N_t$, $P_t$, $K_t$, $S_t$, $N_{min}$, pH, CEC, Bulk density, Water retention, MBN, MBC, MBP, Basal respiration, Ergosterol, Earthworms, Nematodes, GHG emissions, Yield

## Results - Soil total carbon:




*Soil total carbon (mg g$^{-1}$) for each year and each treatment in topsoil (0-30 cm depth). n=4*

## Results - Nitrogen balances of 1st crop rotation:




## Conclusion:

- Stockless organic farms can achieve positive trends in SOC contents and balanced nitrogen balances, especially in compost treatments
- With time, stronger differentiation of treatments is expected
- Including the results of ongoing analyses of soil physics and biology, GHG emissions and crop yields will allow a multifactorial evaluation

## Acknowledgements:

Technical staff of Frankenhausen
Laboratory staff
All student assistants
Hessian Ministry of Agriculture

ÖKO AKTIONS PLAN.
HESSEN
Funded by:
Hessisches Ministerium für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz

# 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

**CARDINAEL Rémi**[1,2,3*], BOUHENACHE Abderrahim[1,2,4], FALCONNIER Gatien[1,2,3,5], CHIKOWO Regis[3,6]

[1] CIRAD, UPR AIDA, Harare, Zimbabwe
[2] AIDA, Univ. Montpellier, CIRAD, Montpellier, France
[3] Department of Plant Production Sciences and Technologies, University of Zimbabwe, Harare, Zimbabwe
[4] Université de Reims Champagne Ardenne, INRAE, FARE, UMR A 614, 51097 Reims, France
[5] International Maize and Wheat Improvement Center (CIMMYT), Harare, Zimbabwe
[6] Plant, Soil and Microbial Sciences Department, Michigan State University, East Lansing, USA

*Corresponding author: remi.cardinael@cirad.fr

## Background

- Extreme rainfall events, such as droughts, dry spells, and erratic and very heavy 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.

## Objective

- Assess the long-term agronomic and environmental performances of innovative cropping systems under extreme rainfall events in sub-humid Zimbabwe, combining field monitoring and soil-crop modelling.

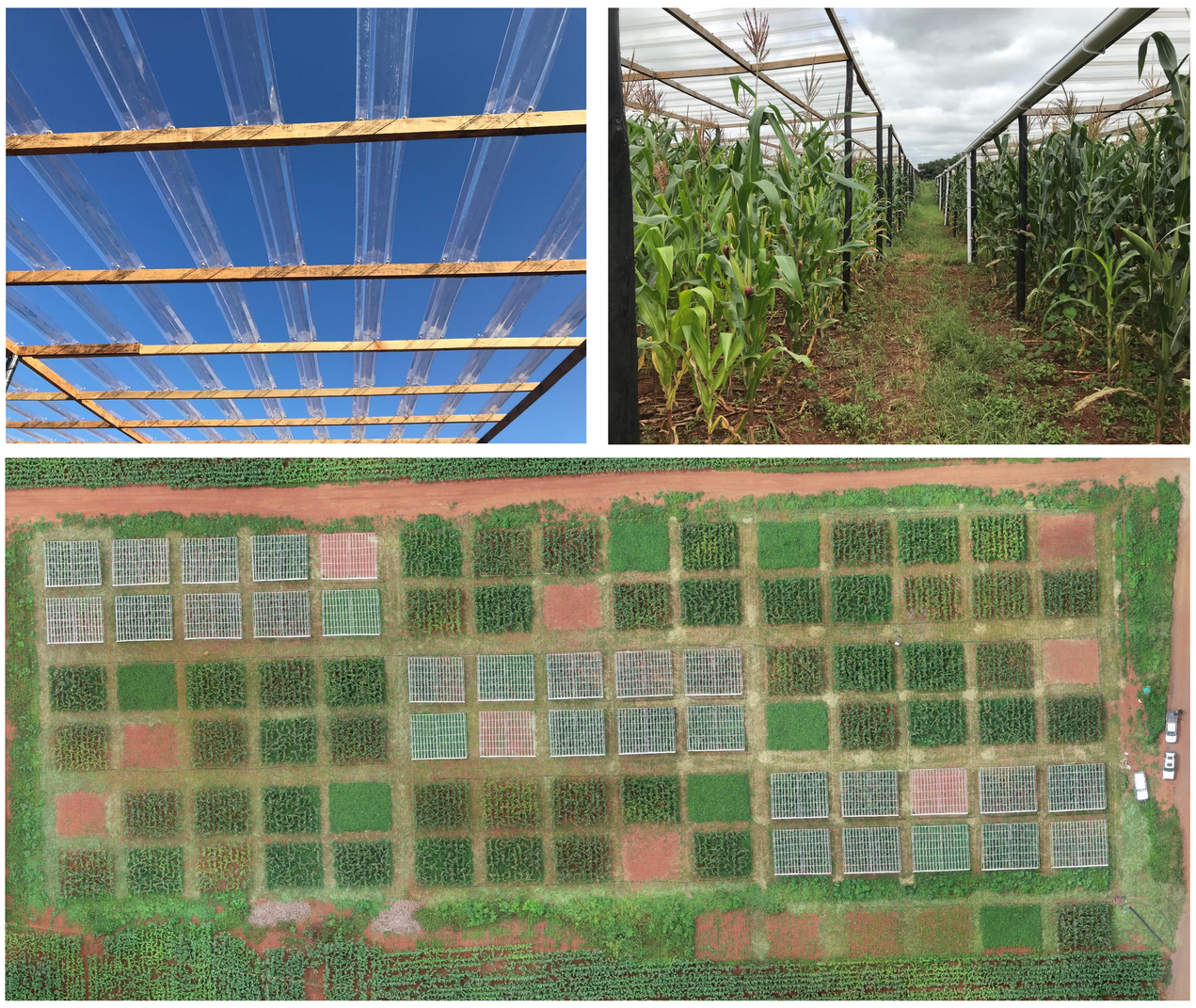


**Figure 2.** Rainfall exclusion system (top) and aerial view of the University of Zimbabwe Farm (UZF) trial (bottom).

## Monitored variables

### *Plant*

- Crop phenology, plant height, leaf area index (Licor LAI 2200C, SunScan) during the season. Crop biomass at flowering stage. Crop biomass, yield and yield components at harvest. Biological nitrogen fixation ($^{15}N$ dilution method). Plant transpiration (sap flow). Mulch decomposition.

### *Soil*

- Initial basic soil properties (texture, pH, P-Olsen, CEC, SOC, total N) down 1m depth.
- Regular measurements of soil mineral nitrogen and soil water content along the profile. Continuous measurements of soil moisture and temperature at 1, 5, 15 cm.
- Greenhouse gases emissions ($CO_2$, $N_2O$, $CH_4$) using static chambers.

### *Climate*

- Weather station for common climatic variables.
- Photosynthetically active radiation under rainout shelters.
- Shortwave and longwave radiation using radiometers (energy balance).

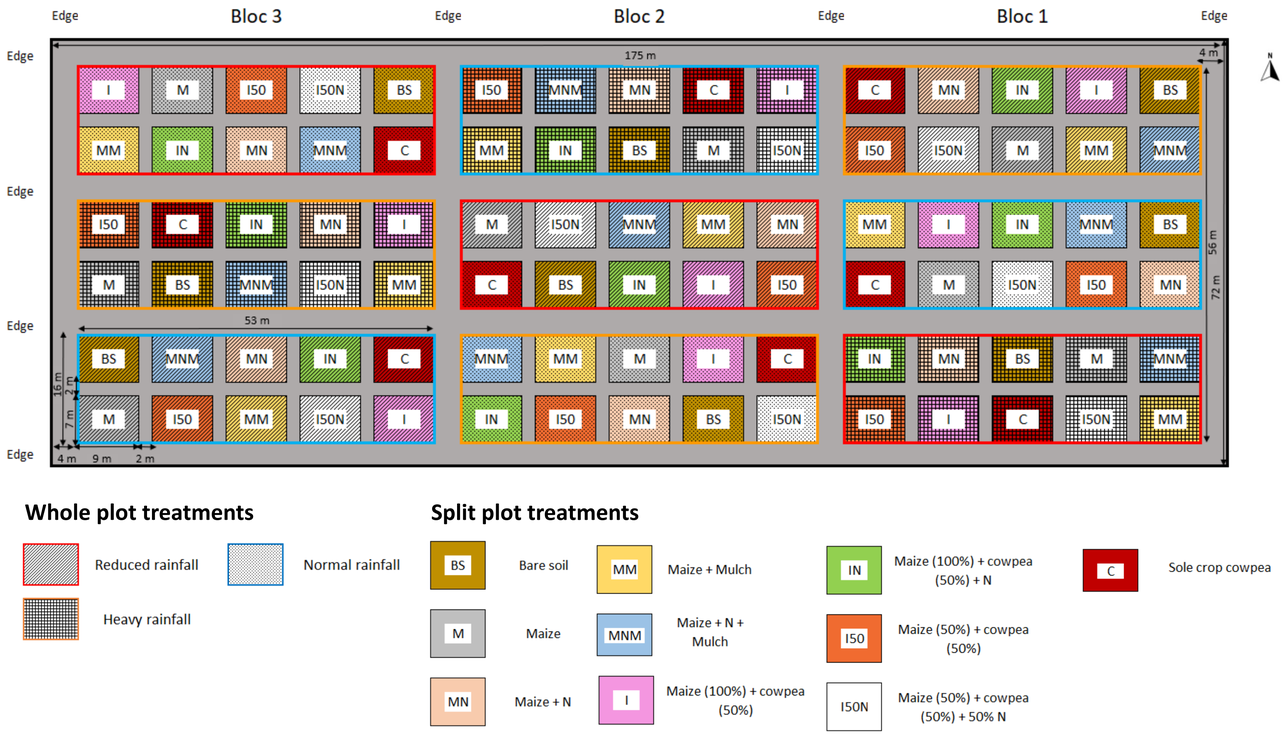



**Figure 1.** Experimental design of the University of Zimbabwe Farm (UZF) trial.

## Description of the experiment

- The experiment has been established in October 2022 on 1.4 ha at the University of Zimbabwe Farm (UZF) (17°42'13.5"S, 31°00'29.4"E).
- A split-plot design was used. Three whole plot treatments are repeated three times (**Figure 1**):
  - Reduced rainfall (-30%)
  - Normal rainfall
  - Heavy rainfall events (100 mm/24h)
- The split plot treatments are:
  - Bare soil
  - Maize
  - Maize + N
  - Maize + Mulch
  - Maize + N + Mulch
  - Maize (100% density) + cowpea (50% density) intercropping
  - Maize (100% density) + cowpea (50% density) intercropping + N
  - Maize (50% density) + cowpea (50% density) intercropping
  - Maize (100% density) + cowpea (50%) intercropping + 50% N
  - Cowpea
- The mulch is made of maize residues from the previous season applied at 6 t DM/ha. Mineral nitrogen fertilizer (+N) is applied at 80 kgN/ha/yr.
- Grass strips (2-4 m wide) were planted to prevent lateral water flows between treatments.
- The reduced rainfall treatments are achieved with a rainfall exclusion system (**Figure 2**), with transparent shelters covering 30% of the surface.
- The heavy rainfall events are obtained with an irrigation system installed at the site. At least 2 events per season are simulated. The date of these events can vary one year from another.

## Ongoing projects

https://raiz.org.zw/
https://intercropvalues.eu/
https://dscatt.net/
https://faircarbon.wordpress.com/

Exciting ideas? Willing to develop new collaborations? Come and join us!

# 1962 THE LIVADA LONG-TERM EXPERIMENTS 2023

**PATRICK URSAN [1]**

Agricultural Research and Development Station Livada, România

## Introduction

**Acidic soils, characterized by low pH levels, pose significant challenges to agricultural productivity and environmental sustainability. These soils are often deficient in essential nutrients, limiting plant growth and impairing nutrient cycling processes. To address these issues, liming and fertilisation have been recommended to increase soil fertility and sustain crop productivity.**
**Long-term experiments have become paramount in understanding the intricate interactions between soil chemistry, plant nutrition, and greenhouse gas (GHG) emissions under different agroecosystems.**

## Materials and Methods

**The long-term field experiments managed by the Research and Development Station Livada include one amendment x fertilisation experiment and three fertilisation experiments which were established in 1961 and 1967, respectively. The experiments are located in North-Western Romania (47°52'07.3"N 23°07'10.2"E) which has a continental temperate climate. The annual average temperature recorded at the weather station A.R.D.S. Livada over the last 60 years is 9.9°C, while the annual average amount of precipitation is 753.2 mm.**

**The experimental soils at Livada Research Station are classified as Luvisols (haplic luvisol-WRB Classification System), with acidic pH, poor in potassium, relatively low humus content as well as low base saturation.**

Fig. 1 Aerial view of experimental trials

The long term experiment with amendments and mineral & organic fertilisation

-bifactorial-
( 9A x 8B )

| | Factor A<br>Liming levels<br>(t/ha/year) | | Factor B<br>Fertilising levels<br>(kg/ha/year) |
|---|---|---|---|
| 1 | 0 (Control) | 1 | 0 (Control) |
| 2 | 0,081 | 2 | $N_{100}$ |
| 3 | 0,161 | 3 | $P_{70}$ |
| 4 | 0,161 | 4 | $N_{100}$ $P_{70}$ |
| 5 | 0,202 | 5 | $N_{100}$ $P_{70}$ $K_{60}$ |
| 6 | 0,403 | 6 | $FYM_{20}$ |
| 7 | 0,242 | 7 | $N_{100}$ $P_{70}$ $K_{60}$ $FYM_{20}$ |
| 8 | 0,323 | 8 | $N_{100}$ $P_{70}$ $K_{60}$ + Mg |
| 9 | 0,645 | | |

"Mangelversuch"

Lime=calcium carbonate

N=ammonium nitrate
K=potassium salt
P=superphosphate
FYM=farmyard manure (t/ha/year)

—Plot size: 6m x 7m—

**The design of the amendment x fertilisation experiment is of the 9A x 8B type with factor A representing lime doses and periodicity and factor B representing fertilisation levels. The three fertilisation experiments are of the type 5P x 5N, 4NP x 4K and 4NP x 4FYM the factors being doses of nitrogen, phosphorus, potassium and farmyard manure. All experiments were established in four replicates.**

**Routine soil and plant analyses were carried out in different treatments to assess plant nutrient status and soil nutrient cycling. Furthermore, a portable infrared gas analyzer (LCi-ADC Bioscientific Ltd ) was used to investigate the effects of amendments and fertilisation on soil respiration *in situ*. The cumulative yield analysis method (Svab 1981) was used to highlight magnesium deficiency from experiments with nitrogen, phosphorus and potassium.**

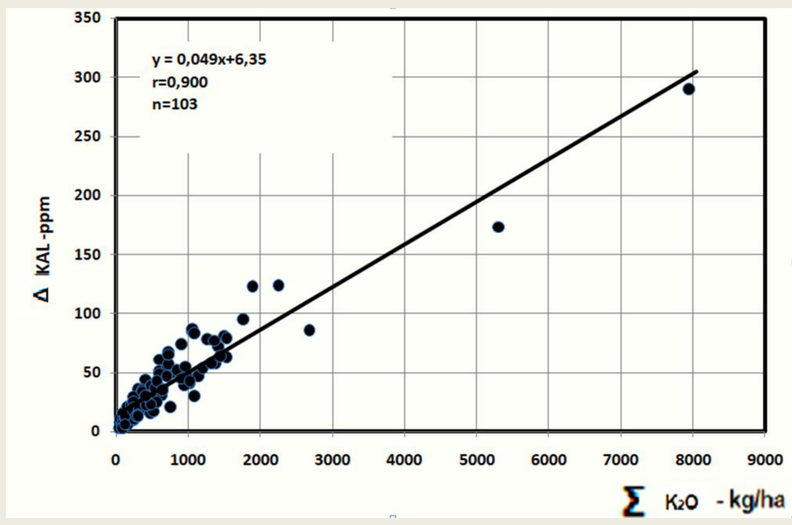



Fig. 5 The effect of long-term fertilisation (1968-2020) with potassium (K) on the accumulation of K mobile in soil, soluble in ammonium acetate-lactate

**There is a direct proportional relationship between the cumulative doses of potassium (K2O) and difference amplitude of mobile potassium content. The application of potassium salt in progressively increasing doses, every 4 to 5 years, for over 50 years aided in the systematic accumulation of potassium; its maximum value being approximately 300 ppm.**

Tab. 2 The effect of long-term liming and fertilisation (1962-2022) on soil respiration

| Fertilising | Soil Respiration (µmol CO 2 /m-2s-1 ) | | | Mean |
|---|---|---|---|---|
| | Liming-CaCO3 | | | |
| | pH (H2O) | | | |
| | (4,67-6,01) | (5,32-6,89) | (6,73-8,05) | |
| | Unlimed | 0,323 t calcar /ha/year | 0,645 t calcar /ha/year | |
| 0 | 2,03 | 4,27 | 5,24 | 3,85 |
| N | 1,76 | 3,65 | 5,71 | 3,71 |
| P | 2,85 | 4,55 | 5,23 | 4,21 |
| NP | 4,23 | 5,57 | 6,29 | 5,36 |
| NPK | 4,25 | 6,22 | 6,85 | 5,77 |
| FYM | 6,02 | 8,10 | 8,60 | 7,57 |
| NPK+FYM | 6,85 | 11,30 | 12,52 | 10,22 |
| Mean | 4,00 | 6,24 | 7,21 | x |

**Neutralizing soil acidity stimulated biological activity in the soil, thereby increasing soil organic matter mineralisation and implicitly impacting carbon dioxide emissions. The obtained results suggest that liming and fertilisation can have a significant effect on soil organic matter turnover and $CO_2$ emissions in acidic soils.**

## Results

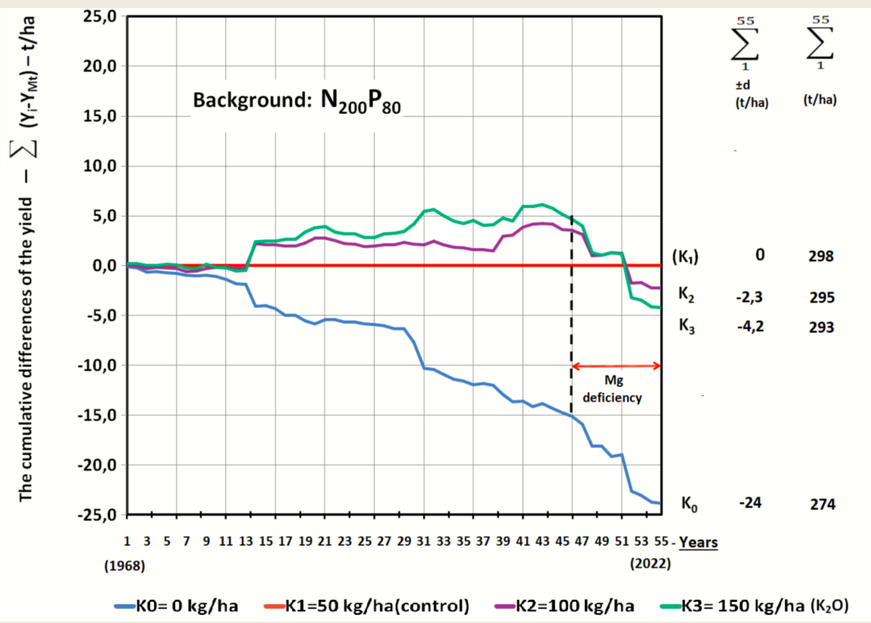



Fig. 2 The cumulative difference of the yield under 4 doses of potassium with a background of nitrogen and phosphorus fertilisation.

Visible symptoms of Mg deficiency

**In Romania, the issue of magnesium deficiency in crops was initially found at the long-term experiments from Livada. In the last 10 years, the amplification of this phenomenon has led to a drastic limitation of crop yields.**

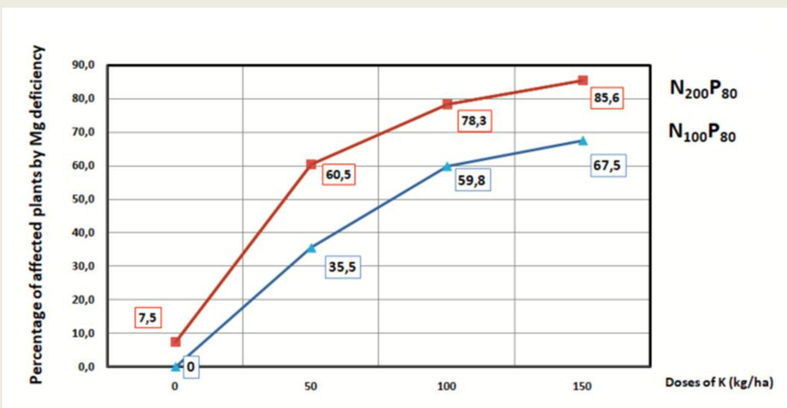



Fig. 3 Percentace of affected plants by magnesium deficeincy due to fertilisation with K asociated with N and P

**Magnesium deficiency became more apparent in variants with high doses of nitrogen (<100 kg N), while leaf chlorosis intensified with increasing doses of K. Thus, magnesium deficiency becomes visible on older leaves, since magnesium is translocated to new and younger leaves.**

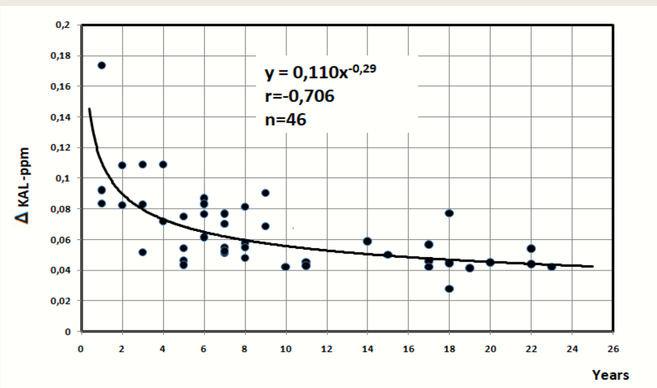



Fig. 4 The decrease in time of the content of mobile potassium in the case of cessation of fertilisation with potassium

**As the experimental time increases duration, in the case of control plot (unfertilised and unlimed) , after the cessation fertilisation, the accumulation rate of mobile potassium in the plowed horizon tends to decrease, reaching a relatively stable level after 8-10 years. The lack of evolution in the rate of potassium change can be interpreted through the return to the initial level of potassium accumulation in soil (equilibrium).**

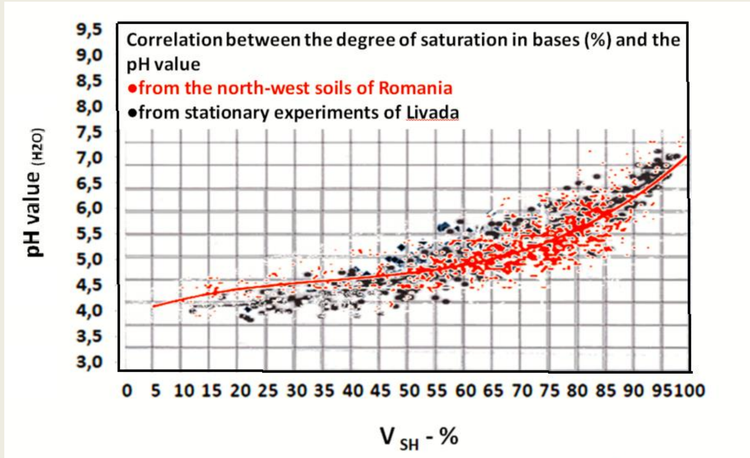



Fig. 6 Overlap of dispersions regarding the correlation between the degree of saturation in bases (%) and the pH value from **stationary experiments of Livada** and from the **north-west soils of Romania**.

**Analyzing the correlation between the degree of saturation in bases and the pH value (Fig. 6), an almost perfect overlap of the dispersion of values derived from the stationary experiences and those derived from the agrochemical and pedological maps carried out in the area was found. The overlap of the two dispersions highlights that the stationary experiences soils very faithfully reflect the reality in the field, and can be the basis of prospective research on the collateral effects of the amendment of acidic soils and its environmental implications.**

Want to know more?

SCAN ME!

patrick-andrei.ursan@student.usamvcluj.ro

# Development of an silvoarable agroforestry LTE in the Netherlands

## Experimental design and monitoring choices

Maria-Franca Dekkers, Isabella Selin Noren, Maureen Schoutsen

### Background

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.

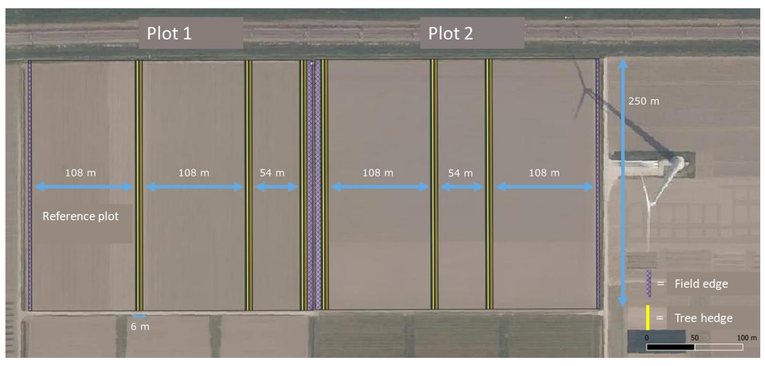
### Objective

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 yield, biodiversity, carbon sequestration, microclimate and buffering against extreme weather events are monitored.

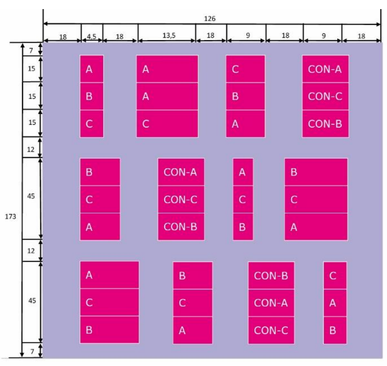
### Design criteria

After discussions on the trade-off between windbreak function and production function of the woody crop, site requirements of tree species, product marketing (niche vs. mainstream), impact on labour costs, years to full production, landscape incorporation and the magnitude of all ecosystem services the following system criteria were formulated:

- Scalable up to 25.000 ha; potentially interesting system for common practice for arable farmers
- Good connection with the real situation of the agricultural entrepreneur (market, labour and intrinsic motivation)
- Including a productive woody crop with good market prospects
- Scientific set-up and international relevance
- Microclimate effects can be measured relatively quickly (6-10 years)
- A nature-based system in which ecosystem services can be investigated, such as; biodiversity, climate adaptation and carbon sequestration
- Consistent with design and cultural identity of the landscape




AF LTE 1: Distance



AF LTE 1: Tree shape

### Justification of design choices

Based on these criteria, hazels in combination with (at least during establishment phase) a fast-growing mixed (biodiverse) wind break hedge have been chosen as woody crops in an alley cropping system with an organic rotation of arable crops. In the 'distance' LTE effects at different distances from the hedge are investigated. In the 'tree shape' LTE different pruning strategies and the effects of the number of hazel rows are researched.

- Hazels are economically viable (although it is uncertain what happens to the price when production is scaled up). Harvest can be done mechanically (this is not the case for fruit trees). Hazels are a CAP subsidised crop, which makes the initiation phase of agroforestry easier.

Agroforestry LTE's at the WUR research facility in 2022

- The mixed hedge is chosen as a quick windbreak for the hazels, as they are quite vulnerable to wind? and it is uncertain what wind break effects effect hazels can produce and how many years after planting. The mixed hedge might be removed in a later phase, when the hazel hedge can take over the windbreak function.
- Organic management would allow a better mapping of the full effect of the system on biodiversity and natural disease and pest control.

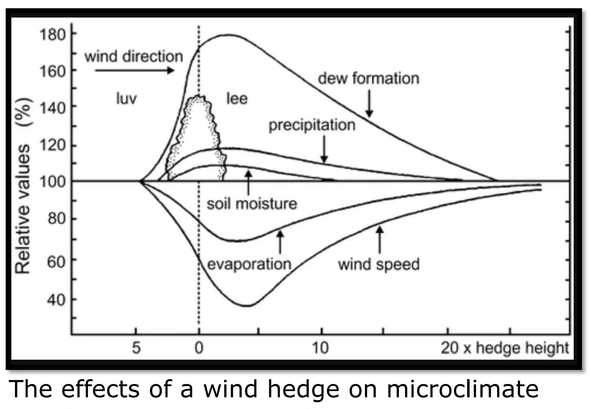
### Research questions

1. What is the effect of the system on the cultivation, yield and quality of arable crops?
   a. How do these effects occur (looking in particular at the microclimate and aerodynamics)?
   b. What are the distances from the hedge at which these effects occur?
   c. How can these effects be translated and replicated in other agroforestry systems?
2. What is the effect of the system on soil quality, climate adaptation, carbon sequestration, biodiversity and farm economics?
3. Which tree shape, pruning strategy and number of rows of hazel is most fitting in silvoarable agroforestry systems?
   a. What is the effect of tree shape and pruning strategy on labour requirement?
   b. What is the effect of tree shape, pruning strategy and number of rows on hazel productivity?

### Monitoring

*- Microclimate*

The 'distance' LTE is continuously monitored with 22 soil stations that measure soil moisture and temperature; and 6 weather stations which record solar radiation, precipitation, air temperature, humidity and wind speed and direction.

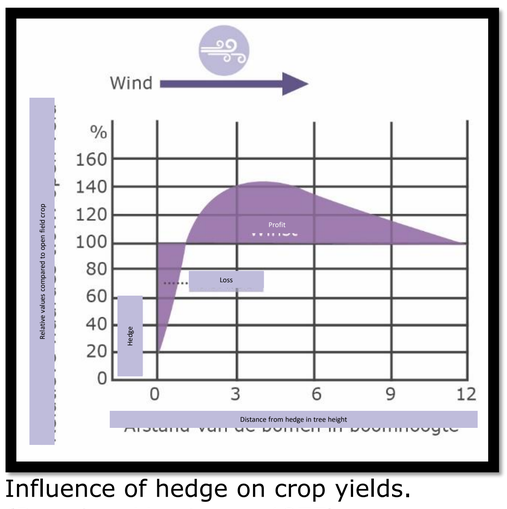



The effects of a wind hedge on microclimate with the wind direction at a right angle to the hedge (Leuschner & Ellenberg, 2017)

*- Biodiversity*

Biodiversity is measured at three distances from the hedge (25, 50 and 75 m) and within the hedge. Moths are captured using LED buckets. Flying insects and crawling insects are captured using malaise and pitfall traps. The presence of the nut weevil is also monitored.

Soil and weather station in the 'distance' LTE




Influence of hedge on crop yields. (Based on Voortman, 1977)

*- Yield of arable crops and hazels*

*- Soil quality and carbon sequestration*

*- Optical porosity*

With sensors and digital tools the volume and porosity (permeability by wind) of the hedge will be determined.

*- Economic analysis*

The economic performance of the experiments in terms of input and labour costs and revenue will be compared over the course of 25 years to an organic arable farming systems without hedges.

Wageningen University & Research
Edelhertweg 1, 8219PH Lelystad
maria-franca.dekkers@wur.nl
T + 31 (0)320 291157

The WUR agroforestry LTE facilities are available for external parties to carry out measurements. Ideas on this from external parties are welcome.

### Sources

Leuschner, C., & Ellenberg, H. (2017). Forest Edges, Scrub, Hedges and Their Herb Communities. In Ecology of Central European Forests (pp. 747-774). Springer, Cham.
Voortman, R. L. (1977). houtwallen in het landschapsonderzoek van Enschede. Nederlands bosbouw tijdschrift.
www.wur.nl/agroforestry

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

Jeremy Whish and Lindsay Bell

CSIRO Agriculture and Food Australia

## Introduction

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 (Figure 1), 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.

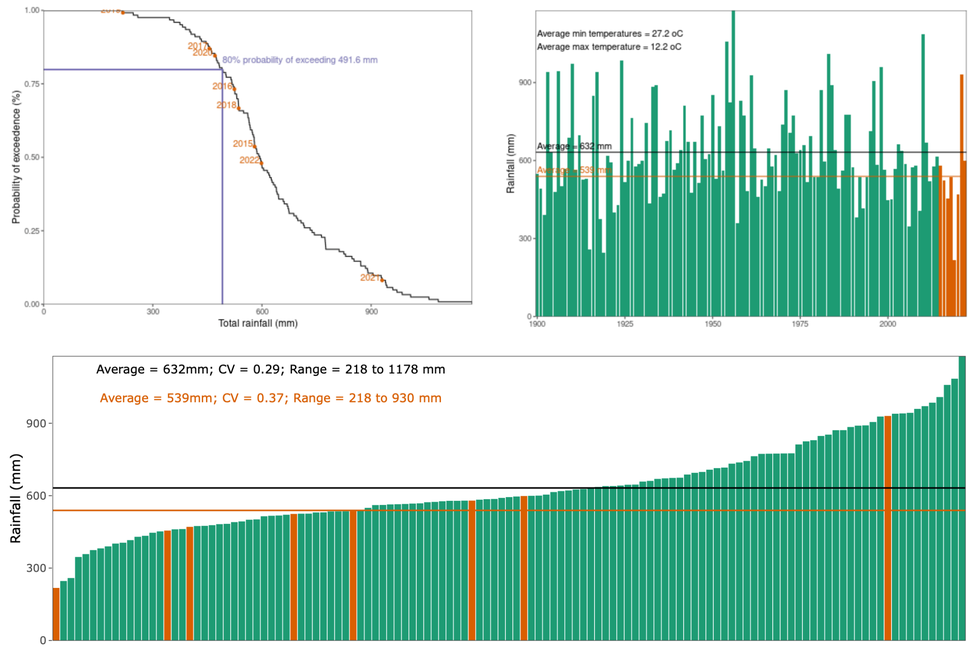



**Figure 1**. Longterm rainfall records for a typical southern Queensland site, showing the seasonal variability and distribution. The Orange bars show the 8 experimental years of the systems trial

## Problem

We are investigating how modifications to the farming system affect performance.

- Changing Crop intensity – ( time spent in crop),
- Increased legume frequency – (a legume every second crop),
- Increased crop diversity – double break of resistant crops,
- Nutrient strategy of fertilising to 90% of yield potential vs 50%.

## Environment

The Large soil water holding capacity of the deep clay soils of the region are used to buffer against rainfall variability (Figure 1).
Long term simulations are used to offer a probabilistic assessment of the risk associated with sowing on different volumes of water (Figure 2)
This approach is used to develop rules that trade off risk of poor returns against increased cropping frequency, The opportunity to increase cropping intensity lies in reducing the fallow period and sowing crops in both summer and winter seasons (double crop).

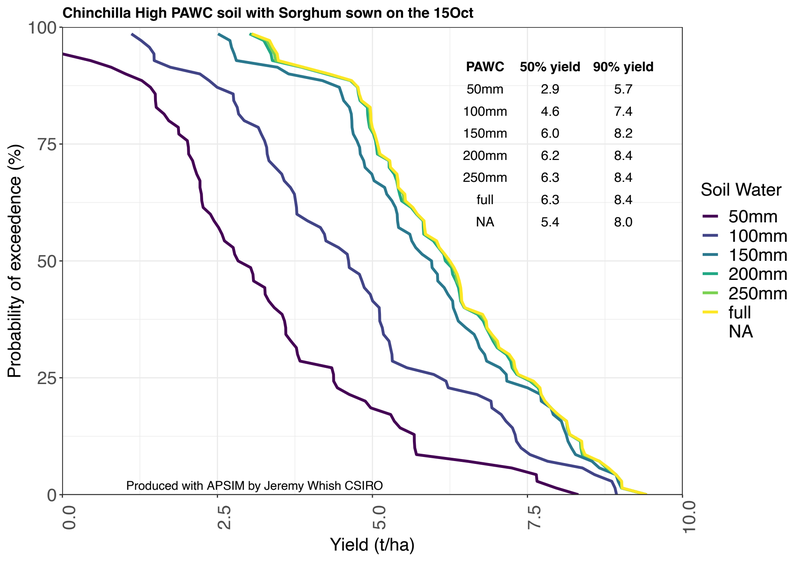



**Figure 2**.
Probabilistic results of long-term simulations with different initial soil water contents.

## Cases study: Changing crop intensity

In this example we compare a **low** intensity sequence 3 crops in 4 years with a **high** intensity sequence 1 crop in each year. The final option is an **opportunity** crop that only gets sown when our sowing rule, 100mm of plant available soil water is satisfied.

**Table 1**.Table of crop sequences showing the low intensity (0.75 crops/yr) , high intensity (1 crop/yr) and opportunity (between .75 and 1, crop/yr)

| | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Intensity |
|---|---|---|---|---|---|---|---|---|---|
| | Summer | Winter | Summer | Winter | Summer | Winter | Summer | Winter | |
| Low | Sorghum | Fallow | Fallow | Chickpea | Fallow | Wheat | Fallow | Fallow | 0.75 |
| High | Sorghum | Fallow | Fallow | Chickpea | Fallow | Wheat | Mungbean | Fallow | 1 |
| Opportunity | Sorghum | Fallow | Fallow | Chickpea | Fallow | Wheat | Mungbean / Fallow | Fallow | 0.75-1 |

## Results:

The Pareto optimal solution showing that strategically increasing intensity when conditions offer the best probability of success maintains profitability and reduces risk.

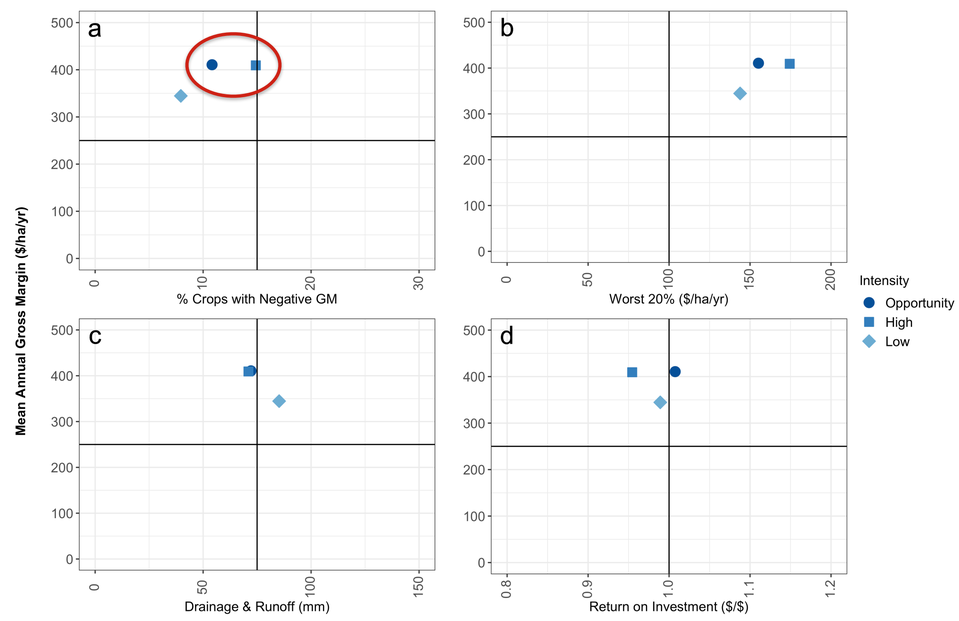



**Figure 3**. The Pareto optimal solutions for different system metrics

## Conclusion

This approach shows how simulation can be used to assess the risk of adopting specific sowing rules to increase cropping intensity. We are appling a similar approach to each of the other strategies.

## References

Hochman, Z., Garcia, J.N., Horan, H., Whish, J., Bell, L., 2021. Design of sustainable dryland crop rotations require value judgements and efficient trade-offs. Environ. Res. Lett. 16, 064067. https://doi.org/10.1088/1748-9326/ac0378

Hochman, Z., Horan, H., Navarro Garcia, J., Hopwood, G., Whish, J., Bell, L., Zhang, X., Jing, H., 2020. Cropping system yield gaps can be narrowed with more optimal rotations in dryland subtropical Australia. Agric. Syst. 184, 102896. https://doi.org/10.1016/j.agsy.2020.102896

Holzworth, D.P et al. 2014. APSIM – Evolution towards a new generation of agricultural systems simulation. Environ. Model. Softw. 62, 327–350. https://doi.org/10.1016/j.envsoft.2014.07.009

FOR FURTHER INFORMATION
Jeremy Whish
Agriculture and Food
Jeremy.Whish@csiro.au

Acknowledgements
Grains research and development corporation GRDC Australia for financial support.

# EcoServ Long-Term Experiment

## Agroecosystem functioning along a cropping system diversification gradient

**Background**

Crop production faces the dual challenges of producing enough food, feed, and energy, while maintaining ecosystems and biodiversity. Meeting these challenge requires the regeneration of above- and below-ground biodiversity to create a functioning agroecosystem capable of providing and supporting a variety of important ecosystem services beyond crop production. Diversifying our current cropping systems in conjunction with actions that can restore soil health and biodiversity is key to achieving these goals. However, the interaction and long-term effects of such measures on environmental and economic sustainability have not yet been studied.

**Experimental design**

The experiment was established in 2019:

- **Two crop rotations**
  1. 100% cereals
  2. 60% cereals, 20% oilseeds, 20% grain legumes

**Two tillage strategies**

1. Inversion tillage annually
2. Minimal tillage to a maximum depth of 5cm

- All treatment combinations **with and without inclusion of service crops**
- Plot size 24m x 12m
- Two replicates per treatment, **fully phased design** (all crops all years)
- Fertilisation adjusted according to Nmin at treatment level
- Weed and pest management adjusted at treatment level
- Weed management is **glyphosate free since the start of the experiment**

**Collection of base data**

- Soil moisture, soil temperature and EC in all plots with hourly resolution (2023 onwards)
- Air temperature, air humidity, precipitation, solar radiation, wind speed and wind direction (15 min res.)
- Soil health assessment every third year (soil physical, biological and chemical parameters)
- Annual weed seedbank assessment at species level in all plots
- Archived soil, biomass and grain samples from 2023 onwards
- Multispectral aerial images for calculation of vegetation indices at different crop growth stages from 2023 onwards
- Support with additional data collection and lab analysis on request

**Call for collaboration**

EcoServ has currently two partner experiments. It is intended to extend the network of similar experiments for testing the transferability of the results across different environments.

**Alexander Menegat**
Associate Professor
Alexander.menegat@slu.se

**Thomas Keller**
Professor
Thomas.keller@slu.se

**Funding**
The SLU Agricultural Long-Term Experiments are funded by the Faculty of Natural Resources and Agricultural Sciences (NJ)

SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE

**Authors**
Johanna Rüegg, Research Institute for organic agriculture FiBL, Switzerland
Chigusa Keller, Research Institute for organic agriculture FiBL, Switzerland
Ulf Schneidewind, Ecotop Foundation, Bolivia
Joachim Milz, Ecotop Foundation, Bolivia
Laura Armengot, Research Institute for organic agriculture FiBL, Switzerland & BETA TC, Spain

# Design of long-term experiments with perennial crops:

## Learnings and challenges of 15 years of research in a cacao agroforestry trial

## Introduction

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 monocultures (MONO), agroforestry systems (AF) and dynamic agroforestry (SAFS) under organic (ORG) and conventional (CONV) management. Plot size is 48 x 48 m, with a net plot of 24 x 24 m and each production system is replicated 4 times.

## Dynamic vs. stable management

In perennials, the delay until full production is considerable, and differences in long-term performance might be only visible after 20+ years (i.e. cacao can live and produce up to 80-100 years). An important good practice of Latin American cocoa producers is to regularly improve their varieties by re-grafting them, a practice that has been taken up in the LTE in Bolivia. For perennial crops such adaptions to the LTE design take several years until they show their implications on systems level (Fig. 1).

## Dynamic vs. stable design of AF

Even though tree density in the AF is quite high, the net plot size of 24x24 m can limit conclusions, for instance on fruit or timber productivity as well as biomass production and carbon storage, since very few trees of each 'category' or species can be evaluated (Fig. 2).

For fruit trees, a late starting production (>10 years) as well as mortality can restrict the results on productivity. Initially planting shade trees in higher density and diversity and selecting the most promising ones over time, together with constant replanting in the first years and nurturing natural regeneration, is a solution to overcome the problem of tree mortality and increases resilience. Replanting in mature AF becomes increasingly difficult, due to shaded conditions, and not all species might be suitable. The main drawback is that it leads to different designs in the replications.

## Reporting results for perennial systems

We advocate for transparent communication of systems results including unproductive trees (mortality, freshly grafted or replanted), and especially in AF we recommend taking into account the real surface on which data was collected (Fig. 3).

For reporting results of yields and benefits of different species or varieties, we recommend to take data on individual tree level in order to extrapolate results depending on different scenarios (i.e. selection of varieties, fruit tree density).

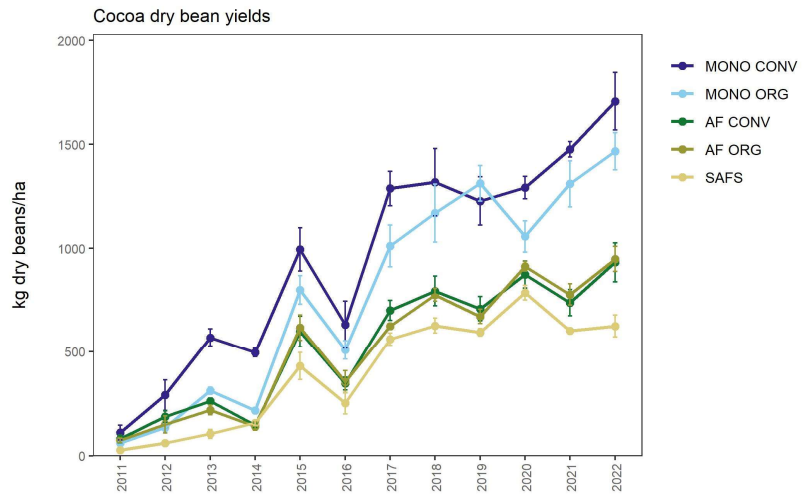



**Fig 1:** Cacao production in the 5 systems planted in 2008. Part of the trees with low productivity were grafted with locally selected material in 2018. After having reached a first plateau from 2017-2020 in all systems, total cacao production increased in both MONO systems since 2020. This increase can be attributed to increasing of production of the grafted trees. However, tree development is delayed in the agroforestry systems.

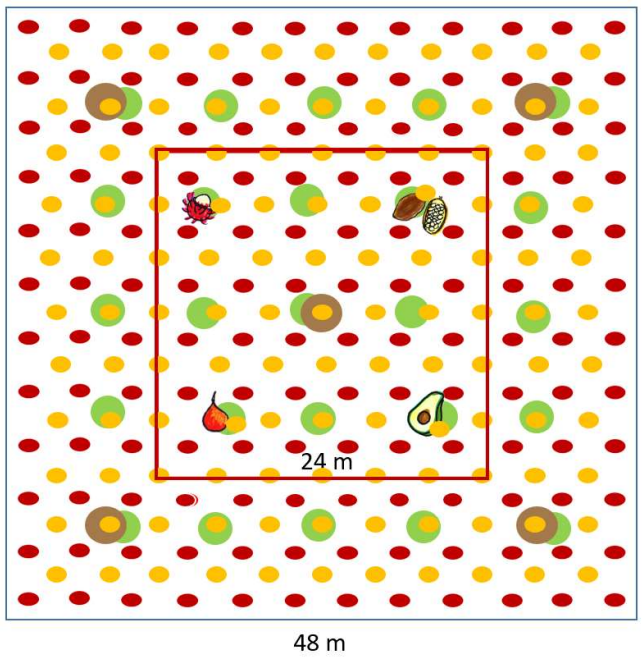



**Fig. 2:** Initial design of the AF plots. Cacao (red) and banana (yellow) were planted at a distance of 4x4m. Within the net plot (red line), four fruit trees of four different species (icons) and one timber tree (brown), as well as 9 leguminous trees for biomass production (green) were included. The planting pattern was continued in the gross plots (blue line).

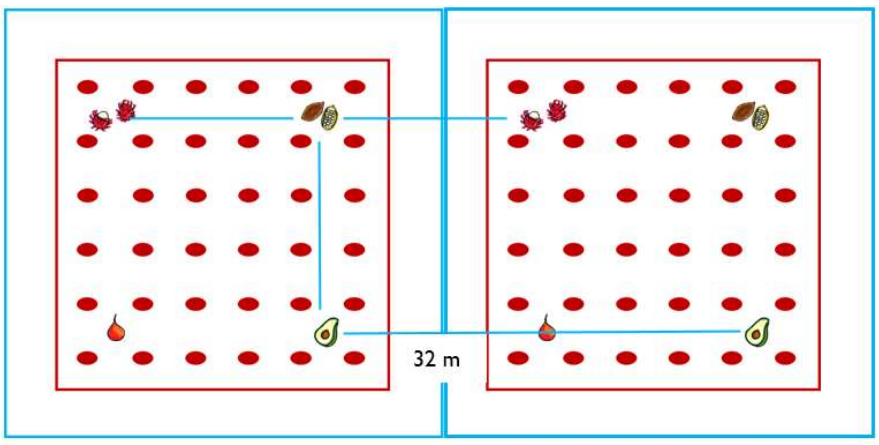



**Fig. 3:** Adaptation of the surface for collection of fruit tree related data to 32x32m in order to not overestimate their production and respect the planting distances of 32m between fruit trees of different species. Blue square representing the new "net plot" and red square representing the original net plot of 24x24m.

**More information on the trial setup and the SysCom project**

Schneider, M., Andres, C., Trujillo, G., Alcon, F., Amurrio, P., Perez, E., & Milz, J. (2017). Cocoa and total system yields of organic and conventional agroforestry vs. monoculture systems in a long-term field trial in Bolivia. *Experimental Agriculture*, *53*(3), 351-374. https://orgprints.org/id/eprint/30480/

https://systems-comparison.fibl.org/

**Partners**

ECOTOP
LED LIECHTENSTEIN DEVELOPMENT SERVICE
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Agency for Development and Cooperation SDC
Instituto de Ecología
FUNDACION PARA EL DESARROLLO SOSTENIBLE PIAF-EL CEIBO
biovision
This project is supported by the Coop Sustainability Fund.
coop

© FiBL 2023

# Designing arable cropping systems for multiple benefits…

## …the need for a long-term perspective

Cathy Hawes, Andrew Christie and Tracy Valentine

The James Hutton Institute, Invergowrie, Dundee DD2 5DA
Email: Cathy.Hawes@hutton.ac.uk

The James Hutton Institute

## Hutton's long-term experiments

Based at Balruddery Farm, Scotland, two complementary experimental platforms aim to test long-term trends in regenerative agriculture. The goal is to achieve multiple economic, environmental and ecological benefits from arable land: maintaining crop yields with less inputs by enhancing soil health and harnessing biodiversity for regulation of ecosystem functions.

### Centre for Sustainable Cropping (CSC)

Established in 2009, the CSC is a 42 ha site across 6 fields, comparing a regenerative crop system against standard commercial practice over multiple 6-course rotations.

Design: split field comparison, year-on-year replication, field-scale (3+ ha) plot sizes for commercially realistic outputs.

Crops: potato, winter wheat, winter barley, winter oilseed rape, spring barley and field beans.

Cropping practices: direct drill, cover crops, legumes and companion crops, green waste compost amendments, targeted weed management, IPM strategies, biofortification, Soil Nutrient Supply (SNS) for reduced mineral N inputs.

### Grieves House Tillage Trial (GH)

Established in 2017, GH 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 inversion plough systems.

Design: Smaller-scale plots allow full within-year replication and a separation of the effects of each management treatment.

Crops: Winter barley, spring barley, winter wheat, beans, winter oilseed rape (Y1-4)

Cropping practices: no-till versus inversion plough, spring (winter fallow) versus winter cropping (autumn sowing of main or cover crops)

**Acknowledgements**
The Hutton long-term platforms are funded by the Scottish Government's Rural and Environment Science and Analytical Services Division. Special thanks go to the Farm and Estates Department for all their work maintaining the sites and enabling practical application of science in real world setting.

Scottish Government
Riaghaltas na h-Alba
gov.scot

## Soil health

| Management practices | Short-term (1-6 years) | Medium-term (6-12 years) | Longer-term (>12 years) |
|---|---|---|---|
| Organic matter amendments | Initial imbalance in soil microbes - increase in soil borne pathogens. | Pathogen pop$^{ns}$ stabilise, soil structure improves, improved conditions for root growth. | Beneficial effect on soil function/ biology and structure. |
| Reduced tillage/ direct drilling | Initial compaction, poorer establishment, weed competition. | Soil structure improves with less disturbance. Trade-off: weed control necessary. | Benefit to soil structure & diversity, esp. evident in extreme weather yrs. Trade-off: weed issues. |
| Winter cover cropping | Immediate positive effect on nutrient retention, erosion risk reduction. | Continued improvement in soil structure, nutrient retention/release, losses. | Benefit to nutrient, soil, water management. Trade-off: added cost to farmers. |

**Table 1.** Temporal trends in soil properties following management to improve structure and organic matter content (observations from CSC, GH and Hawes et al. 2021). Red - negative trade-offs, yellow - neutral overall effect, green - beneficial effects

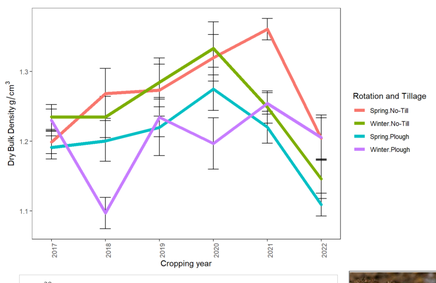



**Fig. 1a** Trends in dry bulk density across spring and winter rotations under inversion plough and no-till soil management.

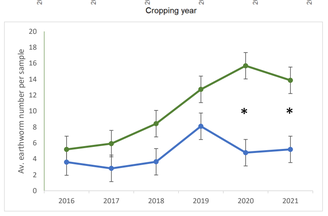


**Fig. 1b.** Trends in earthworm numbers from integrated (green) and conventional (blue) crop systems. * $p < 0.05$

Combining organic matter amendments with reduced tillage and the use of cover crops in a single management system can help overcome trade-offs: increased organic matter stimulates earthworm activity which improves microbial function and soil structure; reduced tillage minimises damage to soil organisms; cover crops provide 'catch and release' nutrient cycling and help mitigate issues with weed burden in no-till systems.

## Biodiversity

| Management practices | Short-term (1-6 years) | Medium-term (6-12 years) | Longer-term (>12 years) |
|---|---|---|---|
| IPM (monitoring, forecasting, biofortification) | Immediate benefit to local invert populations. Initial trade-off: increased pest/disease risk. | Detoxification improves habitat quality. Pest populations more stable. | New populations established and population stability improved. |
| In-field weed diversity (10% cover) | Increased in-field habitat utilisation by beneficials. Trade-off: targeted weed management difficult to achieve. | Increased habitat utilisation brings benefit to crop pest control and pollination. Trade-off potential weed burden. | As before, though weed competition with crop minimised in more diverse weed communities. |
| Diverse field margins | Immediate benefit for farmland wildlife. Trade-off: cost of establishment. | Farmland biodiversity improvements. Trade-off: cost of maintenance. | Biodiversity established, additional benefits (C sequestration, weather amelioration). |

**Table 2.** Temporal trends in biodiversity following management to reduce non-target impacts and improve habitat quality (observations from CSC and Hawes et al. 2021).

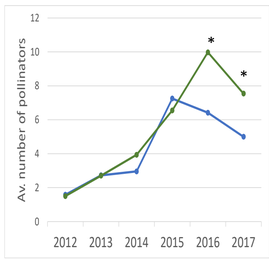



**Fig. 2a.** Pollinator abundance in integrated (green) and conventional (blue) field margins (* $p < 0.05$).

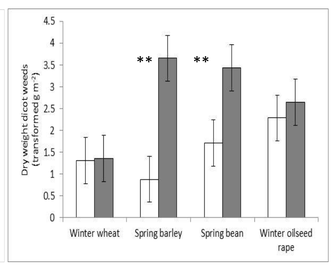



**Fig. 2b.** Dicot weed biomass in integrated (solid) and conventional (open) crop systems (** $p < 0.001$, Hawes et al 2018).

Biodiversity management gives more immediate short-term results, but with less obvious direct economic benefit than is achieved through improvements to soil health. However, the indirect benefits in terms of pest control, pollination and long-term system stability are essential components of regenerative agriculture in enabling a reduction in agrochemical inputs.

## Crop productivity

| Management practices | Short-term (1-6 years) | Medium-term (6-12 years) | Longer-term (>12 years) |
|---|---|---|---|
| IPM (monitoring, forecasting) | Less inputs required, but potential initial increase in pest/disease risk. | Pest/disease populations stabilise, crop yield maintained with less agrochemical input. | Continued as before. |
| IPM (biofortification) | Immediate improvement in crop resilience to disease. | Continued as before. | As before. |
| Soil Nutrient Supply (SNS) | Benefit in minimising excess mineral N input. Trade-off: requires annual soil analysis. | Minimised fertiliser use without impacting yield. Benefit increases over time as soil health improves. | Continued improvement with soil health. |
| Legume cropping, under-sowing | Increase renewable N input improves SNS. | As before. | As before. |

**Table 3.** Temporal trends in crop health/yield following management to reduce reliance on agrochemical inputs (observations from CSC, GH and Hawes et al. 2021).

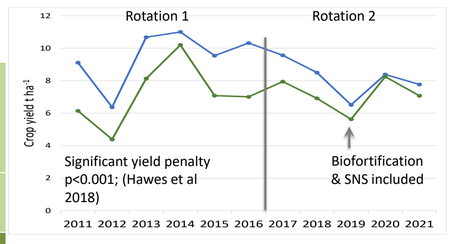



**Fig. 3a.** Winter wheat yields in conventional (blue) and integrated (green) cropping. Yield gap closes with improved soil health and introduction of multiple integrated options.

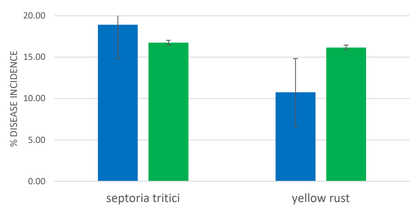



**Fig. 3b.** Biofortification in integrated (green) vs. conventional fungicide treatment (blue) in winter wheat. Disease levels maintained below 20% leaf area in both and biofortification slightly outperforms conventional for Septoria control based on 2022 data.

Integrating management interventions from soil health and biodiversity objectives along side sustainable nutrient supply, precision agriculture and IPM strategies gives the best overall result in terms of reduced reliance on agrochemical inputs while maintaining crop productivity. Biodiversity goals are not necessarily in conflict with economic return where long-term regenerative farming strategies are adopted.

## Conclusions

- The degree of trade-off between costs and benefits of regenerative agriculture varies with time-scale and the specific management intervention in question.
- Initial costs may be higher for some management strategies than others, but the longer-term benefit can outweigh these early conversion-phase risks.
- Financial compensation to encourage uptake may be needed in the short term for some interventions, with benefits of long-term incentive opportunities for provision of public goods.
- Costs and risks may be offset by combining management strategies as part of a holistic approach.
- Long-term data are needed for quantitative evaluation of costs and benefits of regenerative approaches at a whole-systems level.

# UNIVERSITY OF DEBRECEN

# HOW CAN BE MANAGED THE ORGANIC MATTER CONTENT OF ACIDIC SANDY SOIL?

**Marianna MAKÁDI, Viktória OROSZ, Csilla ALMÁSI, Tibor ARANYOS, Ágnes HADHÁZY, István HENZSEL**

Research Institute of Nyíregyháza, Institutes for Agricultural Research and Educational Farm, University of Debrecen, 4400 Nyíregyháza, Westsik Vilmos út 4-6., Hungary

Contant: makadim@agr.unideb.hu

Adding farmyard manure (FYM) into the soils cultivated conventionally has been the basic method for nutrient supply and soil improving used from centuries. Nowadays, its application is limited by the decreasing number of farmed animals and the changes in the technology of animal husbandry. Therefore, other organic matter (OM) sources are needed. The use of green manure (GM) and OM-containing wastes and by-products could be good alternatives of FYM.

Long-term effect of regular application of FYM, GM and rye straw with or without N, P, K fertilizers and, of sewage sludge compost are studied in two long-term experiments in Nyíregyháza, Hungary (Fig. 1.).

*Figure 1. Location of the SSC and Westsik's experiments in Nyíregyháza, Hungary.*

The **Westsik's LTE** was established in 1929. 15 crop rotations are planned without replication along two sandy hills. Test plants were rye, potato, lupine and oat with vetch until 2022. In 2023, the potato was changed to maize. The crop rotations are summarized in Table 1.

Samples were collected after harvesting in 3 replications from each plants' plot from 0-20 cm soil layer. The yearly mean were calculated for each crop rotation.

*Table 1. Treatments in the Westsik's LTE.*
*(N: Nitrogen, active ingredient; P: $P_2O_5$; K: $K_2O$ (kg $ha^{-1}$))*

| Crop rotation | Phase 1 | Phase 2 | Phase 3 | Phase 4 |
|---|---|---|---|---|
| I. | Fallow | Rye | Potato | |
| II. | Lupine green manure + P63; K56 | Rye + P31; K28 | Potato + N43 | |
| III. | Lupine for grain + P63; K56 | Rye + P31; K28 | Potato + N43 | |
| IV. | Rye + 3.5 t/ha rye straw manure + N65; P47; K56 | Potato +N43; P47; K28 | Rye | |
| V. | Rye + 11.3 t/ha fermented straw manure with N + N65; P47; K56 | Potato +N43; P47; K28 | Rye | |
| VI. | Rye + 26.1 t/ha fermented straw manure + N65; P47; K56 | Potato +N43; P47; K28 | Rye | |
| VII. | Rye + 26.1 t/ha fermented straw manure | Potato | Rye | |
| VIII. | Lupine for grain + P32; K28 | Rye + lupine green manure +N43; P31; K28 | Potato +P31; K28 | Rye +N43 |
| IX. | Lupine for green fodder + P63; K56 | Rye + N43; P31; K28 | Potato + N43 | |
| X. | Oat with vetch + 26.1 t/ha FYM | Rye | Potato | |
| XI. | Oat with vetch + 26.1 t/ha FYM + P63; K56 | Rye + P31; K28 | Potato + N43 | |
| XII. | Rye for green fodder + lupine green manure + P63; K56 | Rye + P31; K28 | Potato + N43 | |
| XIII. | Rye + lupine green manure + N43; P32; K28 | Potato + N17; P31; K28 | Rye + N26; P31; K28 | |
| XIV. | Rye + lupine green manure + N43; P32; K28 | Potato + N17; P31; K28 | Rye + N26; P31; K28 | |
| XV. | Rye + lupine green manure | Potato | Rye | |

The **sewage sludge compost (SSC) LTE** was established in 2003. The soil is regularly treated with SSC in every 3rd years at the rates of 0, 9, 18 and 27 t $ha^{-1}$, in five replications (Fig. 2.). Test plants were maize, triticale and green pea between 2006-2018, while maize, rye and rye with hairy vetch from 2019.

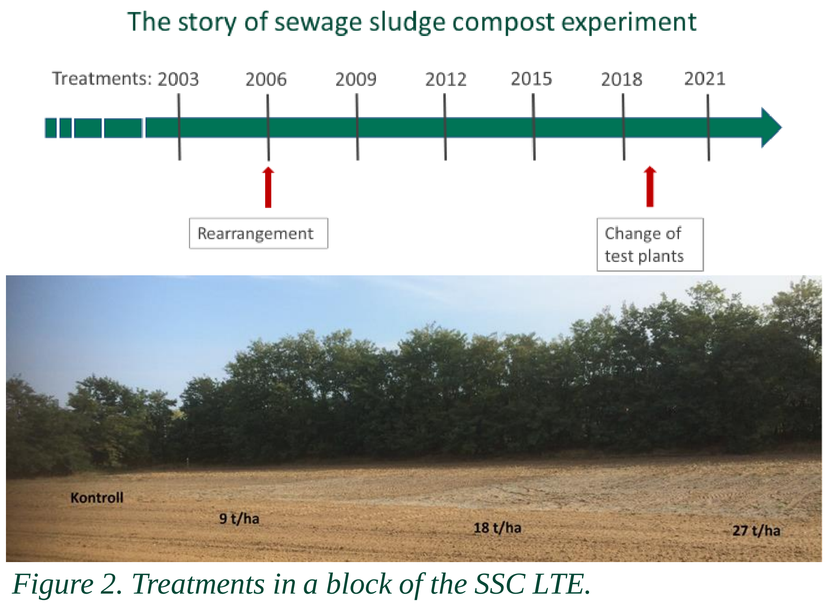



*Figure 2. Treatments in a block of the SSC LTE.*

Soil was sampled yearly after the harvest from the 0-20 cm soil layer. Samples were collected from all plots until 2017. After that time, the plots of triticale/ maize than rye/rye with hairy vetch were sampled. SOM content was measured by wet digestion method in both LTEs.

The means of pH(KCl) for the Westsik's LTE and SSC LTE were 4.27 and 5.65 in 2022, respectively.

## CHANGES OF SOIL ORGANIC MATTER CONTENT AFTER DIFFERENT OM INPUT.

***The OM content of soil varied yearly in both experiments.***

In the **Westsik's LTE** (Fig. 3), the rye straw manure with chemical fertilizers caused the increase in soil OM content in crop rotations IV-V-VI, comparing to the fallow plots (I). The FYM + NPK treatment and lupine green manure with NPK could stabilize the SOM level with higher yields of cultivated plants (results are not shown) in the crop rotations XI-XIV. The lowest SOM content was measured in crop rotations VII, IX and XV where VII and XV works without chemical fertilization while IX contains lupine for green fodder (transporting plant material from the plots) with NPK fertilizers in different phases of crop rotation. The crop rotation XV also run without chemical fertilizers where the nutrient supply is based on lupine as a green manure.

Taken into account that the soil enzymes activity were usually higher in the crop rotations XI-XIV than in IV-VI (Kátai et al., 2022), the increased OM content in the straw manured crop rotations could be the results of the lower microbial activity because of the more difficult microbial destruction of the straw than the green manure.

In the **Sewage Sludge Compost LTE** (Fig. 4) the small decrease can be found in the OM level in all treatments from 2019. In this year the test plants were changed and both the rye and rye with hairy vetch residues are transported from the field, while earlier only the triticale residue was taken over. This result indicate the importance of plant residue in the SOM content. The OM content of the soil is the lowest one in the control treatment where the maize and pea/maize residues are the only external OM sources of the soil. The OM content of soil is always higher in treated than non-treated plots The difference is small between control and 9 t $ha^{-1}$ SSC treatment while the effect of the two higher doses are similar to each other and the SOM in these treatments are higher than in control plots. The difference between control and 18 t $ha^{-1}$ and control and 27 t $ha^{-1}$ SSC are usually significant. ($p<0.05$, results are not sown).

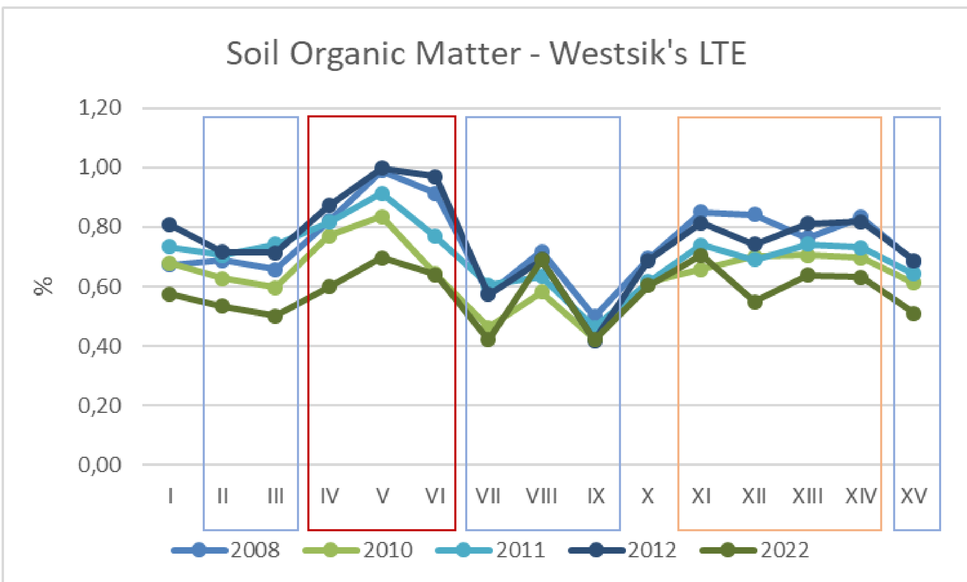



*Figure 3. Changes of Soil Organic Matter content in crop rotations of Westsik's LTE.*

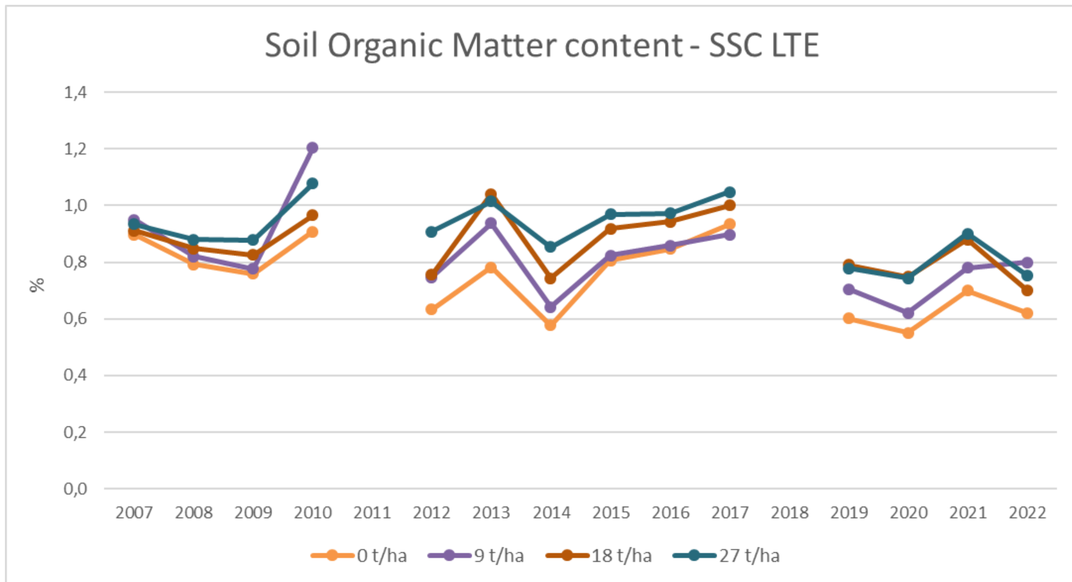



*Figure 4. Changes of Soil Organic Matter content in the Sewage Sludge Compost LTE.*

The SSC is a mixture of organic and inorganic materials containing 40 %(m/m) sewage sludge, 20 %(m/m) straw, 35 %(m/m) rhyolite and 5 %(m/m) bentonite. The OM content is generally between 20-25% (m/m) of the SSC. The OM added to the soil in every 3rd years are presented in Table 2. Based on these results, at least 5 tonnes of external SSC OM/3 years are needed for keeping the SOM unchanged compared to the starting point in acidic sandy soil. Otherwise, the long-term SSC application improve the soil physical, chemical and biological properties (Aranyos et al., 2016) comparing to the control soil.

*Table 2. Added OM (t $ha^{-1}$) to the soil in the SSC LTE.*

| | 0 t $ha^{-1}$ | 9 t $ha^{-1}$ | 18 t $ha^{-1}$ | 27 t $ha^{-1}$ |
|---|---|---|---|---|
| 2006 | 0 | 2.31 | 4.62 | 6.94 |
| 2009 | 0 | 1.85 | 3.71 | 5.56 |
| 2012 | 0 | 2.49 | 4.97 | 7.46 |
| 2015 | 0 | 2.27 | 4.54 | 6.80 |
| 2018 | 0 | 4.32 | 8.64 | 12.96 |
| 2021 | 0 | 2.21 | 4.43 | 6.64 |

## CONCLUSIONS

- From the used OM sources, the **rye straw manure with NPK** and the **higher doses of SSC** increased the SOM compared to the control plots.
- **Yearly variation** of soil OM content could be caused by different plant biomass grown on different nutrient supply of OMs applied, combined with the effect of whether (temperature, precipitation).
- The effect of OMs added to the soil are different**, depending on their quality and the added chemical fertilizers** which resulted in changes in soil N:P:K stoichiometry.
- **Destruction of OM in ploughed sandy soil is a quick process** because of the high soil temperature in summer and the good aeration of the soil. Therefore, the added OM could not be accumulated in the soil and the increase of the quantity of SOM needs of high mass of OM added to the soil.
- **Decreasing soil disturbance and aeration** of the upper soil layer could be important in sandy soils for increasing the soil organic matter content.
- **Conventional agricultural practices with ploughing and OM supply could save the OM level of acidic sandy soil but alternative agricultural practices, mainly reduced tillage methods with continuous soil covering will be needed for increasing the SOM content at a higher rate.**

## LITERATURE

Kátai J., Zsuposné Oláh Á., Makádi M., Henzsel I., Tállai M. 2022. Effect of mineral and organic fertilizers on some soil chemical and biological properties in a 90-year-old long-term experiment. Agrokémia és Talajtan 71 (1), 101-118. DOI: 10.1556/0088.2022.00094

Aranyos T.J., Tomócsik A., Makádi M., Mészáros J., Blaskó L.(2016): Changes in physical properties of sandy soil after long-term compost treatment. INTERNATIONAL AGROPHYSICS 30: 269-274.

www.slu.se

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

**The Mellby field experiment started in 1984 on separately tile-drained plots with the aim to examine effects of cover crops on nutrient leaching in systems with mineral and organic fertilizers**

*Lolium perenne*

Perennial ryegrass, undersown, ploughing in spring

No cover crop, ploughing in autumn

**Cover crop effects on leaching**

**N: 55-64 % reduction**

**P: variable effects**

Source: Aronsson H et al. 2016. J Soil and Water Conserv 71 (1):41-55

*The Mellby site (R0-8403)*

Sandy loam, lat.56° 29' N, long.13° 00' E
Mean temp 8.2°C, mean prec 812 mm $yr^{-1}$

*Treatments*

Cover crop vs no cover crop
Fertilization of main crops:
mineral N, pig slurry, no N

*Measurements*

Drainage
Flow-proportional water samples (N, P, K)
Yields of main crop, and N, P, K content
Cover crop biomass and N, C content
Soil mineral N 0-90 cm depth

## Ryegrass cover crop is an effective measure to increase soil C storage at northerly latitudes

*Measurements and ICBM model*

- Aboveground biomass: 550-1050 kg DM $ha^{-1}$
- C sequestration rate: 320 +/- 28 kg $ha^{-1}$

Source: Poeplau C et al. 2015. Geoderma Regional 4:126-133.

## P accumulation in the soil from historical fertilization was more important for P leaching than the direct effect of one single dose

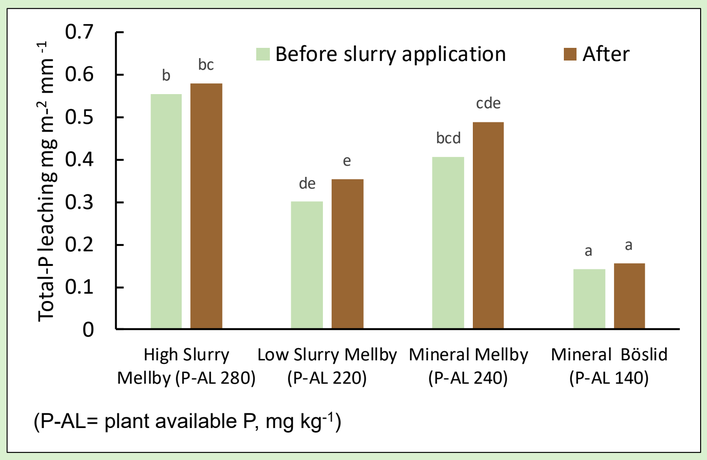
*-Two sandy soils with different P contents Mellby=high, Böslid=low*

*-Rainfall simulation study on topsoil columns*

*-Before and after a single dose of pig slurry (22 kg P $ha^{-1}$)*

*Long-term annual P application rates were: High slurry 44 kg, Low slurry 30 kg, Mineral 20 kg P*

Source: Liu J et al. 2012. Soil Use and Manage 28:457-467

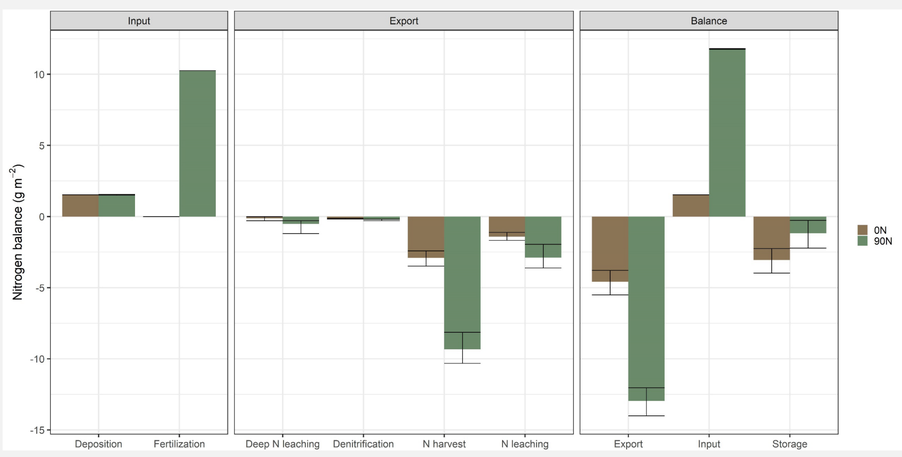



## Long-term modelling of carbon and nitrogen flows vs observations (35 years) show:

- Stable but low yields in the unfertilized treatment (0N) during 35 years (no cover crop)
- Annual average N leaching in 0N was lower, 42 % of that in the treatment with mineral fertilizer (90N). But N leaching per yield N in 0N was higher, 180 % of that in 90N
- Carbon stocks were declining in both treatments without cover crops

*Future plans*

*Modelling cover crops with the CoupModel using climate scenarios to reveal the trade-off between crop yield, nitrogen losses and carbon sequestration in a changing climate*




Source: Nimblad Svensson et al. 2023. Manuscript

**Helena Aronsson**
Assoc professor
Helena.Aronsson@slu.se

**Lisbet Norberg**
Researcher
Lisbet.Norberg@slu.se

**David Nimblad Svensson**
PhD-student
David.Nimblad.svensson@slu.se

**Jian Liu**
Research Scientist
Jian.Liu@nibio.no

**Thomas Kätterer**
Professor
Thomas.Katterer@slu.se

**Elisabet Lewan**
Assoc professor
Lisbet.Lewan@slu.se


SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE

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

***Author:*** **Cardenas, L.[1]*, L Olde[1], N Loick[1], B Griffith[1], T Hill[2], S Zhu[2], J Hood[3], C Segura[1], H Sint[1], P Harris[1], M. Lee[1,4]**
***Addresses:*** [1]Rothamsted Research, Devon; [2]University of Exeter; [3]Rothamsted Research, Harpenden; [4]Harper Adams University.
***Presenter: laura.cardenas@rothamsted.ac.uk**

**INTRODUCTION** Grasslands cover around 25% of the global ice-free land surface, used mainly for forage and livestock production and are considered significant contributors to soil carbon (C) sequestration. Different pastures offer opportunities to improve productivity and reduce $CO_2$ emissions. Cultivation of grassland to produce arable crops can be on the other hand harmful to the environment due to soil and nutrient losses, loss of soil fertility and biodiversity[1]. We aimed to address: i) if the permanent pasture system (PP) is, in the short-term, a net sink for $CO_2$, ii) if 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.

**METHODS** We previously evaluated baseline pasture management interventions at the Rothamsted Research North Wyke Farm Platform[1] (Fig. 1), under commercial farming conditions, over two years and consider their impacts on net $CO_2$ exchange using the Eddy Covariance technique (Fig. 2)[2]. We then assessed the effect of plough on net emissions and soil organic carbon (SOC) as one of the three NWFP farmlets was converted to grow arable crops in 2019.

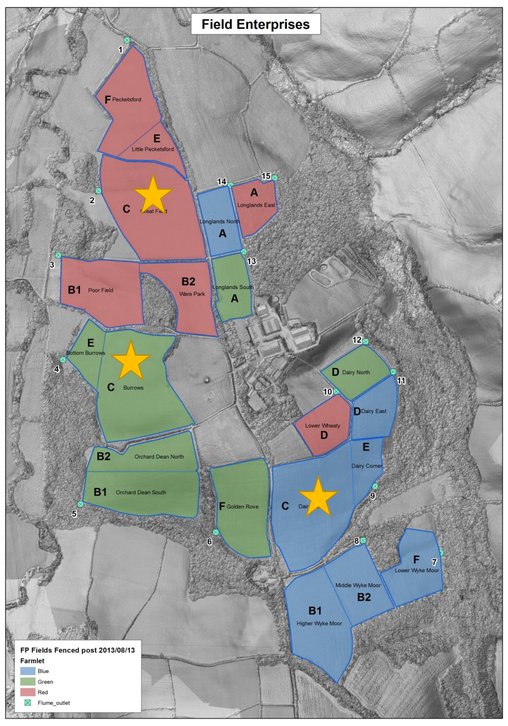



**Fig. 1. North Wyke Farm Platform, sites of towers marked with stars**

**RESULTS** Baseline net $CO_2$ fluxes for the PP and HS treatments resulted in a small source for PP and a small sink for HS over two years, whilst it was a net source for HSC[3]. The plough of HS in 2019 released large $CO_2$ amounts, up to 3 times the baseline values in 2020 (Fig. 3).
Due to the plough, we did not measure for few months so are not able to calculate the annual flux for 2019, but the monthly values shown in Fig. 4, demonstrate the larger fluxes in this treatment compared to the pastures that remained pastures. The SOC results show that there was a loss of C after the plough (Fig. 5).

**Fig. 2. Eddy covariance tower**

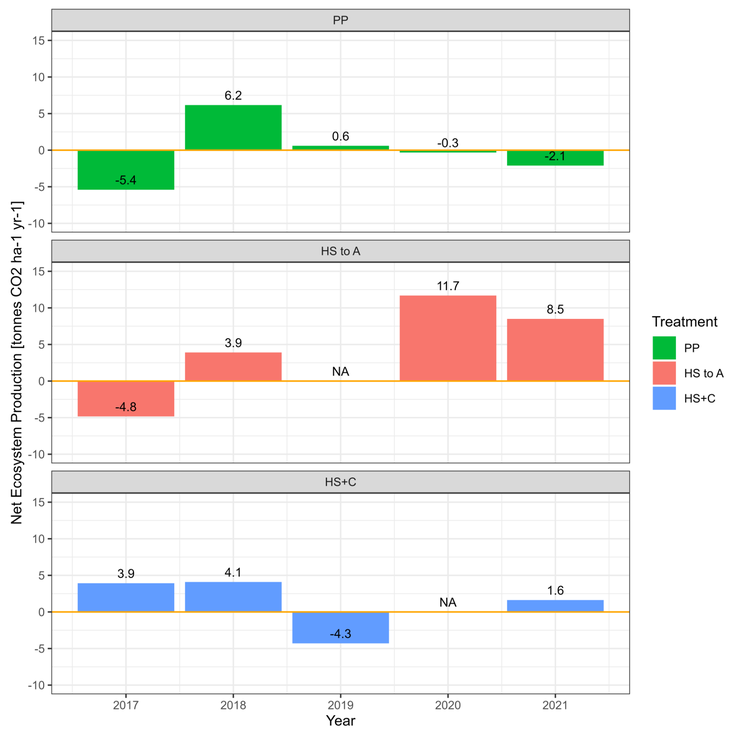



**Fig. 3. Cumulative $CO_2$ fluxes by year and by the three fields, $tCO_2$ $ha^{-1}y^{-1}$**

**Fig. 4. Cumulative monthly $CO_2$ fluxes for a. PP, b. HS/plough, c. HSC, g $m^{-2}$**

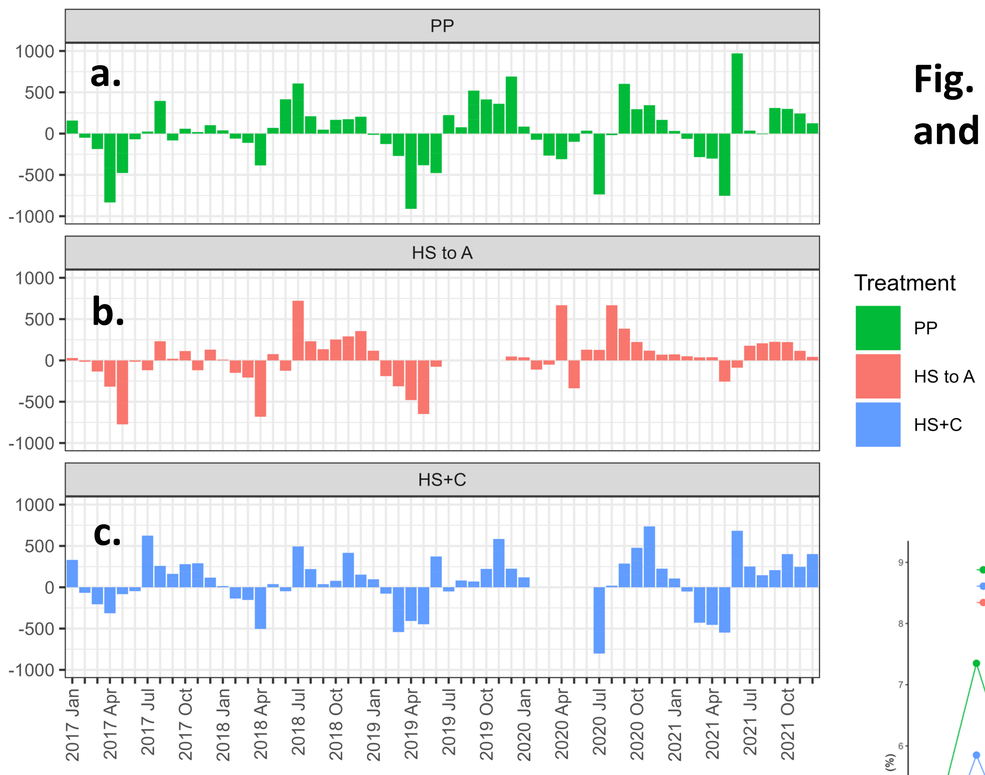
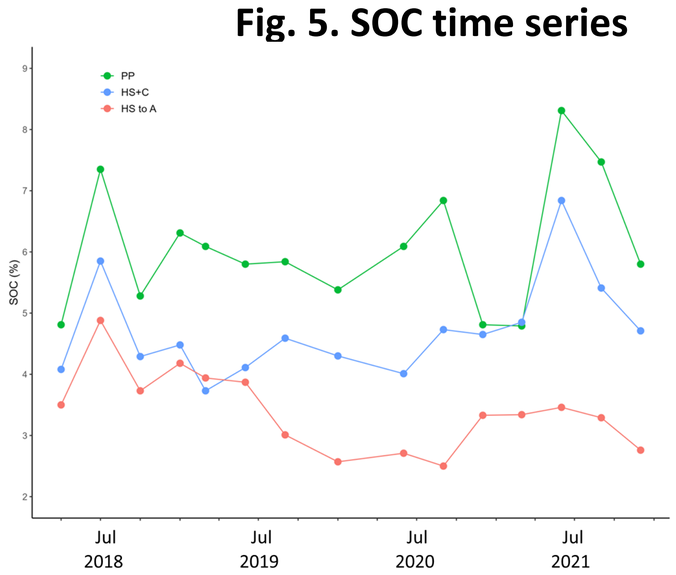



**Fig. 5. SOC time series**




## CONCLUSIONS

We found that pasture type had an influence on the atmospheric $CO_2$ balance on baseline emissions with a net of 0.76, -0.91 and 8.02 t $CO_2$ $ha^{-1}$ $y^{-1}$ for 2018-2019. The plough of one of the pastures in 2019 released significant amounts of $CO_2$ in the 2 following years after the conversion, of 11.7 vs -0.3 t $CO_2$ $ha^{-1}$ $y^{-1}$ in the arable and PP, respectively, also producing a decrease in SOC.

## REFERENCES

[1]Griscom et al., 2017. Natural climate solutions. Proceedings of the National Academy of Sciences of the United States of America 114, 11645-11650.
[2]Baldocchi, 2014. Measuring fluxes of trace gases and energy between ecosystems and the atmosphere - the state and future of the eddy covariance method. Global Change Biology 20, 3600-3609.
[3]Cardenaset al. 2022. Comparison of $CO_2$ fluxes of three different grazed pastures using Eddy Covariance measurements. STOTEN, 831,154819

**Acknowledgements.** We thank the Institute Strategic Programme Soil to Nutrition supported by BBSRC (BBS/E/C/000I0320). The authors would like to thank K Tozer (AgResearch) and D Beaumont for the botanical survey in 2018. The North Wyke Farm Platform is a UK National Capability, also supported by BBSRC (BBS/E/C/000J0100). The Eddy Covariance equipment deployed in this work was funded by CIEL (https://www.cielivestock.co.uk/) and the raw data is available on the Farm Platform Portal (https://nwfp.rothamsted.ac.uk/).

UK Centre for Ecology & Hydrology · ROTHAMSTED RESEARCH · Harper Adams University · UNIVERSITY OF EXETER · UKRI Biotechnology and Biological Sciences Research Council

# DEPLETION OF SOIL ORGANIC CARBON AND POROSITY AFTER ONLY TWO ARABLE HARVESTS DECREASED NITROGEN USE EFFICIENCY

*C. Segura [1], L. Cardenas [1], A. Louro-Lopez [1], A. Manley [1], M. Verbeeck [1], J. Hood [2], W. Rickard [3], S. Mooney [4], A. Neal [1]*

*[1] Net Zero and Resilient Farming, Rothamsted Research; [2] Intelligent Data Ecosystems, Rothamsted Research*
*[3] Sustainable Soils and Crops, Rothamsted Research; [4] The Hounsfield Facility, University of Nottingham*

## INTRODUCTION

Farm management decisions are often associated with altered soil functions.

On the Longlands fields of North Wyke Farm Platform, we are able to identify altered soil multifunctionality with consequences for carbon sequestration, water resilience and atmospheric emissions within two harvests.

## METHODS

Experiment carried out in Longlands North, Longlands South and Longlands East fields (Fig. 1). The three fields have been under different managements since 2013 (Table 1) and have the same soil type.

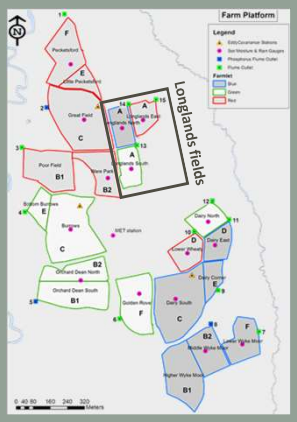



Figure 1. North Wyke Farm Platform (NWFP) fields and treatments. Blue: Improved pasture. Green: Permanent pasture. Red: Arable (since 2019).

Table 1. Main management in Longlands fields over time.

| Field | Management |
|---|---|
| Longlands South | Permanent pasture since 2012. Not ploughed. Inorganic N fertiliser applied. Sheep grazed |
| Longlands North | Improved pasture. Permanent pasture ploughed in 2013 and 2017 to reseed improved pastures with clover. Sheep grazed |
| Longlands East | Converted from improved pasture with deep rooting grass to arable in 2019 |

### Soil system data from:

- Long term data from NWFP (e.g. SOC, soil moisture, water flow, turbidity) to investigate trends over time
- Soil sampling (September 2021) to determine:
  - Physico-chemical soil properties: texture, bulk density, pH, TC, TN and bulked soil isotopes (5 composite samples from 0-10 cm and from 0-30 cm)
  - Soil porosity using X-Ray Computed Tomography scans (5 soil cores in each field)
  - Soil water retention curves (SWRC)
  - Microbiome genotype by metagenomics, phenotype by PLFA analysis (5 composite samples in each field)
- Gas emission measurements (May 2021-Nov 2021) using automatic and static chambers (Fig. 2) after rainfall and field events (e.g. fertiliser applications in permanent pasture and arable, ploughing in arable)

Figure 2. Gas sampling (5 chambers in each field at 3 timepoints).

### Next steps:

- Modelling: Connected porosity and soil hydrodynamic performance
- Shotgun metagenomics

ROTHAMSTED RESEARCH

## PRELIMINARY RESULTS

### Soil organic carbon (SOC)

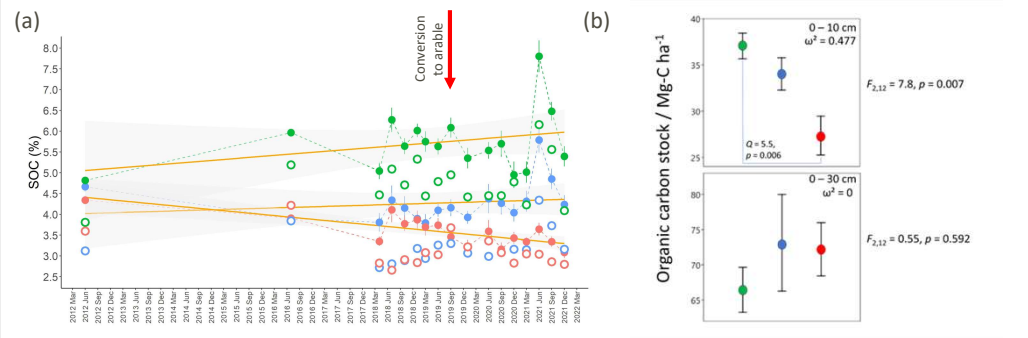



Figure 3. (a) SOC concentration trends in NWFP soils (Mean ± SE) suggest depletion in SOC after conversion from improved pasture to arable. NWFP soil surveys carried out from 2012 to 2021 (0-10 cm soil depth). White filled points correspond to SOC in Longlands fields. (b) SOC stocks (Mg C ha$^{-1}$) measured in Sept 2021 in Longlands fields indicate a significant effect of management on the first 10 cm of soil (ANOVA, Tukey post-hoc test).

### X-Ray CT images

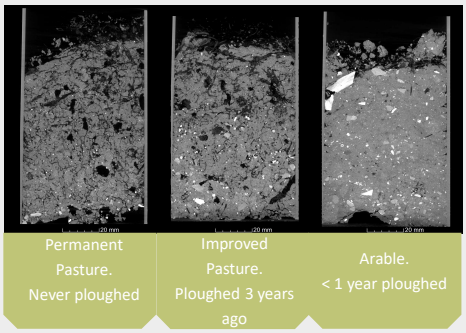



Figure 4. Representative 2D X-ray attenuation images of soils. Nominal resolution is 75 µm; darker shades are pores and lighter shades the soil matrix.

### Soil water retention curves

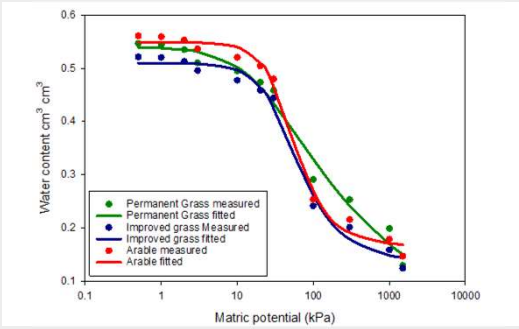



Figure 5. Soil water retention curves. After 30 kPa the capacity to retain water in the improved and arable drops off sharply, whereas the permanent pasture can retain greater amounts of water (30 kPa has the equivalent pore size of 10 microns).

### Biomass of phospholipid fatty acids

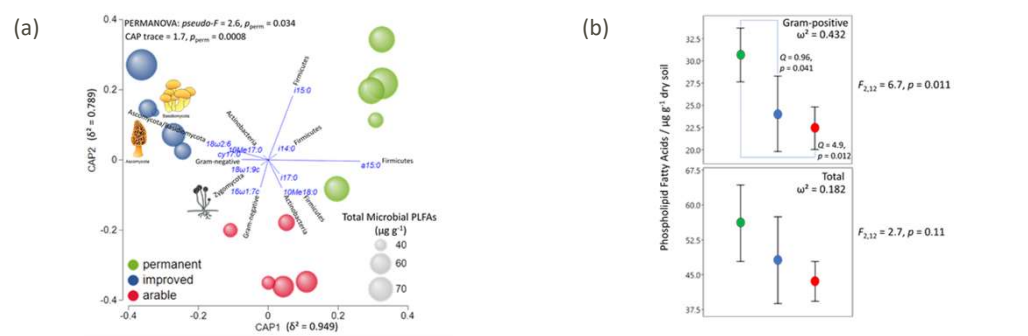



Figure 6. Summary of phospholipid fatty acid analysis: (a) PLFA-contingent canonical analysis of principal coordinates in Euclidean space classifies assemblages into three clusters according to treatment, greater concentrations of acids associated with Firmicutes are associated with separation of the permanent pasture from improved pasture and arable soils, Gram-negative bacteria were more abundant in arable soils and saprotrophic fungi was more abundant in improved pasture soils; (b) mean biomass estimates (± SE) indicate a significant influence of management upon Gram-positive bacterial biomass, but no significant influence on total (Gram-positive + Gram-negative + fungal) biomass.

### N losses (%)

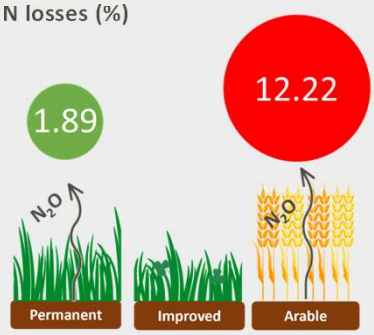



Figure 7. % N loss (x $10^{-5}$) as $N_2O$ calculated from inorganic N applications and cumulative emissions during the gas sampling period (May 2021-Nov 2011).

### Gross $CO_2$ emissions (kg ha$^{-1}$)

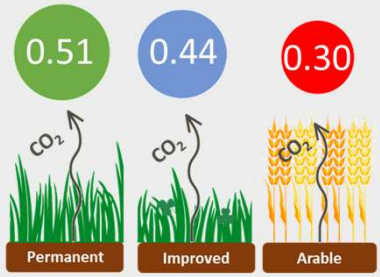



Figure 8. Cumulative $CO_2$ emissions (kg ha$^{-1}$) from May 2021 to Nov 2021 indicate lower soil respiration in the arable field (wheat).

*Acknowledgements*
We thank Adrian Joynes, Neil Donovan, Liz Dixon, Louise Olde, Susan Tandy, Jake Le-Grice, Charlie Morten and the NWFP team for their valuable help. This work was funded by WP 1 (BBS/E/C/000I0310) and 2 (BBS/ E/C/000I0320) of the programme Soils to Nutrition. Data and access to the North Wyke Farm Platform were provided by BSS/E/C/000J0100.

University of Nottingham UK | CHINA | MALAYSIA

UKRI Biotechnology and Biological Sciences Research Council

# Long-term effect of tillage practices on soil organic carbon in the Mediterranean region of South Africa

A van der Merwe[1*], J Labuschagne[2] & M Booyse[3]

[1]Directorate: Plant Sciences, Western Cape Department of Agriculture
[2]Department of Agronomy, University of Stellenbosch
[3]Agricultural Research Council Biometry, South Africa
*Corresponding author: Annemarie.vanderMerwe@westerncape.gov.za

## BACKGROUND

The Western Cape Province produces 55% of South Africa's wheat (360 000 ha) annually. The Long Term Experiment (LTE) was established in 2007 at Langgewens Research Farm (33°17'0.78'' S, 18°42'28.09'' E). The farm has an average rainfall of 400 mm per annum of which ± 80% falls in winter between April to September. The shale-derived sandy loam soil has a high stone content (45%). Soil organic carbon (SOC) is naturally low in South Africa and was initially found to be between 0.74-1.26 %, with an average of 1.02%.

## OBJECTIVE

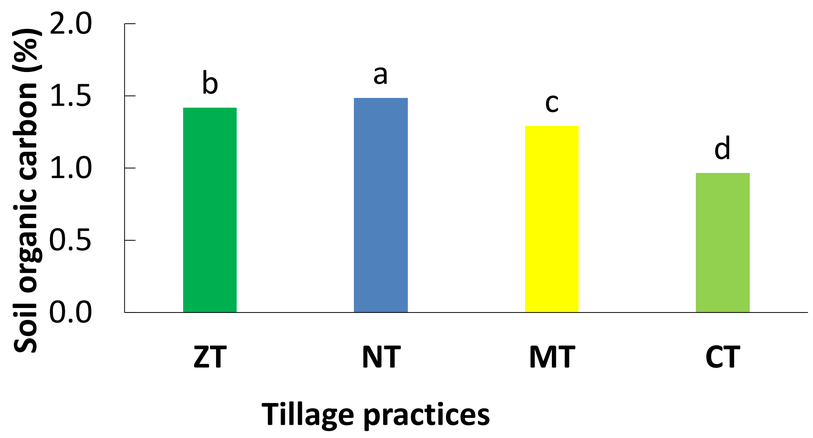
Quantify the influence of soil organic carbon (SOC) content in the 0-15 cm layer and the distribution of SOC under different degrees of soil disturbance in the top 30 cm.

## MATERIAL & METHODS

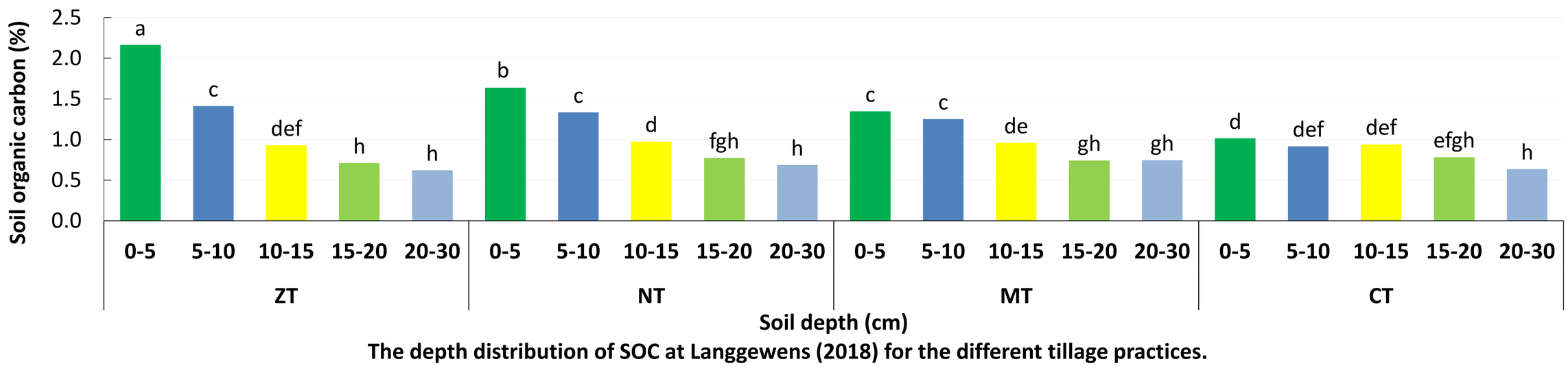
- Zero tillage (**ZT**) - soil left undisturbed and planted with a disc planter
- No-till (**NT**) - soil left undisturbed and planted with a no-till tined planter
- Minimum–till (**MT**) - soil scarified to a depth of 100 to 150 mm in March/April and then planted with the no-till planter
- Conventional-till (**CT**) - soil scarified to a depth of 100 to 150 mm in March/ April, then ploughed before planting and planted with the no-tillage planter
- Complete randomized block design with 4 replicates
- Soil samples were collected with a 40 mm pipe to the depth of 0-15 cm and increments of 0-5, 5-10, 10-15, 15-20 and 20-30 cm
- Soil organic carbon was analysed using the Walkley-Black method

## RESULTS & DISCUSSION

- **NT** is significantly **higher** 1.49 %, ($P$ <0.05)
- In **ZT** the SOC **increased** to 1.42 %
- For **MT**, SOC **increased** to 1.29 %
- Under **CT**, SOC **decreased** to 0.96 %
- Stratification of SOC took place under ZT, NT and MT




**The SOC at Langgewens (2021) for 0-15 cm of different tillage systems.**




**The depth distribution of SOC at Langgewens (2018) for the different tillage practices.**

## CONCLUSION

The study showed that SOC decreased, as the degree of soil disturbance increased with the exception of ZT. The higher SOC in the topsoil may be due to reduced soil disturbance and residue retention. The effect of the mouldboard plough reduced the stratification of C under CT. It proves that a build-up of C is possible in the top 10 cm when the tillage was reduced (ZT, NT, MT) in a dry Mediterranean climate of the Langgewens Research Farm.

## ACKNOWLEDGEMENT

Winter Cereal Trust and South African Winter Cereal Industry Trust

ROTHAMSTED RESEARCH

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

Fergus Blyth[1,2], Professor Simon Willcock[1,3]

[1]Rothamsted Research, [2]University of Glasgow , [3]Bangor University

Contact Information

LinkedIn ID: fergus-blyth-a32a98225

2439256B@student.gla.ac.uk

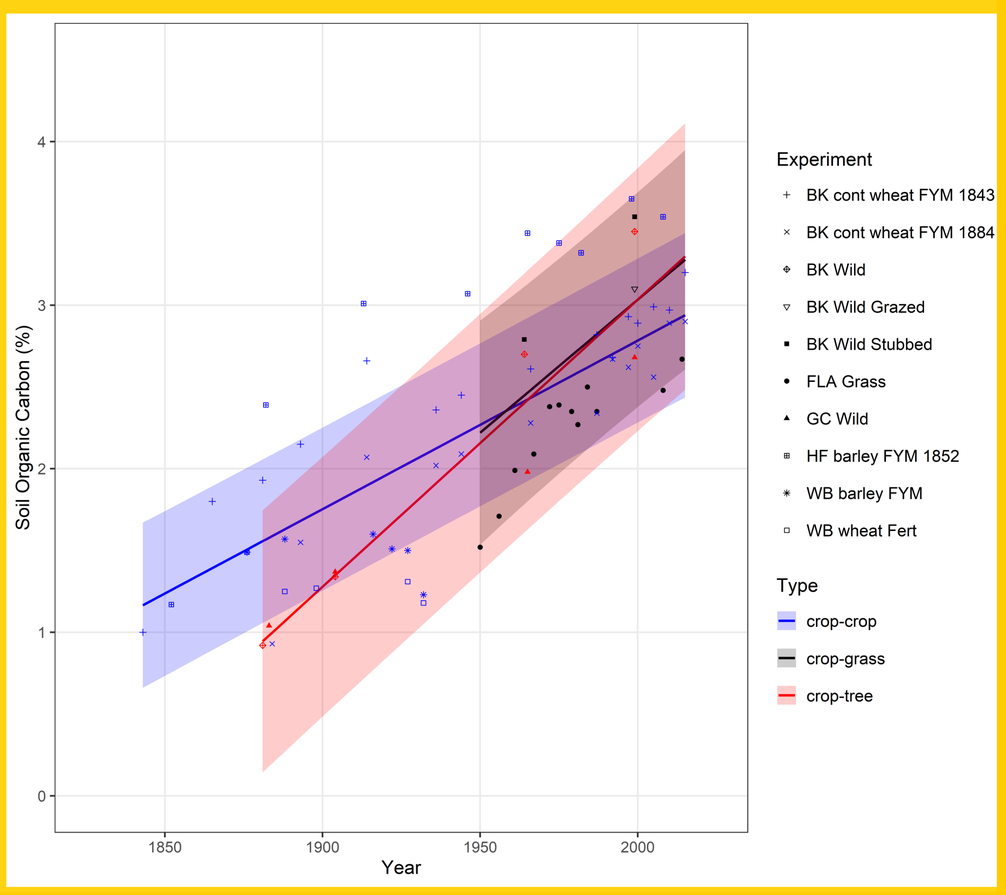
fergus.blyth@rothamsted.ac.uk

## INTRODUCTION

- Agricultural land across the globe has seen widespread declines in soil carbon and biodiversity, with biodiversity decreases also appearing in more natural ecosystems.
- Rewilding has been proposed as a solution for addressing these decreases in natural ecosystems and has also been suggested as a course of action for agricultural land. However, definitions of what constitutes rewilding vary, and empirical data on rewilding results remains scarce.
- One potential measurement of rewilding success is SOC, with greater levels of SOC widely acknowledged to be a positive for both natural ecosystems and agricultural land.

## METHODS

- SOC datasets from Rothamsted LTEs were selected to give a range of changes in land treatment.
- They were then split according to whether they displayed loss or gain of soil carbon and combined into a “loss” and a “gain” dataset.
- Each experiment was assigned a category under a factor “Type”, to show what change in land treatment had occurred. For instance, the Geescroft Wilderness experiment was classified as “crop-tree” to reflect its transformation from arable land to regenerated woodland.
- A linear mixed effects model was generated for each dataset, with “Experiment” as a random effect and “Type” as a fixed effect.



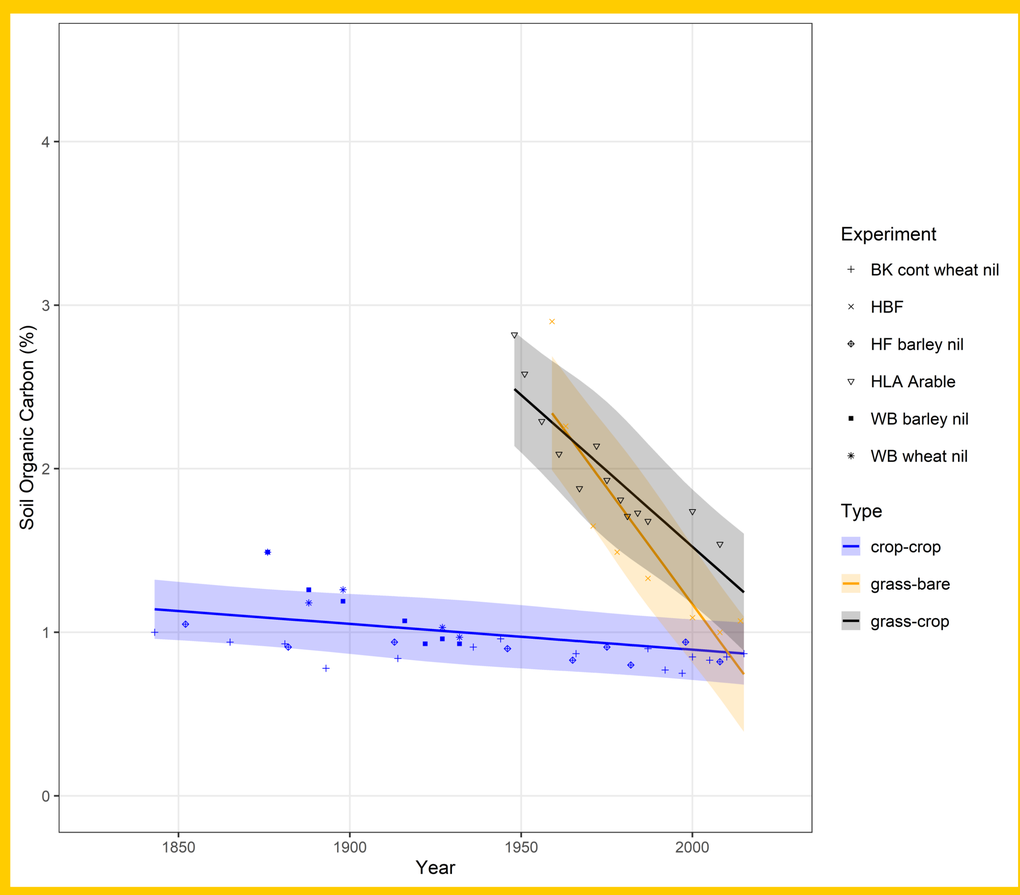




Figure 1 (left) and Figure 2 (right) show gain and loss of soil organic carbon plotted against years. Lines are the model’s predicted values for each land treatment type, generated from experiment values.

## RESULTS

- The fastest rate of loss or gain observed was the grass-bare treatment where SOC levels dropped by approximately 1.5% in just over 50 years. This is approximately 3 times the rate of the crop-crop gain treatment where SOC increased by 1.7% in 170 years.
- The crop-tree treatment demonstrated the highest rate of gain of SOC with a gain of 2% in 120 years. Although over a shorter time span, the crop-grass rate was very similar to the crop-tree rate.
- We observed a contrast in the crop-crop treatment where the application of FYM to crop-crop experiments in the gain dataset led to an increase of SOC at 10 times the rate observed for the loss of SOC on crop-crop areas where no fertiliser of any sort was applied.

## CONCLUSIONS

- We have demonstrated that SOC can decrease rapidly given certain conditions and regaining it is a complex process with disadvantages for each choice.
- Although restoring cropland to woodland provides the best increases in SOC in the quickest time, it is a time-consuming process that requires the land to be left untouched.
- Raising SOC through FYM application allows land to still be used for agriculture, although this requires continuous supplies of FYM and is not as fast as other treatments.
- Going forward, we would seek to incorporate other LTE datasets that fit our categories to improve the strength of our model.

References

- e-RA, Rothamsted Research. Available at https://www.era.rothamsted.ac.uk/index.php.
- POULTON, P.R. et al. (2003) “Accumulation of carbon and nitrogen by old arable land reverting to Woodland,” Global Change Biology, 9(6), pp. 942–955

Acknowledgements

Thanks are given to Dr Jonah Prout and Dr John Addy for their assistance with R coding, and to Dr Margaret Glendinning and Dr Sarah Perryman for their general advice and support.

UKRI Biotechnology and Biological Sciences Research Council

# Soil Organic Carbon Pools as Early Indicators for Soil Organic Matter Stock Changes under Different Tillage Practices in Inland Pacific Northwest

Rakesh Awale, Micco Emeson, Stephen Machado

*Columbia Basin Agricultural Research Center (CBARC), Oregon State University, Pendleton, Oregon, USA*

## 1. RATIONALE

- Soil organic matter (SOM) is essential for sustaining soil health and crop productivity.
- Tillage disturbs soil and influences residue distribution and soil micro-environment that can affect SOM turnover rates.
- However, changes in SOM stocks in response to agronomic practices are slow and show years later when it is too late for adjustments in management.
- Physical, chemical, and microbiological pools of SOM are more sensitive and can provide early signs of management changes compared to bulk SOM.
- Identifying early indicators of SOM dynamics will allow early management decisions and quick remedial actions.

## 2. AIMS

- Evaluate long-term (53 years) effects of tillage intensity and timing on SOC and total N (proxies for SOM) and their pools.
- Determine the most responsive SOM pool(s) to tillage practices in a winter wheat – spring pea rotation in Inland Pacific Northwest, USA.

## 3. WHEAT-PEA LONG-TERM CROPPING SYSTEMS EXPERIMENT (WP-LTE, established 1963)

- *Location* : CBARC, Pendleton, Oregon, USA (45°42'*N*, 118°35'*W*)
- *Climate* : Semiarid with cool wet winters and hot dry summers (418 mm mean annual precipitation and 8°C mean annual temperature)
- *Soil* : Walla Walla silt loam (*coarse-silty, mixed, mesic Typic Haploxeroll*), 0-1% slope
- *Design* : Split plot (2 crop phases, main plots & 4 tillage systems, sub-plots), 4 reps
- *Crop rotation* : 2-year winter wheat – spring pea (both phases present every year) wheat phase (October to July) & pea phase (March/April to June/July)
- *Sub-plot size* : 36.5 m long x 7.3 m wide
- *Crop cultivars* : Semi-dwarf soft white winter wheat Green peas (until 1990) & dry peas (since 1991)
- *N management* : 90 kg/ha N (wheat phase) & 22 kg/ha N (pea phase) for the last 20 years.
- *Soil sampling* : In 2016, two soil cores (3.8 cm diam.) composited from 0- to15-cm surface

### 3.1. Tillage Treatments in the WP-LTE

| Treatments | Primary tillage | | | |
|---|---|---|---|---|
| | After Wheat Stubble | Depth (cm) | After Pea Vines | Depth (cm) |
| 1. Fall Plow (FP) | Moldboard plow (fall) | 20-25 | Moldboard plow (fall) | 20-25 |
| 2. Spring Plow (SP) | Moldboard plow (spring) | 20-25 | Moldboard plow (fall) | 20-25 |
| 3. Disk/Chisel (DT/CT) | Disk (fall) | 10 | Chisel (fall) | 20 |
| 4. No-till (NT) | No-till | - | No-till | - |

5. Grass Pasture (GP): An undisturbed/unfertilized native vegetation (consisting tall fescue, bulbous blue grass, green & yellow foxtails), maintained since 1931 at the CBARC in proximity to the WP-LTE, served as a reference for comparisons of changes in SOM dynamics in the WP-LTE.

### 3.2. Laboratory Analyses

| Soil Properties | Procedures |
|---|---|
| Soil organic C (SOC) & total N (TN) | Dry combustion at 950°C using CN analyzer |
| Bulk density (BD) | Dividing oven dry (105°C) soil mass by soil volume |
| pH | 1:2 (soil: 0.01 *M* $CaCl_2$ solution) using pH meter |
| Particulate organic matter C (POC) & N (PON) | Combustion of coarse soil fraction (53 - 2000 µm) using CN analyzer |
| Permanganate oxidizable C (POXC) | Extracted using 0.02 *M* $KMnO_4$ solution |
| Extractable organic C (WEOC) & total dissolved N (TDN) | Extracts of deionized water analyzed using TOC/TN analyzer |
| C mineralization (Cmin) | $CO_2$-C evolved from soils, incubated at 25°C & 60% WHC for 30 days, analyzed in infrared $CO_2$ analyzer |
| Microbial biomass C (MBC) & N (MBN) | Chloroform-fumigation incubation (MBC) & 0.5 *M* $K_2SO_4$ extract analysis in TOC/TN analyzer (MBN) |
| Inorganic N (KEN) | Extracts of 2 *M* KCl analyzed using continuous flow segmented analyzer for $NO_3$-N & $NH_4$-N |

## 4. RESULTS

### Table 1. Tillage Effects on Bulk Soil Characteristics (0-15 cm)

| Treatments | SOC | | Total N | | C:N | Bulk Density | $pH_{CaCl_2}$ |
|---|---|---|---|---|---|---|---|
| | g kg$^{-1}$ | Mg ha$^{-1}$ | g kg$^{-1}$ | Mg ha$^{-1}$ | | g cm$^{-3}$ | |
| Grass pasture | 24.2$^{a}$ | 40.1$^{a}$ | 1.78$^{a}$ | 2.96$^{a}$ | 13.5$^{a}$ | 1.11$^{a}$ | 6.35$^{a}$ |
| No-till | 17.9$^{b}$ | 34.7$^{b}$ | 1.33$^{b}$ | 2.59$^{b}$ | 13.5$^{a}$ | 1.30$^{b}$ | 5.02$^{b}$ |
| Disk/Chisel | 18.2$^{b}$ | 34.3$^{b}$ | 1.36$^{b}$ | 2.57$^{b}$ | 13.3$^{ab}$ | 1.28$^{b}$ | 5.29$^{b}$ |
| Spring plow | 17.2$^{b}$ | 33.9$^{b}$ | 1.33$^{b}$ | 2.64$^{b}$ | 12.9$^{b}$ | 1.32$^{b}$ | 5.33$^{b}$ |
| Fall plow | 16.3$^{b}$ | 31.8$^{b}$ | 1.26$^{b}$ | 2.45$^{b}$ | 12.9$^{b}$ | 1.30$^{b}$ | 5.28$^{b}$ |

Means followed by different lower-case letters within a column are significantly different (P ≤ 0.5)

### Table 2. Tillage Effects on Physical and Chemical Pools of SOM (0-15 cm)

| Treatments | POC | PON | POC:PON | POXC | WEOC | TDN | WEOC: TDN | KEN |
|---|---|---|---|---|---|---|---|---|
| | g kg$^{-1}$ | | | mg kg$^{-1}$ | | | | mg kg$^{-1}$ |
| Grass pasture | 4.85$^{a}$ | 0.27$^{a}$ | 17.9$^{a}$ | 706$^{a}$ | 223$^{a}$ | 42.3$^{a}$ | 9.30$^{a}$ | 31.2$^{a}$ |
| No-till | 4.48$^{a}$ | 0.26$^{a}$ | 17.0$^{a}$ | 676$^{b}$ | 181$^{b}$ | 22.1$^{a}$ | 9.61$^{a}$ | 11.4$^{a}$ |
| Disk/Chisel | 4.56$^{a}$ | 0.25$^{ab}$ | 18.1$^{a}$ | 659$^{bc}$ | 183$^{b}$ | 25.0$^{a}$ | 9.24$^{a}$ | 14.1$^{a}$ |
| Spring plow | 3.67$^{b}$ | 0.21$^{b}$ | 17.3$^{a}$ | 648$^{cd}$ | 159$^{c}$ | 21.0$^{a}$ | 8.80$^{a}$ | 12.2$^{a}$ |
| Fall plow | 3.72$^{b}$ | 0.21$^{b}$ | 17.7$^{a}$ | 633$^{d}$ | 153$^{c}$ | 28.6$^{a}$ | 7.28$^{a}$ | 19.2$^{a}$ |

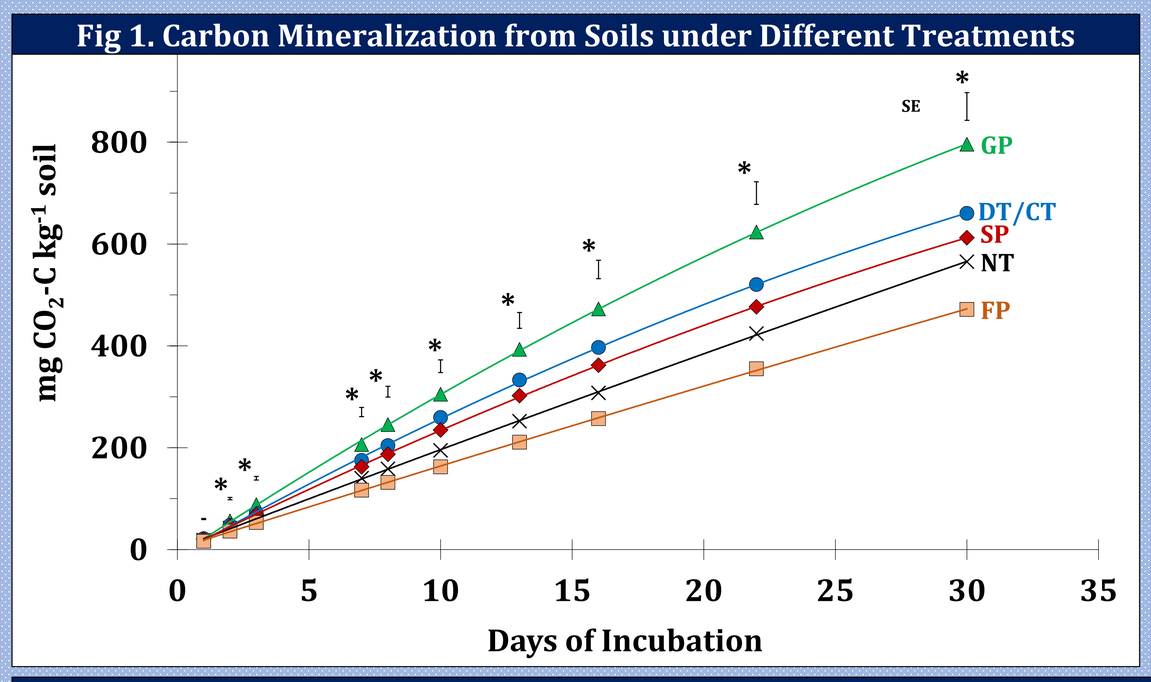
Means followed by different lower-case letters within a column are significantly different (P ≤ 0.5)

### Table 3. Treatment Effects on Microbiological Pools of SOM (0-15 cm)

| Treatments | MBC | MBN | MBC:MBN | BR | Cmin | $qCO_2$ |
|---|---|---|---|---|---|---|
| | mg kg$^{-1}$ | | | mg kg$^{-1}$ d$^{-1}$ | mg kg$^{-1}$ | µg g$^{-1}$ d$^{-1}$ |
| Grass pasture | 678$^{a}$ | 135$^{a}$ | 7.9$^{a}$ | 32.7$^{a}$ | 796$^{a}$ | 46.5$^{ab}$ |
| No-till | 531$^{b}$ | 45$^{b}$ | 15.7$^{a}$ | 21.2$^{bc}$ | 565$^{bc}$ | 41.7$^{bc}$ |
| Disk/Chisel | 570$^{b}$ | 54$^{b}$ | 15.3$^{a}$ | 26.1$^{b}$ | 661$^{b}$ | 45.3$^{ab}$ |
| Spring plow | 509$^{bc}$ | 74$^{b}$ | 12.3$^{a}$ | 25.5$^{b}$ | 612$^{b}$ | 50.4$^{a}$ |
| Fall plow | 418$^{c}$ | 63$^{b}$ | 13.6$^{a}$ | 16.3$^{c}$ | 472$^{c}$ | 39.8$^{c}$ |

Means followed by different lower-case letters within a column are significantly different (*P* ≤ 0.5)

### Fig 1. Carbon Mineralization from Soils under Different Treatments




### Table 4. Pearson's Correlation Coefficients (r)† of SOM Pools

| SOM pools | SOC | TN | C:N | POC | PON | POC: PON | POXC | WEOC | TDN | WEOC: TDN | MBC | MBN | MBC: MBN | Cmin | BR | $qCO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TN | 0.95 | | | | | | | | | | | | | | | |
| C:N | 0.51 | ns | | | | | | | | | | | | | | |
| POC | 0.69 | 0.61 | 0.53 | | | | | | | | | | | | | |
| PON | 0.71 | 0.68 | 0.39 | 0.90 | | | | | | | | | | | | |
| POC:PON | 0.34 | ns | 0.50 | 0.69 | 0.31§ | | | | | | | | | | | |
| POXC | 0.78 | 0.72 | 0.51 | 0.73 | 0.70 | 0.42 | | | | | | | | | | |
| WEOC | 0.78 | 0.71 | 0.53 | 0.78 | 0.73 | 0.47 | 0.79 | | | | | | | | | |
| TDN | 0.51 | 0.60 | ns | 0.35 | 0.47 | ns | ns | 0.32§ | | | | | | | | |
| WEOC:TDN | ns | ns | ns | ns | ns | ns | ns | ns | -0.75 | | | | | | | |
| MBC | 0.70 | 0.66 | 0.40 | 0.77 | 0.68 | 0.53 | 0.76 | 0.67 | ns | ns | | | | | | |
| MBN | 0.51 | 0.64 | ns | 0.35 | 0.45 | ns | 0.32 | 0.37 | 0.80 | -0.49 | ns | | | | | |
| MBC:MBN | -0.31§ | -0.39 | ns | ns | ns | ns | ns | -0.28§ | -0.43 | 0.30† | ns | -0.56 | | | | |
| Cmin | 0.69 | 0.61 | 0.50 | 0.79 | 0.62 | 0.68 | 0.70 | 0.77 | ns | 0.29§ | 0.73 | ns | ns | | | |
| BR | 0.66 | 0.62 | 0.40 | 0.75 | 0.58 | 0.66 | 0.67 | 0.70 | ns | 0.32§ | 0.73 | ns | ns | 0.93 | | |
| $qCO_2$ | 0.32§ | 0.30§ | ns | 0.40 | ns | 0.49 | 0.31§ | 0.42 | ns | 0.30§ | ns | ns | ns | 0.71 | 0.80 | |
| KEN | 0.45 | 0.56 | ns | 0.28§ | 0.41 | ns | ns | ns | 0.99 | -0.75 | ns | 0.81 | -0.44 | ns | ns | ns |

†Correlations significant at *P* ≤ 0.05, except §significant at *P* ≤ 0.10; ns, non-significant.

### Table 5. Best Stepwise Multiple Linear Regression Model for Predicting SOC

| Response variable | Full model | | | Final model | | |
|---|---|---|---|---|---|---|
| | Predictors | *F*-statistic | $R^2$ | Predictors | *F*-statistic | $R^2$ |
| SOC | POC, PON, POXC, WEOC, MBC, BR, Cmin, $qCO_2$ | 9.7 | 0.74 | POXC, WEOC | 34.9 | 0.69 |

## 5. SUMMARY & CONCLUSIONS

- Tillage timing and intensity had no influences on bulk SOM (SOC and total N) within the WP-LTE.
- Conversely, physical (POC, PON), chemical (POXC and WEOC), and microbiological (MBC, BR, Cmin, and $qCO_2$) pools of SOM responded significantly to tillage practices.
- The C-pools were more strongly correlated than the N-pools with SOC.
- POXC and WEOC were the most sensitive SOM pools to tillage that can be used for early detection of SOM trends for the purposes of adjusting management practices to enhance SOM accretion and improving soil health.
- Adoption of no-tillage and low disturbance tillage systems (disk/chisel) increases SOM storage compared to intensive tillage practices (fall and spring plow) under wheat-pea cropping system overtime in the Inland Pacific Northwest.

Oregon State University
Columbia Basin Agricultural Research Center

***Poster Presentation***:
Long Term Experiments: Meeting Future Challenges Conference
Rothamsted Research, West Common, Harpenden, UK
20-22 June, 2023

Abbreviations: SOM, soil organic matter; SOC, soil organic carbon; TN, total nitrogen; WP-LTE, wheat-pea long term experiment; GP, grass pasture; FP, fall plow; SP, spring plow; DT/CT, disk/chisel tillage; NT, no-tillage; BD, bulk density; POC, particulate organic matter carbon; PON, particulate organic matter nitrogen; POXC, potassium permanganate oxidizable carbon; WEOC, water extractable organic carbon; TDN, total dissolved nitrogen in water; MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; Cmin, cumulative $CO_2$-C mineralized in 30 days; WHC, water holding capacity; BR, basal respiration ($CO_2$ evolved non-fumigated soils); $qCO_2$, metabolic quotient (basal respiration per MBC); KEN, KCl extractable inorganic nitrogen.

***Further Details:***
Awale, R., Emeson, M.A., and Machado, S. (2017). Soil organic carbon pools as early indicators for soil organic matter stock changes under different tillage practices in Inland Pacific Northwest. *Frontiers in Ecology and Evolution*. 5:96. doi: 10.3389/fevo.2017.00096

# The effect of long-term application of vegetable, fruit and garden waste compost on soil organic carbon and nitrogen cycling in an arable crop rotation in Flanders, Belgium

Soil service of Belgium NPO

MIEKE VERBEECK, STIJN MARTENS, MIA TITS, ANNEMIE ELSEN

*Soil Service of Belgium, Willem De Croylaan 48, 3001 Leuven, Belgium*

## Introduction

Compost is considered a valuable soil improving amendment, providing carbon and nutrients to build soil organic carbon (SOC) and sustain crop growth. Vegetable, fruit, garden (VFG) and other green wastes can be selectively collected and composted, hereby providing biowaste compost for agricultural use. However, the high total nutrient concentration and the slow-release characteristics of the nutrients in some types of compost warrant cautious use. In this study, the effect of long-term domestic biowaste application on soil organic carbon and residual N after the growing season was investigated, in addition to determining the fertilizer value of the biowaste in a long-term experiment.

## Methods

Table 1 Experimental design of the VFG-compost trial (VFG = vegetable, fruit and garden waste)

| | | | Compost dose (ton/ha) **yearly** | | | Compost dose (ton/ha) **2-yearly** | | | Compost dose (ton/ha) **3-yearly** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | No fertilizer | Only mineral N | 15 | 30 | 45 | 15 | 30 | 45 | 15 | 30 | 45 |
| **Cropped** | | | | | | | | | | | |
| **Fallow** | | | | | | | | | | | |

Table 2 Crops

| Crops |
|---|
| Winter wheat (1:2) |
| Potato (1:6) |
| Sugar beet (1:5) |
| Carrot (1:6) |
| Chicory |
| Onion |

Figure 1 Aerial views of the experiment, depicting the 12 treatment plots (10x10m) + 2 subplots (5x5m; fallow in the compost treatments) in 4 replicate blocks

Table 3 Important event dates

| Year | Event |
|---|---|
| **1997** | Start |
| **2003** | Top up available compost-N with mineral N according to agronomic advice (including other nutrients) |
| **2005** | Start including cover crops after winter wheat (mustard) |
| **2014** | Include slow-release N of compost second year after application in agronomic advice calculation |
| **2018** | Change SOC method from Walkley&Black to dry combustion |
| **2023** | 27th year |

Table 4 Soil properties

| Soil properties |
|---|
| Silt loam, Haplic Luvisol |
| $pH_{KCl}$ 6-7 |
| 14% clay (0-35cm) |
| $SOC_{1997}$ (0-30 cm) 1.1% |

Crop measurements:
yearly yield, macro-micronutrients, quality

Soil measurements:
yearly mineral N (90 cm, stock, seasonality, residual), (3-)yearly SOC (23 & 30 cm), 3-yearly macro-micronutrients, sporadic soil physical and biological properties

## Results

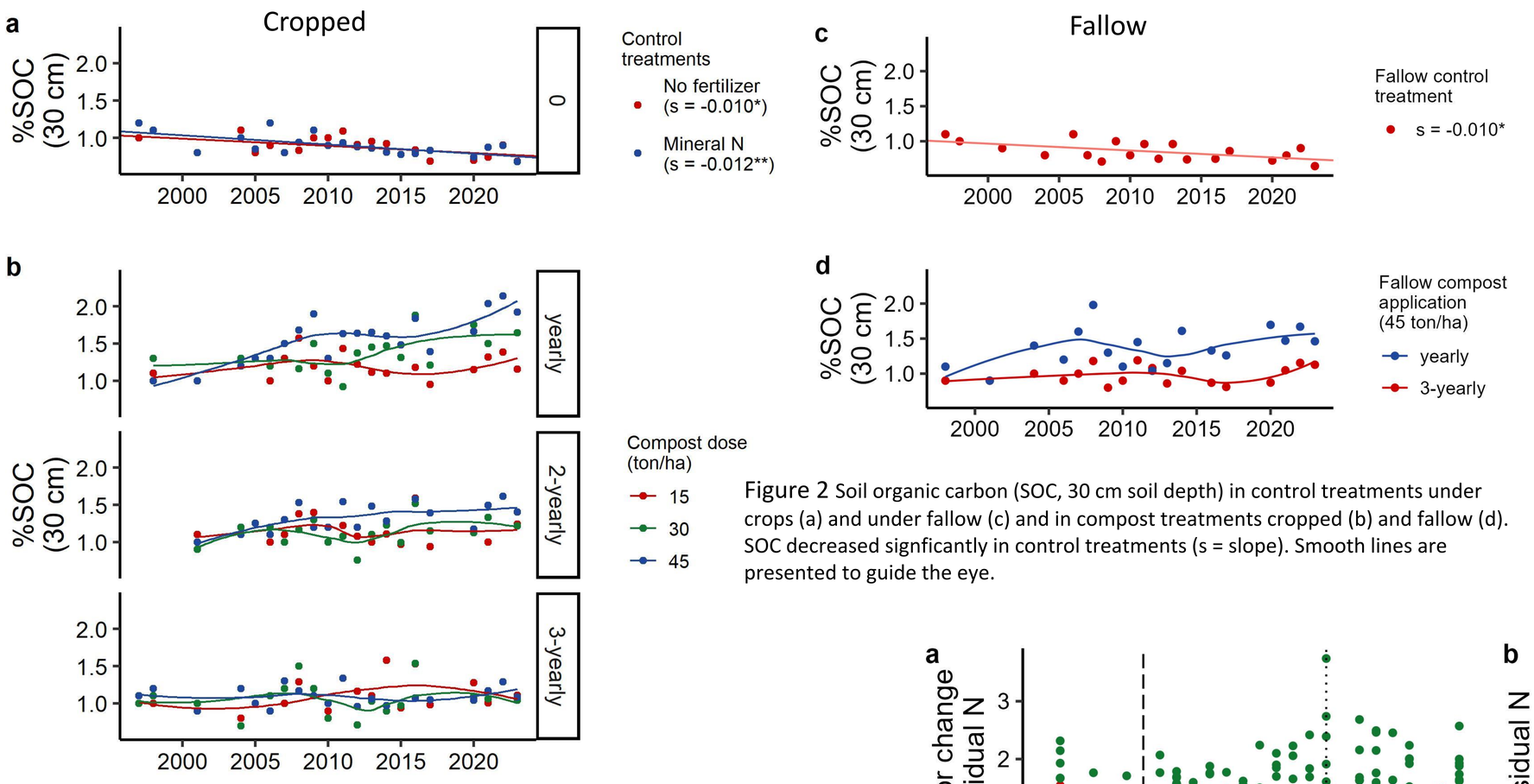



Figure 2 Soil organic carbon (SOC, 30 cm soil depth) in control treatments under crops (a) and under fallow (c) and in compost treatments cropped (b) and fallow (d). SOC decreased signficantly in control treatments (s = slope). Smooth lines are presented to guide the eye.

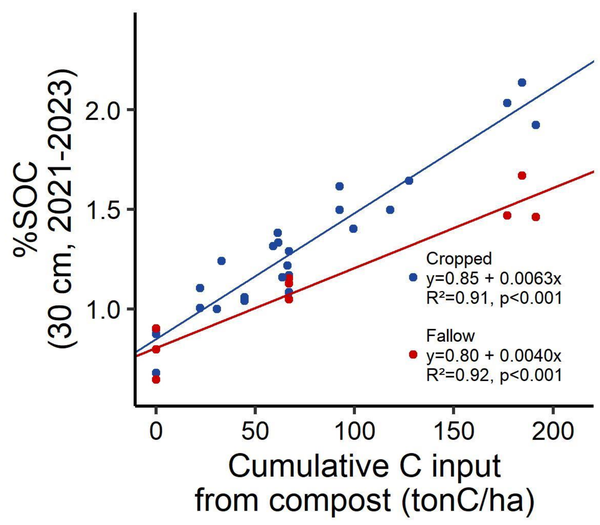



Figure 3 SOC increase with cumulative C input after 25-27 years of compost addition is linear and increased more strongly with increasing dose in cropped conditions compared to fallow. This indicates that the additional effect of crops (residues, root exudates,…) depends on the compost dose/prevalent SOC

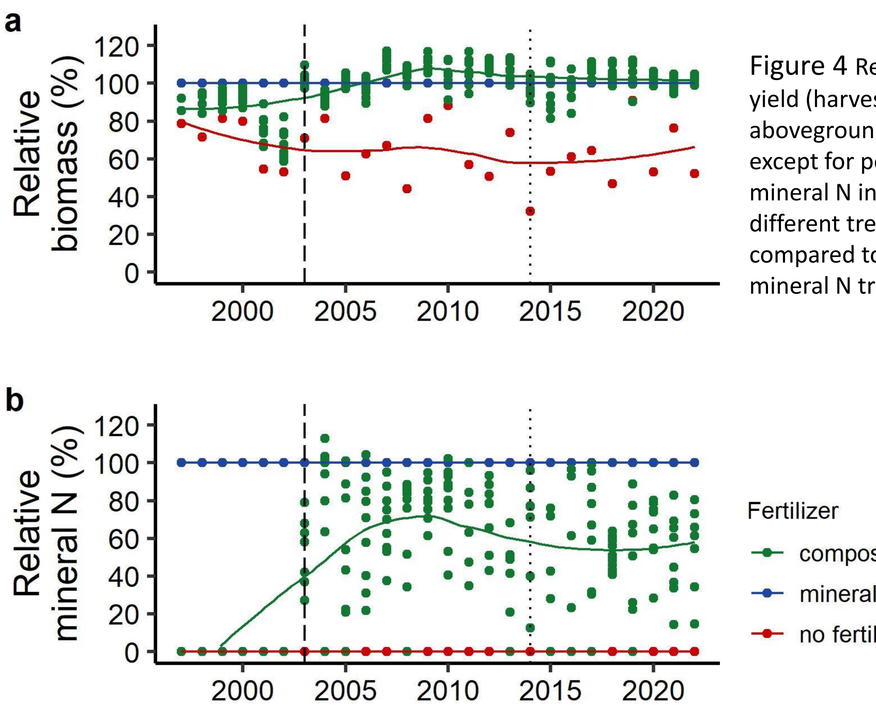



Figure 4 Relative biomass yield (harvested crop and aboveground crop residues except for potato) (a) and mineral N input (b) of the different treatments compared to the only mineral N treatment.

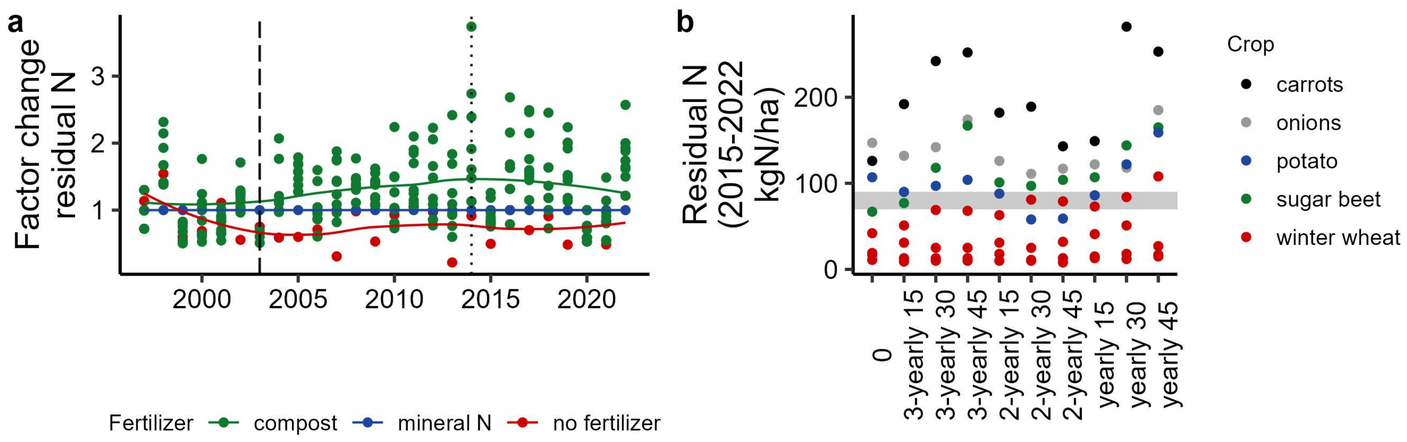



Figure 5 Change of residual N (measured sept-dec) vs. the only mineral N treatment (a) and residual N measurements since 2015 (b). The grey zone = residual N standards (depending on crop type and regional water quality status, implementation EU Nitrate Directive).

Farmers' recommendation:

**Rate & dose = yearly 15 ton/ha**

+ 0.4% SOC (30 cm) after 25 years vs. min N control

Average of -40% of mineral N use vs. min N control

No yield losses

Slightly higher chance to higher residual N:

50% standard violation since 2015, compared to 38% standard violation since 2015 of the only mineral N treatment

**Conclusion**: Compost addition in an arable crop rotation stabilizes or increases SOC concentration, depending on the cumulative added dose, while saving mineral N fertilizer, without yield losses. Increasing cumulative doses of compost induces additional SOC build-up mechanisms under an arable cropping rotation. Medium doses of compost only slightly increase residual N after the growing season. Generally, addition of compost improves biological, chemical and physical soil properties compared to mineral N treatment.

# Perennial cropping systems increased soil carbon and nitrogen more than annual cropping systems – a nine-year field study

Yiwei Shang (ywshang@agro.au.dk)[1], Jørgen Eivind Olesen[1], Poul Erik Lærke[1,2,3], Ji Chen[1,2,3]

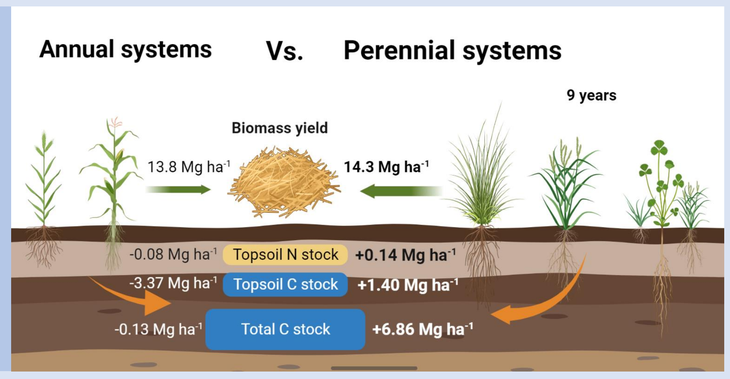
[1]Department of Agroecology, Aarhus University, 8830 Tjele, Denmark

[2]Aarhus University Centre for Circular Bioeconomy, Aarhus University, 8830 Tjele, Denmark

[3]iCLIMATE Interdisciplinary Centre for Climate Change, Aarhus University, 4000 Roskilde, Denmark

## Highlights

- **Perennial cropping systems significantly increased soil C stock at both topsoil (0-20 cm) and the whole profile (0-1 m) over annual cropping systems.**
- **Perennial cropping systems significantly increased topsoil N stock over annual cropping systems.**
- **Perennial cropping systems have the potential to obtain high biomass yield and yield stability.**




## Introduction

Facing the dual challenge of global warming and increased food demand, emerging climate-smart cropping systems need to improve biomass production while mitigating climate change. Perennial crops that sustain productivity for several years without replanting could be a potential solution.

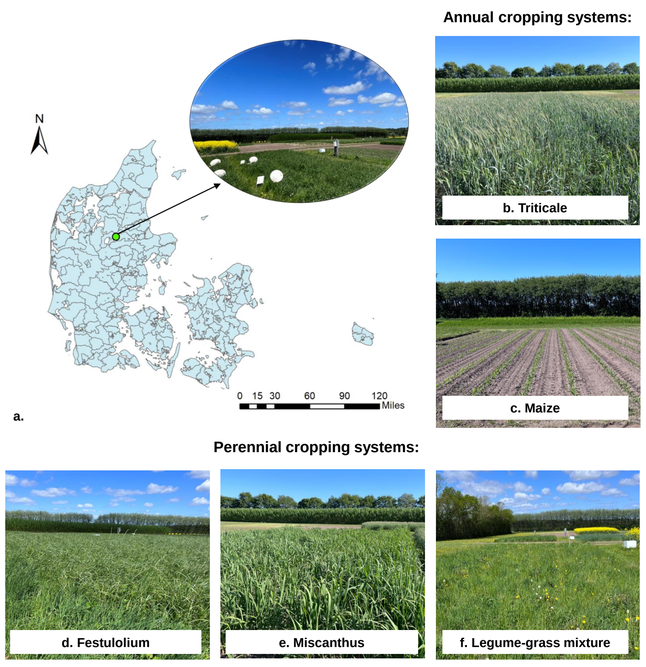
It has been reported that perennial crops have the potential to enhance soil carbon (C) and could be as productive as annual crops. However, many of these studies only focused on the topsoil, whereas the C stock in depth has rarely been investigated. Moreover, given the cascading effects of reactive nitrogen (N) losses, the changes in soil N stock also need to be explored. Additionally, the productivity of perennial cropping systems depends on crop varieties and other environmental factors. Both biomass yield and yield stability need to be thoroughly examined in the long term.

Our study, based on a nine-year field experiment, aimed to verify the two hypotheses that: (i) compared with annual cropping systems, perennial cropping systems may have larger potential for soil C and N sequestration, and (ii) perennial cropping systems have higher biomass yield and yield stability.

## Materials and Methods

The experiment was established in 2012 at Aarhus University, Foulum, Tjele, Denmark (9°35′E, 56°30′N). This site has a cold and wet temperate climate and sandy loam soil.

Here, five different cropping systems were studied. Two annual cropping systems were traditional monoculture of **triticale** (*Triticosecale,* AC-T) and **maize** (*Zea mays* L., AC-M). Three perennial cropping systems include low-fertilized **miscanthus** (*Miscanthus × giganteus* K., PG-M), high-fertilized **festulolium** (*Festulolium pabulare,* PG-F), and zero-N fertilized **legume-grass mixture** (includes red clover, festulolium, and cock's foot, LG-D).



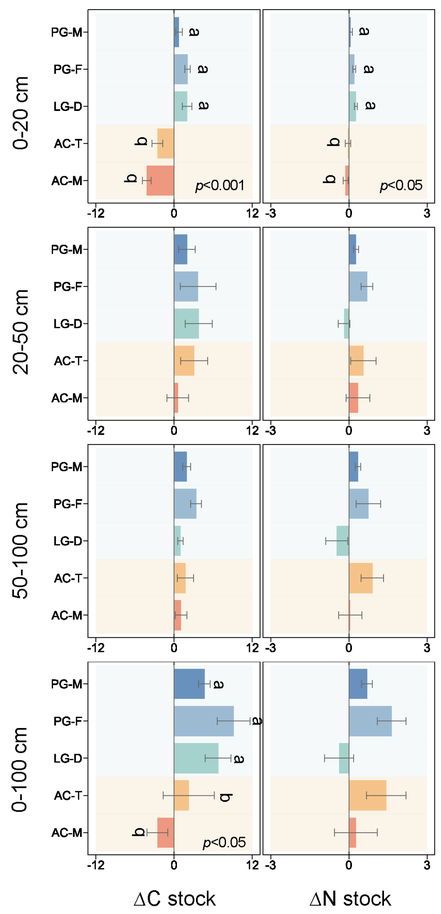

The biomass yield of each year was measured during 2013-2021. Soil C and N concentrations and bulk density at different depths (0-20, 20-50, 50-100 cm) were measured to calculate C and N stocks. The changes in C and N stocks (ΔC stock and ΔN stocks ) from 2012 to 2021 were calculated.

## Results

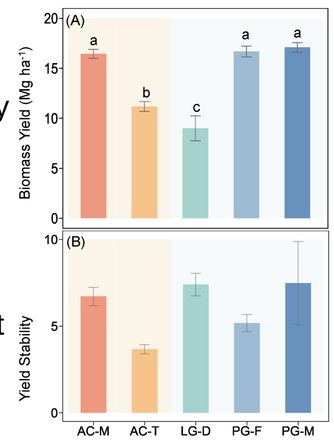
**1. Soil C stock.** Perennial cropping systems increased soil C stocks at 0-1 m by an average of 6.9 Mg ha$^{-1}$ over nine years. As a contrast, ΔC stock in annual cropping systems was +2.7 Mg ha$^{-1}$ for triticale and -1.7 Mg ha$^{-1}$ for maize. Specifically, the C stock in topsoil (0-20 cm) increased by 1.4 Mg ha$^{-1}$ in perennial cropping systems, while it decreased by 3.4 Mg ha$^{-1}$ in annual cropping systems.

**2. Soil N stocks**. Two perennial cropping systems (exclude LG-D[1]) increased soil N stock at 0-1 m by 1.2 Mg ha$^{-1}$ after nine years, while annual cropping systems increased it by 0.9 Mg ha$^{-1}$. Notably, annual systems reduced topsoil N stock by 0.08 Mg ha$^{-1}$ while perennial systems increased it by 0.1 Mg ha$^{-1}$.

[1]LG-D had one season of barley and was renovated in 2018.




**3. Biomass yield and yield stability.** Across the nine years, significantly higher biomass yields were obtained by miscanthus, festulolium, and maize (17.1, 16.7, and 16.4 Mg ha$^{-1}$, respectively). Yield stability was calculated by dividing mean biomass yield by standard deviation. Miscanthus and legume-grass mixture showed the highest yield stability of 7.5 and 7.4, respectively.




## Conclusion

In our nine-year field experiment, perennial cropping systems increased soil C and N stocks more than annual cropping systems. Both perennial and annual cropping systems obtained relatively high biomass yields. Miscanthus and legume-grass mixture showed higher yield stability when compared to other species.

## Acknowledgement

This study is granted by EU H2020 Marie Skłodowska-Curie Actions, Aarhus University Research Foundation, Danish Independent Research Foundation, and the China Scholarship Council. We also thank the Nordic Committee of Agriculture and Food Research and Aarhus University iClimate.

AARHUS UNIVERSITY

iCLIMATE AARHUS UNIVERSITY INTERDISCIPLINARY CENTRE FOR CLIMATE CHANGE

CBIO AARHUS UNIVERSITY CENTRE FOR CIRCULAR BIOECONOMY

P11

# Long-term soil response to different fertilisation schemes – results from a 55 year orchard trial

**Michael Blanke, INRES – Hort Science, University of Bonn, Germany (mmblanke@uni-bonn.de)**

universitätbonn

## Introduction

Long-term trials are scarce, but a prerequisite to fully understand changes in soil dynamics.
The objective of this poster contribution is to report results from a 55 year long-term trial planted with cherry on soil pH, humus accumulation and organic carbon dynamics.

## Material and methods: Climate

The climate is similar to that in Southern England and characterised by.

- Annual average temperature 9.6° C
- Annual precipitation 600 mm
- North Atlantic climate, Westerly winds
- Buffered by the mild river Rhine effect

## Humus accumulation

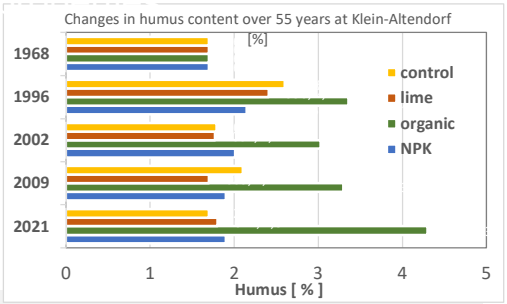



Figure 2. Humus accumulation over 5 decades

After an initial start at 1.8 % humus in 1968, the soil with compost increased humus by 2.5fold to 4.3% in 2021(Fig. 2).

## Soil properties

The experiment was instigated in 1968 at the University of Bonn (50° N), Germany. It is registered in the Bonares ("good things") LTE data bank. The soil is a fertile luvisol, which scores 90 out of 100 in the land fertility scale.and characterised by.

- Soil type: luvisol on loess
- Subsoil loess
- pH 6.3

## Orchard design: Trees

The LTE consists of ca. 0.5 ha with fruit trees planted in N-S oriented rows at a spacing of 3.5 m x 1.5 m (Figure 1). In all four treatments (Table 1) , the tree strip was kept free of weeds using the herbicides approved at the time.

## Orchard design: Replicates

Fruit trees were planted in rows with the treatments across and 8 trees as replicates per treatment. The orchard was managed according to zhe IFP (integrated fruit production) standard.

## -4- Fertiliser treatments

| Plot | Amount | Timing |
|---|---|---|
| Control | n / a | No treatment |
| Lime only | 1 t CaO/ha | Every 10 years |
| Organic | 10 t DM/ha | As compost |
| anorganic | 2x 20kg N/ha | NPK as KAS. |

## Soil organic carbon (SOC)

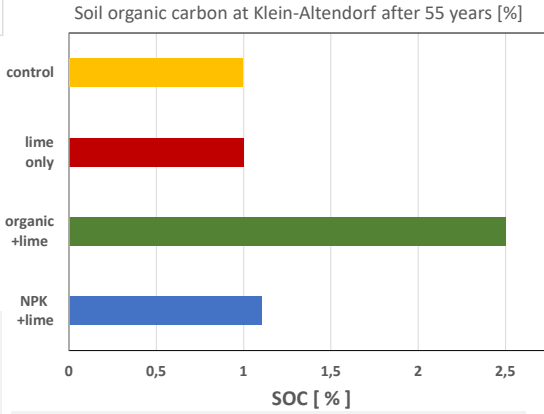



Figure 3: Soil organic carbon (SOC in %) dynamics at Klein-Altendorf/Bonn(50° N)

After 55 years of tillage-free trials, the orchard soil had accumulated (or maintained) 0.99% SOC with regular lime application and slightly more (1.1%) with lime and inorganic fertiliser as standard practise. The regular supply of green compost increased the SOC to 2.5%, equivalent to a rate of 0.028 % SOC/year.

## Soil nutrients / acidification

The Bonn LTE also provides data on soil nutrient dynamics (N, P, K, Mg), mineralisation rate and soil pH.
Lime (1 t CaO/ha/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 slow soil acidification in the herbicide strip reported from East Malling-.

## Conclusion LTE Bonn

1) Fruit trees without fertilisation in the control grew well without nutrient deficiency symptoms or any yield depression
2) Lime (1 t CaO/ha/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 slow soil acidification in the herbicide strip reported from East Malling-
3) Lime and organic fertiliser as certified green compost (10 t DM/ha/a) increased the humus content by 2.5 fold from 1.8 % (in 1968) to 4.3% (in 2021) indicating an annual rate of 0.028% SOC /year and a potential for carbon sequestration, at a rate of 0.7 t CO2/ha/year, if organic matter was regularly supplied.
4) Lime plus inorganic NPK fertiliser (40 kg N/ha/year) increased both pH and soil nutrient content.

## References


- Bonares - https://b-web-e.bonares.de/uebersichtskarteDFV_de/.
- Blanke M. 1997. $CO_2$ fluxes in an apple orchard. In: Impacts of global change on tree physiology and forest ecosystems. Nov. 1996, Wageningen, Kluwer Academic Publishers Vol. 52 (G Mohren et al., eds), 173-186
- Blanke M, Kunz A. 2023: Carbon sequestration durch Humusanreicherung. Erwerbs-Obstbau 65(3) https://doi.org/10.1007/s10341-023-00878-9

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

T. Rittl[1], M. Ebbesvik[1] & R. Pommeresche[1]

[1]*Norwegian Centre for Organic Agriculture (tatiana.rittl@norsok.no)*

## Background

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 (± 20 Norwegian red cows), biological nitrogen fixation and liming. Here, we report the impacts of 30 years organic dairy farm on soil characteristics and ley yields.

## Materials and Methods

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 and quality (e.x. crude protein) have been annually measured since 1991.

***Fig.1.*** *Tingvoll farm in 1990s (left). Permanet pasture in Tingvoll far in 2021 (right).*

## Results

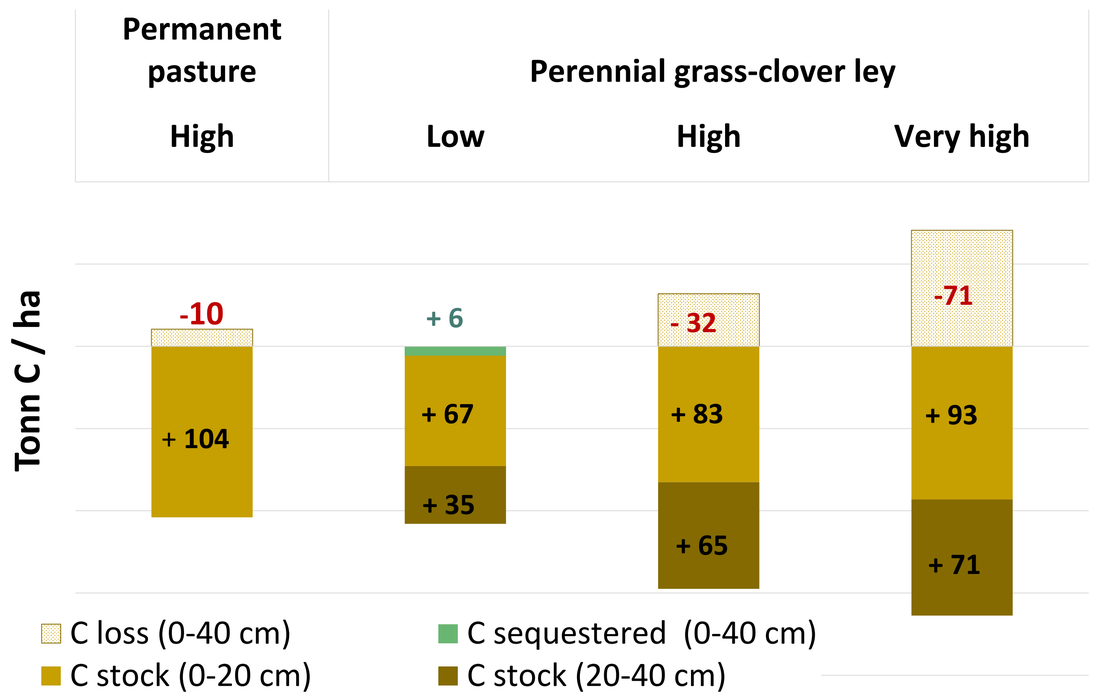



***Fig.2.*** *SOC dynamics and stock over 30-y period in the permanent pasture and perennial grass ley. SOM classes accord to their initial SOM content:* ***very high initial SOM >12%, high 6 < SOM < 12%, low SOM < 6%.***

***Tab.1.*** *Average soil nutrients across the years in the permanent pasture and perennial grass-clover ley*

| Year | P-AL | Mg-AL | K-AL | pH |
|---|---|---|---|---|
| | mg / 100 g | mg / 100 g | mg / 100 g | $H_2O$ |
| **Permanent pasture** | | | | |
| 1990 | 8.83 | 8.82 | 8.43 | 5.25 |
| 1995 | 8.53 | 6.53 | 12.02 | 5.58 |
| 2002 | 8.97 | 8.97 | 9.72 | 5.73 |
| 2009 | 7.52 | 10.42 | 11.14 | 5.82 |
| 2015 | 6.03 | 7.15 | 9.83 | 6.13 |
| 2021 | 7.38 | 7.63 | 14.5 | 5.93 |
| **Perennial grass-clover ley** | | | | |
| 1990 | 18.08 | 8.70 | 8.30 | 5.72 |
| 1995 | 15.46 | 6.61 | 8.11 | 6.00 |
| 2002 | 12.11 | 7.33 | 8.95 | 5.99 |
| 2009 | 10.95 | 6.24 | 10.98 | 5.96 |
| 2015 | 8.45 | 7.27 | 9.62 | 6.19 |
| 2021 | 9.89 | 7.81 | 9.50 | 5.98 |

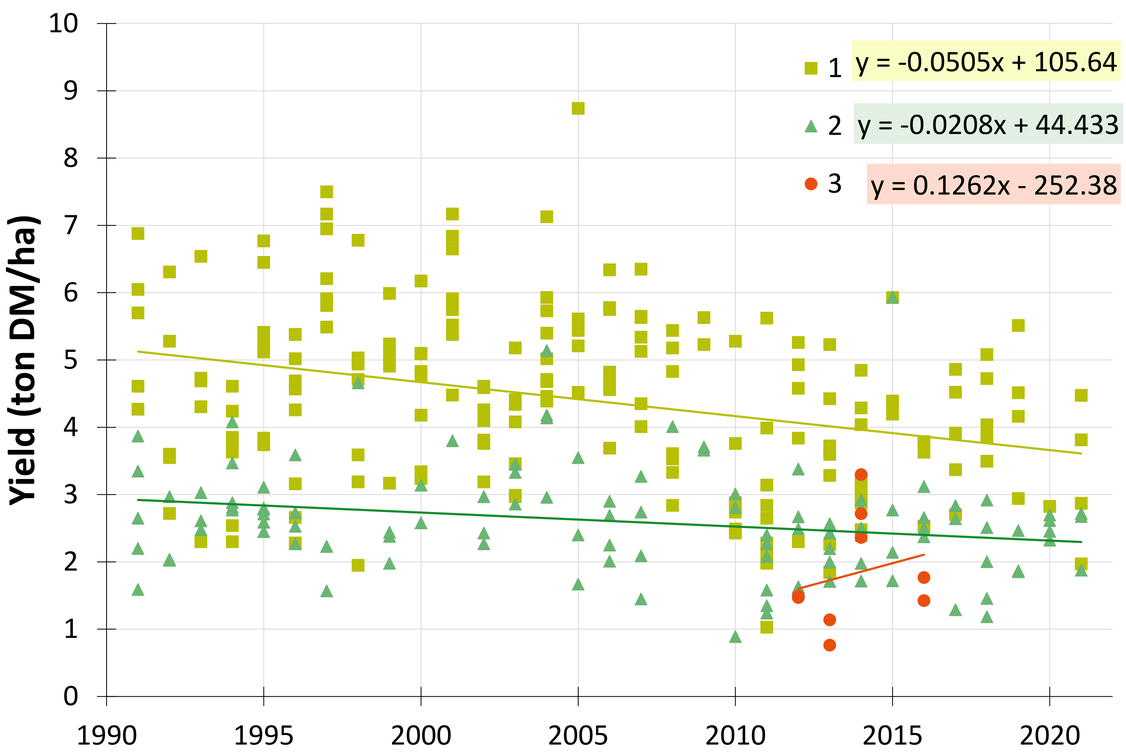



***Fig.3.*** *Yield of perenial grass-clover ley in the 1, 2 and 3 cut.*

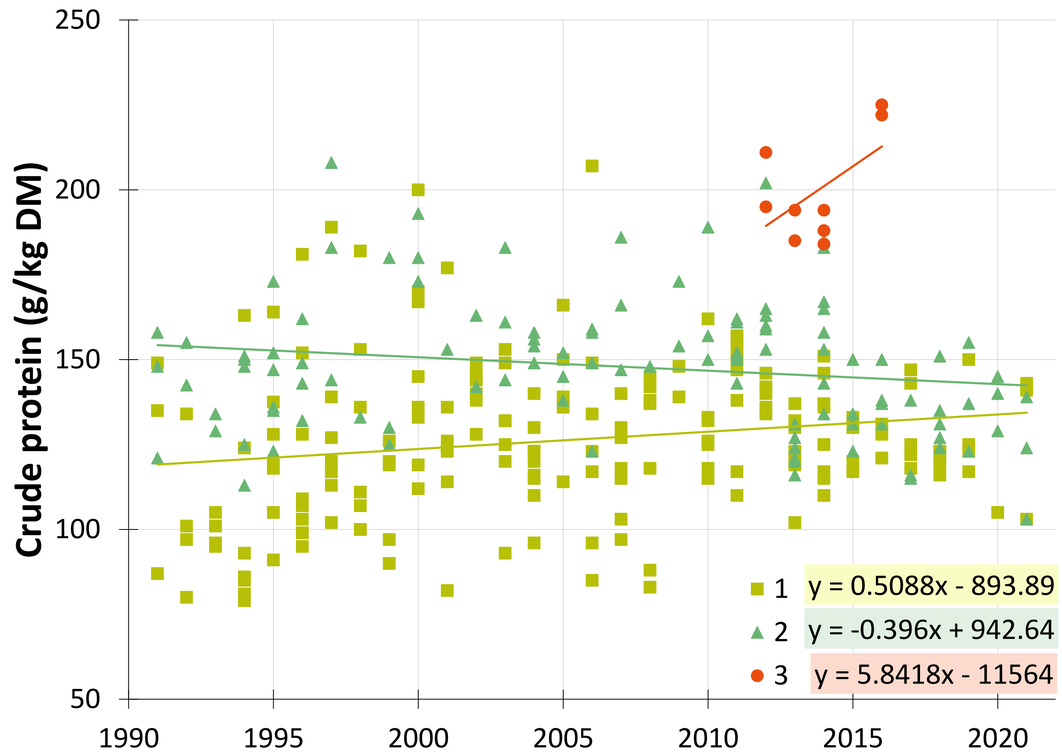



***Fig.4.*** *Crude protein concentration in the perennial grass-clover ley in the 1, 2 and 3 cut.*

## Conclusions

- Our results suggested that cultivated areas are more prone to loss C than permanent pasture, especially in the areas with initial very high SOM content.
- Cultivated areas with low initial C stock levels were the ones that showed an increase in C storage; however, we just have 6 years of data.
- In the topsoil, SOM concentration and plant-available phosphorus (P-AL) and magnesium (Mg-AL) were lower in 2021 than in 1991.
- In fields with native low content of P-AL, P-AL has slight increased, but still characterized as low. Potassium (K-AL) content has increased from 1991 to 2021.
- The yield of the first and second cuts of the ley has slightly decreased since 1991, but the quality of the ley has been stable.

## Facts about Norwegian milk production

- The average herd of cows per dairy farmer increased from 11.7 cows in 1989 to 27.8 in 2018.
- From 1980 to 2018, Norway's dairy cow population has declined from 391 000 to 217 500 .
- The average farm size in 1999 was 14.7 ha. In 2018 this average was 24.9 ha.
- From 2012 to 2018 the total area of organic farming has decreased by 16.7 percent. The demand for organic food, however, has increased within the same time frame. From 2017 to 2018, sales of organic goods through food retailers increased by 8 percent.

*Source: NIBIO*

**www.norsok.no**

**NORSØK**
Norsk senter for økologisk landbruk
Gunnars veg 6, NO-6630 Tingvoll

Tatiana F. Rittl
tatiana.rittl@norsok.no

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

**Aranzazu Louro-Lopez[1], Andrew S. Gregory[2], Jerry Dlamini[3], Murray Lark[4], Alice Milne[2], Russell Swift[5], Jonathan Chambers[5], Hatirarami Nezomba[6], Mary Harty[7], Stanislaw Switek[8], Dominika Radzikowska-Kujawska[8], Patson Nalivata[9], Elijah Phiri[10], Muneta Grace Manzeke-Kangara[2], Xiaoxian Zhang[2], Kevin Coleman[2], Clinton Fowler[2], Vengai Mbanyele[6], Hannah V. Cooper[2], Boitumelo Molise[3], Tabisa Thandathut[3], Ivy Ligowe[11], Tongai J. Mtangadura[6], Florence Mtambanengwe[6], Sarah Reilly[7], Kevin Mcdonell[7], R. Andrzej Blecharczyk[8], Zuzanna Sawinska[8], Jess Hood[2], Andrew Mead[2], Laura M. Cardenas[1]**

*[1]Rothamsted Research North Wyke, EX20 2LJ UK, [2]Rothamsted Research Harpenden, AL5 2JQ UK; [3]University of the Free State, South Africa, [4]University of Nottingham, LE12 5RD UK, [5]British Geological Survey, NG12 5GG UK, [6]University of Zimbabwe, Zimbabwe, [7]University College Dublin, Ireland, [8]Poznań University of Life Sciences, Poland, [9]Lilongwe University of Agriculture and Natural Resources, Malawi, [10]University of Zambia, Zambia and [11]Department of Agricultural Research Services, Malawi*

## BACKGROUND

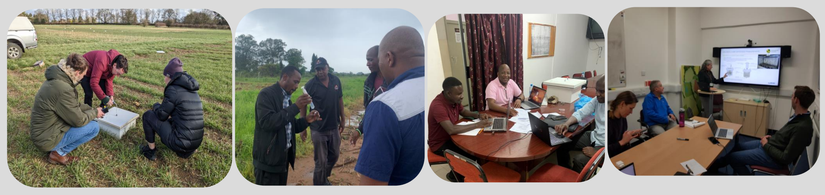
Conservation agriculture (CA) is a mitigation strategy to address climate change as it may increase the resilience of crop yields and improves soil structure and health under fast changing climatic conditions. Avoiding soil disturbance due to tillage increases soil organic matter, which will affect greenhouse gas (GHG) emissions, methane ($CH_4$), carbon dioxide ($CO_2$) and nitrous oxide ($N_2O$), compared to those systems under conventional tillage.

## PROJECT OBJECTIVES

- Assess conservational agriculture practices as approaches to mitigate GHG emissions.
- Develop country-specific emission factors for seven partners: Ireland, Malawi, Poland, South Africa, United Kingdom, Zambia and Zimbabwe.
- Develop data analysis and modelling tools for analysing the impacts of CA activities.

## METHODOLOGIES AND PROGRESS OF THE PROJECT WORKING GROUPS

### WP1
### Protocol development and training



- Site-specific protocols were developed based on a standard protocol and agreed set of hypotheses.
- Training sessions for GHG sampling with static chambers were delivered to each partner.
- Site-specific advice related to gas/soil sampling and analysis is constantly provided.
- Advice and help is provided all times when issues related to site's capabilities arise.

### WP2
### Literature review and meta-analysis

- A literature review was conducted, with more than 3000 papers identified from Web of Science.
- The review has found good evidence of reduced GHG emissions from conservation tillage practices as well as some evidence when fertilisation management and ground cover strategies are used.

Details can be found in the following poster of this conference:

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

- A meta-analysis on the effect of crop rotations on GHG emissions is currently in progress.

### WP3
### Field experiments

**Experimental sites with crop rotations working in the CropGas project**

- A locally-relevant but comparable set of treatments were identified:

Soil management: **Tillage vs Zero tillage**

Fertilisation: **N application vs No N application**

- GHG and soil samplings is ongoing in Poland, Ireland, UK and South Africa.
- Sampling in Malawi, Zambia and Zimbabwe are expected to commence soon.
- Installation of field instrumentation for soil monitoring is ongoing.

### WP4
### Data analysis and modelling

- Data required for modelling under compilation.
- Models: DAYCENT, pore-scale model

As well as the data collected in these 7 sites, the models will use:

- Available soil C data collected from other projects to include in models.
- Available GHG emissions data from field and laboratory experiments in intact soil cores being collected for modelling.
- Available X-Ray Computed Tomography data from some of the experimental sites is being collected for use in the models.

### Additional work
### DENitrification incubation system (DENIS)

- Intact soil cores from the tillage/no tillage plots in LSRE, U.C.D. Lyons and Brody Research Station sites.
- Three laboratory incubations (one per soil type) to monitor $N_2O$ and nitric oxide (NO) emissions after the application of an amendment with N and C in each type of soil.

- Mineral N and WFPS data will be monitored and measured to explain the resulting emissions.

## PROJECT HYPOTHESIS

**H1:** The relative importance of $CO_2$, $CH_4$ and $N_2O$ in the final GHG emissions from managed soils varies between treatments, with reduced $CO_2$ emissions under zero tillage relative to conventional tillage, possibly due to less mineralisation and reduced gas diffusion; reduced $CH_4$ emission and increased $N_2O$ under CA practices due to increased water retention and SOC content.

**H2:** The treatment effects outlined above result in a net reduction in soils global warming potential from GHG emissions from the CA treatments, due to the reduction in $CO_2$ from respiration and $CH_4$ emissions offsetting potential increased $N_2O$ emissions.

**H3:** Process-based models of C and N fluxes from soil, which do not explicitly account for soil pore structure, can not accurately predict the impact of zero tillage on GHG emissions, whereas models, which incorporate characterizations of structure, are able to do so.

# GREENHOUSE GAS EMISSIONS FROM THE LARGE SCALE ROTATION EXPERIMENT: METRIC OPTIONS

ARANZAZU LOURO-LOPEZ[1], MARIA LOPEZ-AIZPUN[1], MIEKE VERBEECK[1*], JOANNA CARTER[2], AMBER MANLEY[1], JONATHAN STORKEY[2], LAURA CARDENAS[1]

*[1]Rothamsted Research North Wyke, EX20 2LJ UK, [2]Rothamsted Research Harpenden, AL5 2JQ UK. *Current address: Soil Service of Belgium, 3001 Heverlee, Belgium*

## INTRODUCTION

The Large Scale Rotation Experiment was established in 2018 at the Rothamsted Research Harpenden site with the aims to test the effect of conservation agriculture: inversion 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 each rotation (Figure 1).

We aim to do an integrated study where three greenhouse gases, nitrous oxide ($N_2O$), methane ($CH_4$) and carbon dioxide ($CO_2$), are measured, using different metrics to express the emissions: cumulative emissions per surface area, 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.

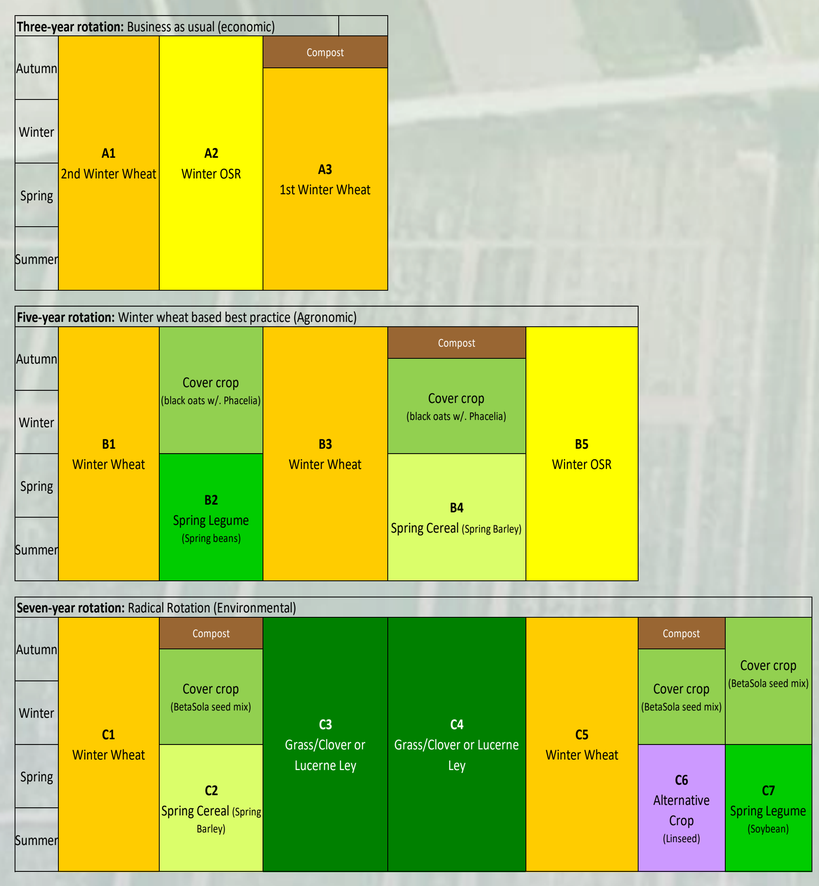



***Figure 1.*** *Large Scale Rotation Experimental, design from GHG emission data collection. Phases from top to bottom: Short-economic return; Greater diversity of crops (including cover crops); Increased environmental sustainability (cover crops and a 2-year ley)*

## MATERIAL AND METHODS

Greenhouse gas emissions were monitored with static chambers between 26th March and 28th November 2019 during the Winter Wheat cropping season in each rotation type (Figure 1). Two treatments were: **Inversion + standard nutrition** and **Zero Till + standard nutrition.**

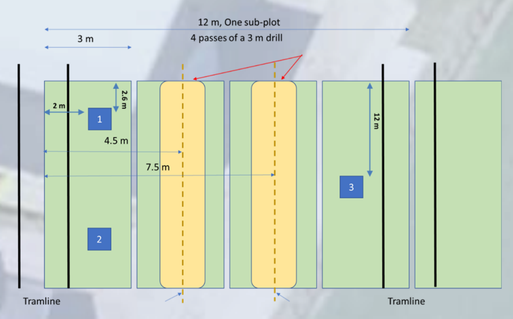



***Figure 2*** *Schematic diagram of a plot and location of chambers*

Each treatment had 6 replicate plots (dimensions: 24 x 12m each, Figure 2) and 3 chambers per plot (i.e. 18 chambers per treatment). The standard nutrition comprised the total application of 220 kg N $ha^{-1}$ (mineral fertilisation), split in 3 doses during the 2019 phase of winter wheat: 40 kg N $ha^{-1}$ on 27th March, 120 kg N $ha^{-1}$ on 12th April and 60 kg N $ha^{-1}$ on 13th May.

## RESULTS

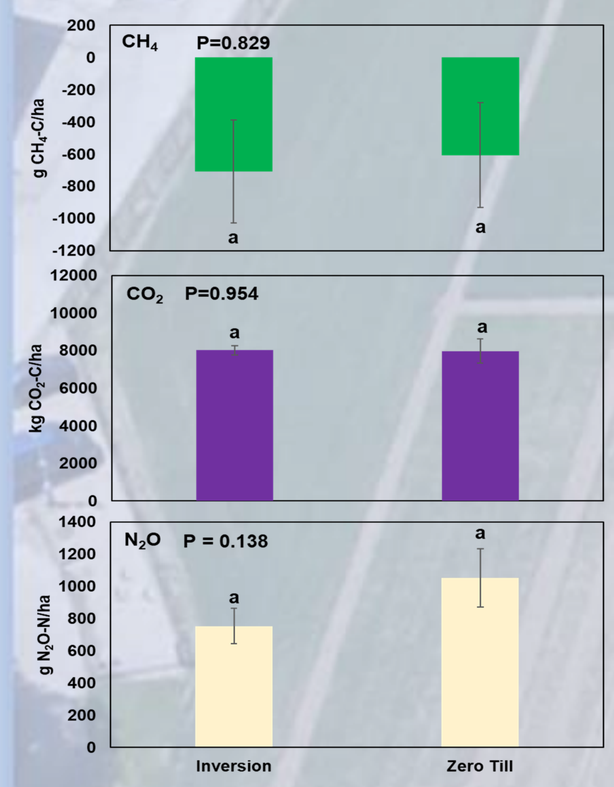



***Figure 3.*** *Cumulative GHG emissions per crop area*

When expressing GHG per crop area, the type of intervention caused no differences on the resulting $CH_4$, $CO_2$, $N_2O$ emissions during the winter wheat season (Figure 3). A large variation in the $N_2O$ emissions from the plots under no till was observed, which caused the absence of significant differences when compared with the soils under the inversion treatment.

When accounting all gases and expressing them as equivalents of $CO_2$ per crop area (using the 20-year Global Warming Potential values reported in the 5th IPCC Assessment Report, Myhre et al. 2013), the winter wheat season emitted an average of 29.6 ton $CO_2$ equivalents/ha from both types of soil interventions presented here.

When using yield-scaled emissions as metric (Figure 4), statistical differences were observed between the two types of intervention. More $N_2O$ (P=0.030) and $CO_2$ equivalent (P=0.030) were emitted from the zero till treatment to produce a ton of winter wheat in comparison with those from soil under inversion. In addition, more $N_2O$ was emitted per kg N offtake from soil under zero till in comparison from with soils under inversion but this difference was not statistically different (P=0.052).

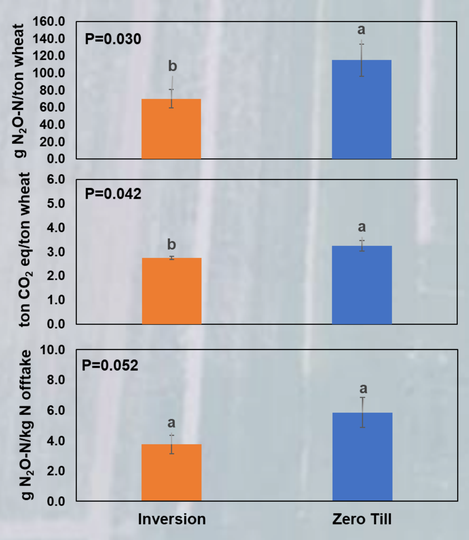



***Figure 4.*** *Yield-scaled emissions*

## CONCLUSIONS

This work shows the different results and importance of choosing the right metric when reporting GHG from agronomic system and when evaluating the environmental effect of agronomic interventions. Regarding the type of soil management, long-term GHG measurements in the LSRE are required to obtain a robust conclusion in relation to the effect of soil intervention on the resulting emissions and yield.

## ACKNOWLEDGEMENTS

We are grateful to the UK Biotechnology and Biological Sciences Research Council (BBSRC)-funded programme Soils to Nutrition (BBS/ E/C/000I0320).

## REFERENCES

Myhre et al. 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN IN PUBLICA COMMODA SEIT 1737

1 Georg-August-Universität Göttingen Physical Geographie; 2 ECOTOP Foundation
3 Forschungsinstitut für biologischen Landbau (FiBL) Schweiz

FiBL

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

*Ulf Schneidewind[1,2], Johanna Rüegg[3], Hans-Martin Krause[3] and Gerhard Gerold[1]*

**ulf.s@ecotop-consult.de; ulf.schneidewind@gmx.de*

## Background & Objectives

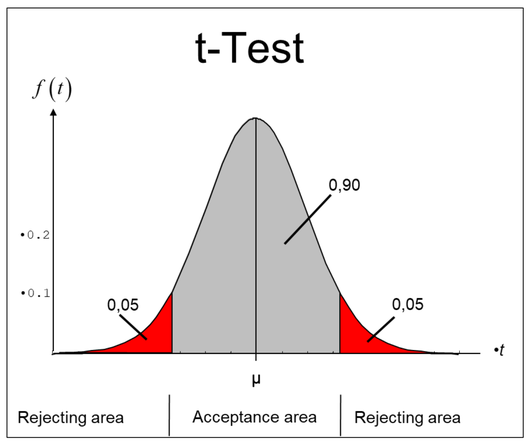
***Background***

In agricultural trials with arable crops, often only pooled samples are taken, which reflect the homogeneity of the cultivated sites. On an experimental plot with permanent crops, especially in agroforestry systems, the soil sampling design is much more challenging.

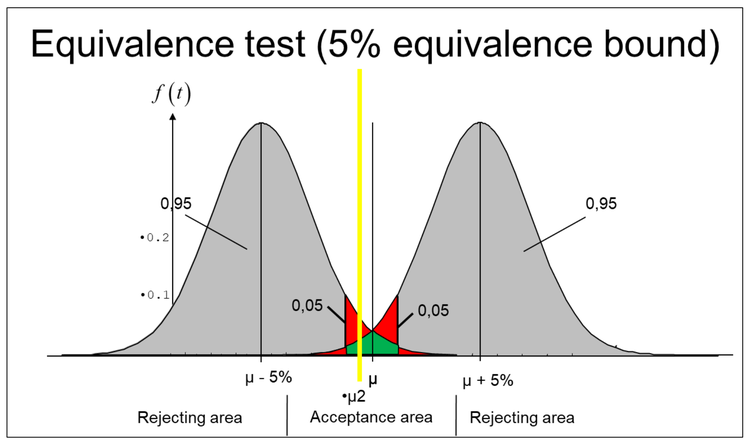
***Objectives***

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.

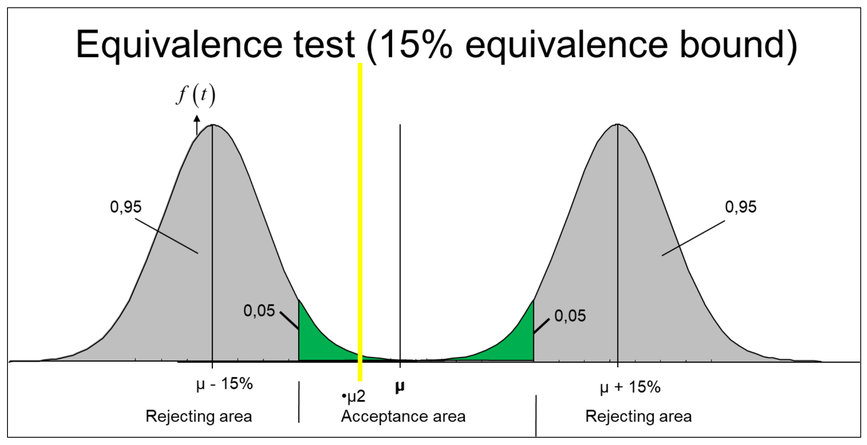
## Statistical methods and Outcomes




The equivalence test (simple t-tests) was used to determine whether the mean values of the pooled samples correspond to the mean value of the individual samples. The values of the single samples were shifted by 5, 10 and 15% (Equivalence limits) and compared with the mean value of the pooled samples.




In a second step, it was calculated how many samples would have to be taken in the field to obtain the same result in a hypothetical second sampling. Percentage by which the mean of a hypothetical second sample should deviate at most from the mean of the first sample were set to 5, 10 and 15%.




Formula for the hypothetical second sampling:

$$n = \frac{s^2}{\vartheta^2}\left(t_{\alpha,v} + t_{\beta(l),v}\right)^2$$

Zar, J. H. (1999): Biostatistical Analysis.

Outcome of the statistical analysis for the equivalence test and for a hypothetical second sampling

| Tolerance range and deviation | Depth (0 - 25cm) ± 5% | ± 10% | ± 15% | | Depth (25 - 50 cm) ± 5% | ± 10% | ± 15% |
|---|---|---|---|---|---|---|---|
| Al | 50 | 13 | 6 | | 24 | 6 | 3 |
| Ca | 3.457 | 864 | 384 | | 324 | 81 | 36 |
| Fe | 42 | 11 | 5 | | 24 | 6 | 3 |
| Mg | 53 | 13 | 6 | | 35 | 9 | 4 |
| Na | 49 | 12 | 5 | | 21 | 5 | 2 |
| P | 1.389 | 347 | 154 | | 122 | 30 | 14 |
| C (tot/org) | 587 | 147 | 65 | | 287 | 72 | 32 |
| N (tot) | 478 | 119 | 53 | | 746 | 186 | 83 |
| pH (H2O) | 48 | 12 | 5 | | 40 | 10 | 4 |
| pH (KCl) | 121 | 30 | 13 | | 97 | 24 | 11 |
| EC | 1.764 | 441 | 196 | | 2.348 | 587 | 261 |
| P-Olsen | 1.231 | 308 | 137 | | 856 | 214 | 95 |
| CEC | 218 | 55 | 24 | | 38 | 9 | 4 |

Red = No equivalence of pooled and single samples
Green = equivalence of pooled and single samples
Numbers indicate the number of samples required for a second pooled sampling, with 5, 10 and 15% tolerated deviation.

## Findings and Conclusions

***Findings***

1. The equivalence tests showed that the pooled samples are only **representative with limitations**.
2. Limitations are especially the case for **plant-available and easily mobilisable** soil parameters like: Organic carbon, total nitrogen and plant-available phosphorus.
3. The calculations of the sample size demonstrate the small-scale variability and the large number of samples for a hypothetical secondary sampling.

***Conclusions***

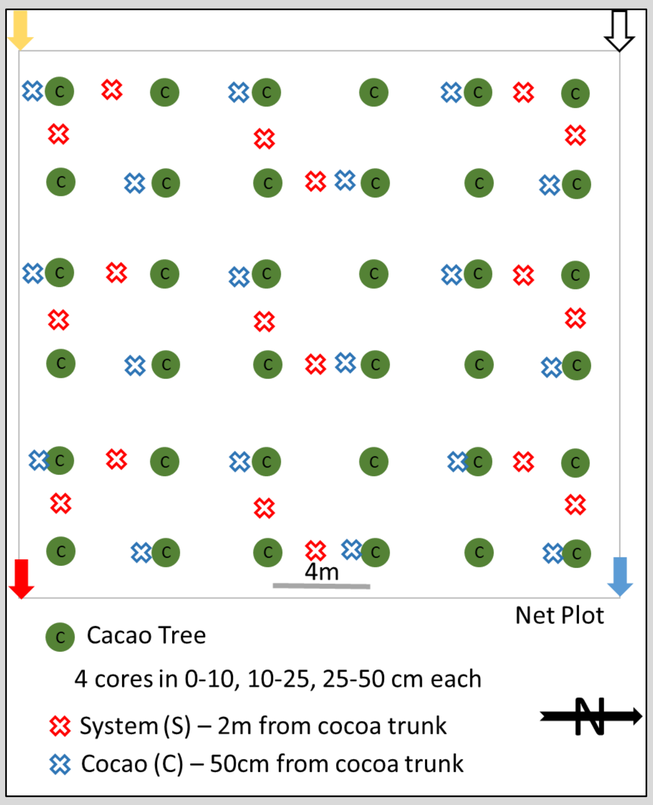
An increase of the **sample size** in agroforestry systems.

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.*

## Implementation




***Implementation***

Based on these results, the sampling design for further studies was modified to take into account different conditions like fertilizing and pruning residues. 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).

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

N. Morris, J. Martlew, D. Clarke & E. A. Stockdale *Farming Systems Research, NIAB, Morley, Wymondham, Norfolk. NR18* 9DF, UK

## The Sustainability Trial in Arable Rotations Experiment

The STAR project (Sustainability Trial in Arable Rotations) is a long-term field experiment at Stanaway Farm, Otley, Suffolk, UK. The aim of this long running experiment is to examine different cultivation and rotational systems for sustainable arable production.

The experiment is a factorial design, replicated over three blocks with plots of 36 x 36 m. Treatments are applied using commercial scale equipment on a Beccles/Hanslope Series clay soil series. The full experiment comprised four rotation and four cultivation treatments (n = 48 plots). Two rotation and three cultivation treatment combinations (n = 6 plots) were selected from the full experiment with a total of 18 plots.

Here we 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. Data was collected at intervals throughout the 2018/2019 growing season. Field monitoring was carried out at approximately bi-monthly intervals (Nov 2018 – Aug 2019). Rotation treatments consisted of:

- Continuous winter wheat (CWW), where winter wheat (*Triticum aestivum*) was grown every season, and an;
- Alternate season mustard brassica cover crop (ALTCC), where a cover crop was alternated annually with winter wheat (*Triticum aestivum*).

Annual cultivation treatments comprised of:
- Plough (PLOUGH), inversion cultivation, 250 mm depth;
- Deep cultivation (DEEP), non-inversion cultivation using a combination of tines and discs, 250 mm depth;
- Shallow cultivation (SHALLOW), non-inversion cultivation using a combination of tines and discs, 100 mm depth.

## Soil penetration and volumetric soil moisture

Penetration resistance (PR) was collected using a manually operated digital penetrometer (Eijelkamp, Digital Penetrologger V.6.13). Ten randomised penetrations were collected for each plot to 600 mm depth using a 1.2 $cm^2$ 30° cone. Volumetric soil moisture (VSM) was measured using a capacitance probe (Delta-T Devices, Profile Probe PR1).

Soil physical properties (Fig. 1.) showed that ALTCC rotation, largely irrespective of cultivation treatment combination, had a lower PR in the subsoil (approx. 350 – 650 mm depth) compared to CWW. Treatment PLOUGH resulted in the formation of a compacted layer with high PR (250 – 450 mm) immediately below the PLOUGH treatment implement working depth (250 mm). This compacted 'pan layer' was evident where the PLOUGH treatment was combined with CWW rotation but not where combined with ALTCC rotation.

Field monitoring data showed that ALTCC treatment had higher subsoil VSM, which persisted later into the growing season and deeper in the soil profile compared to CWW.

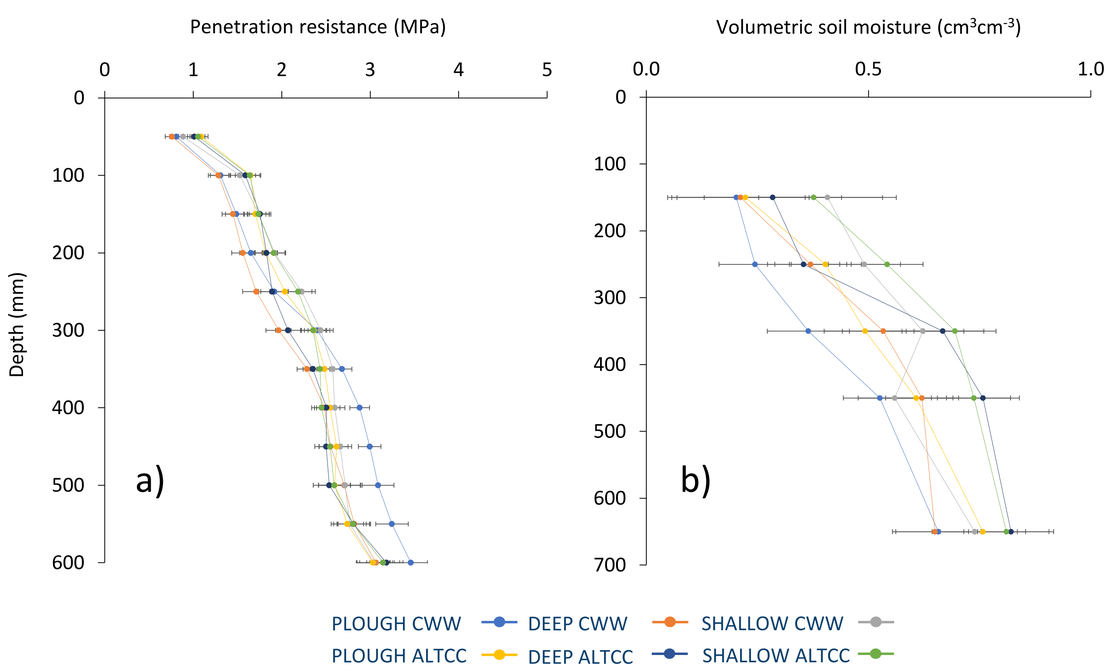



Figure 1. Soil physical properties rotation and cultivation treatment interaction over depth a) penetration resistance (MPa), b) volumetric soil moisture ($cm^3$ $cm^{-3}$).

## X-ray computed tomography

Undisturbed soil cores (800 x 84 mm, h x d) were collected from each plot for laboratory analysis. Samples from the 200 - 400 mm layer were selected for X-ray computed tomography (CT) carried out at the University of Nottingham Hounsfield Facility, UK. Pore size distribution was summarised in Fiji open-source image analysis software using the BoneJ plugin 'particle analyser tool'. Pore size distribution were split into classes of 28 – 1000 µm (meso - macropores), 1000 – 2000 µm (macropores), 2000 – 5000 µm (macropores) and >5000 µm (large macropores/soil cracks).

Figure 2 shows X-ray CT scanning equipment used to determine physical structure. SHALLOW ALTCC had significantly higher pore volume (%) compared to SHALLOW CWW. Reducing the intensity of cultivation (SHALLOW treatment) resulted in an improvement in soil pore volume, surface area and frequency. An additional benefit could be gained from combining SHALLOW treatment with ALTCC rotation in terms of soil pore characteristics and the frequency of large pores.

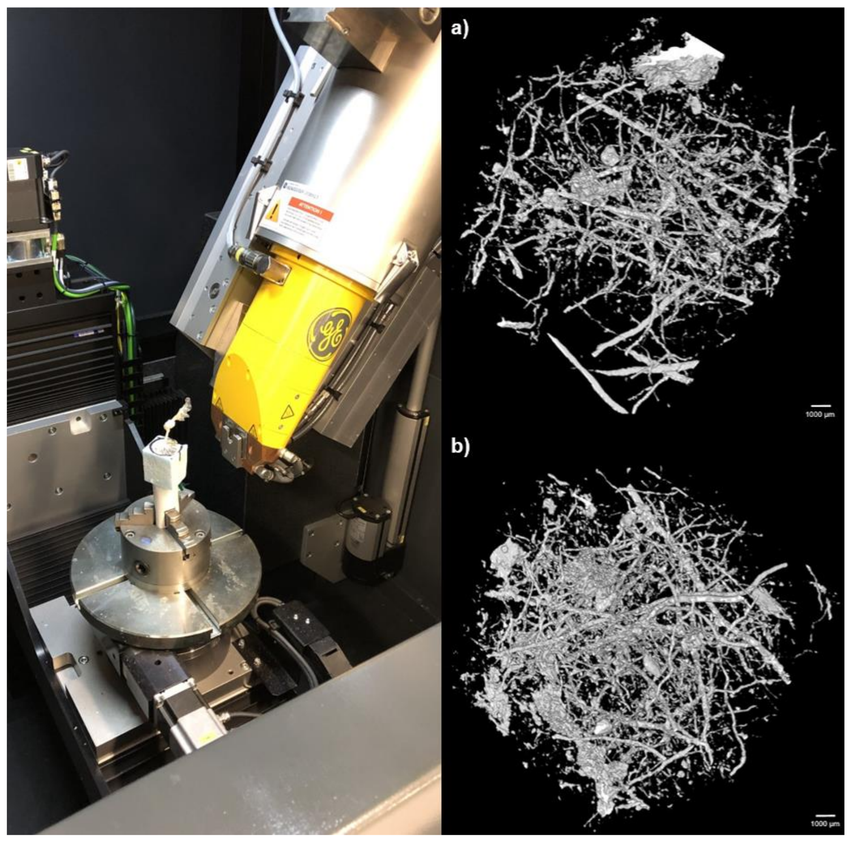



Figure 2. X-ray CT scanning to determine soil physical structure (left), example X-ray CT images of a plough pan (right) a) continuous winter wheat, b) winter wheat alternated with a brassica cover crop.

## Relative yield (% cf. plough) in winter wheat

Relative yield in winter wheat was calculated as a percentage of the plough for DEEP and SHALLOW cultivations and averaged over the seasons 2006 and 2019. Results in Table 1 show little difference in winter wheat yield between cultivation or rotation approach.

Table 1. Relative yield (% cf. plough) in winter wheat between 2006 and 2019

| | PLOUGH | DEEP | SHALLOW |
|---|---|---|---|
| Relative yield (% cf. plough) in CWW | 100 | 99 | 103 |
| Relative yield (% cf. plough) in ALTCC | 100 | 102 | 99 |

## Conclusion

Repeated cover cropping (ALTCC) demonstrated positive rotational benefits to soil physical structure that indicated improved physical properties compared to CWW rotation. However, reducing the intensity of cultivation (SHALLOW) resulted in a stronger impact on soil physical structure.

Findings showed that long-term use of seasonal cover cropping (ALTCC) combined with non-inversion cultivation (SHALLOW) resulted in lower penetration resistance and increased soil moisture, and provided the most significant benefits to soil water retention, root morphology and pore characteristics as measured by X-ray CT.

Reducing the intensity of cultivation through using non-inversion cultivation (SHALLOW) or (DEEP) had a generally positive impact on physical properties and strongly influenced any benefit garnered from ALTCC rotation with no significant loss to yield.

The Sustainability Trial in Arable Rotations trial 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..

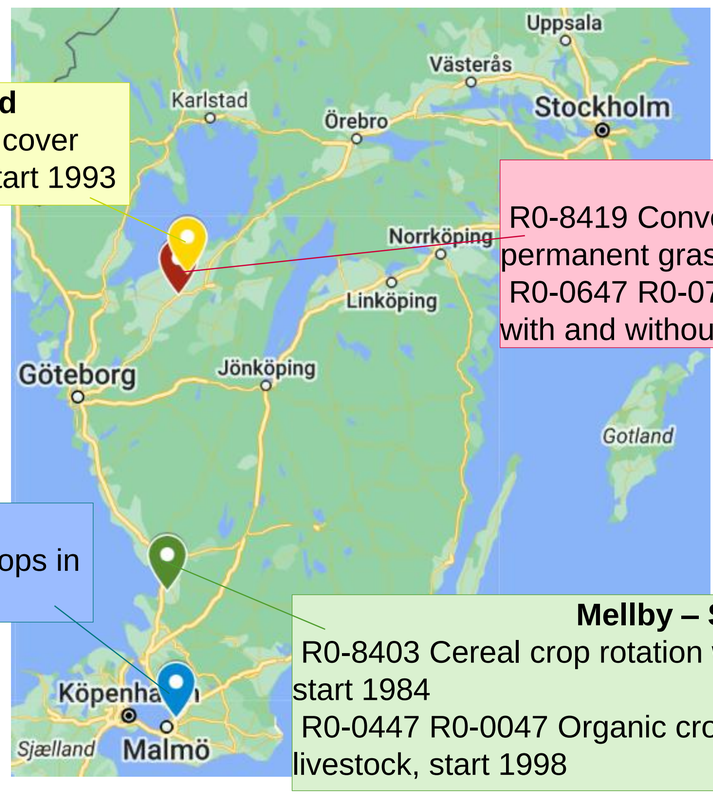
www.slu.se

# Long-term field experiments in Water quality management

## Separately tile-drained plots for nutrient leaching measurements

### LONG-TERM MEASUREMENTS OF WATER QUALITY

**The long-term field experiments in water quality evaluate 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. 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.**




**Fotegården – Loamy sand**
R0-8410 Cereal crop rotation with cover crops, autumn and spring tillage, start 1993

**Lanna - Clay**
R0-8419 Conventional tillage, no-till and permanent grass, start 1993
R0-0647 R0-0747 Organic cropping systems with and without livestock, start 1998

**Lönnstorp – Clay loam**
R0-0701 Strategies for cover crops in southern Sweden, start 1993

**Mellby – Sandy loam**
R0-8403 Cereal crop rotation with pig slurry and cover crops, start 1984
R0-0447 R0-0047 Organic cropping systems with and without livestock, start 1998

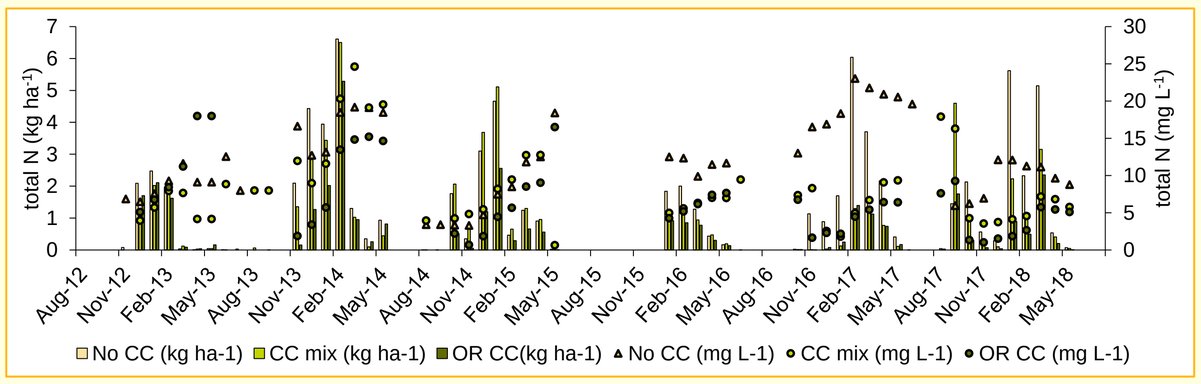
**Separately tile-drained plots**
The experiments are constructed with separately tile-drained plots (840 to 4000 m$^2$) for leaching measurements and sampling:

- Drainage
- Water samples, N, P and K
- Soil mineral N, 0-90 cm depth
- Yield of main crop and N, P, K content
- Cover crop biomass and N, C content
- Basic soil mapping

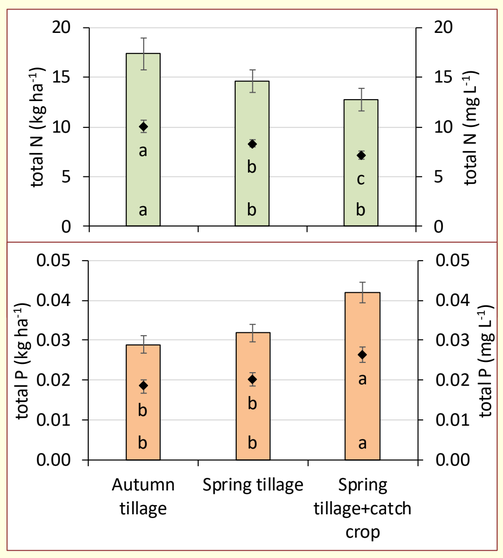
Data is stored in databases, soil and grains are archived.

### NUTRIENT LEACHING

Nutrient leaching are presented as yearly or monthly load and concentration in the drainage water.




**Monthly leaching losses of N from R0-0701.** During six years, cover crops sown after harvest of main crop were studied for their ability to reduce N losses from a clay loam. Oilseed radish (OR CC) was most effective but the cover crop mixture (CC mix, hairy vetch/rye, oilseed radish/buckwheat) also had the potential of reducing N losses, compared to the control plots without cover crops (No CC).
*Source: Norberg L. & Aronsson H. 2020. Effects of cover crops sown in autumn on N and P leaching. Soil Use and Management, 36:200–211.*




**Average yearly leaching losses of N and P during 14 years from R0-8410.**
Preliminary data show that spring tillage in combination with a perennial ryegrass cover crop reduces the losses of N but increases the losses of P from a sandy loam.
*Source: Norberg L. & Aronsson H. 2023. in prep.*

**Inside a measuring station.**
Tipping buckets for continous flow measurement and peristaltic pumps taking flow-proportional water subsamples collected in the plastic containers. The analysis program include total N, $NO_3$-N, total P, $PO_4$-P and K, with some variation between experiments and years.

**Lisbet Norberg**
Researcher
lisbet.norberg@slu.se

**Helena Aronsson**
Senior lecturer
helena.aronsson@slu.se

**Maria Blomberg**
Research engineer
maria.blomberg@slu.se


SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE

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

*Munisath Khandoker 1, 2, Stephan Haefele 1 & Andrew Gregory 1*
*1 Rothamsted Research, AL5 2JQ, UK; 2 Lancaster University, LA1 4YW, UK*

## INTRODUCTION

*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. Enzymes used as assays of carbon (C), nitrogen (N), and phosphorus (P) are:*

***N-acetyl-β-glucosaminidase (NAG)***

- *Hydrolyses the production of chitin.*
- *Important for carbon and nitrogen cycling as chitin is converted to glycoproteins.*
- *NAG plays a key role in contributing to local nitrogen levels in microbial communities.*

***β-1,4-glucosidase (GLU)***

- *Hydrolyses cellobiose to glucose.*
- *Important for carbon cycling by cellulose degradation.*
- *Used as an indicator for the presence of higher simple sugars.*

***Acid phosphatase (PHO)***

- *Mineralises organic phosphorus (P) to inorganic P.*
- *A key limiting factor in crop growth and essential for agriculture and crop yields.*

*These enzymes were used in our study because of their associations with C sequestration and macronutrient cycling.*

## METHODS AND MATERIALS

Soil samples were taken from the Highfield long-term experiment, which is located at Rothamsted Farm in Harpenden, UK. (Figure 1). The soil type here is characterised as a silty clay loam of the Batcombe series, with an underlying geology of London clay with flint over chalk. The Highfield Ley-Arable experiment started in 1948 in a field that had been in permanent grass since 1838. In 2008, some plots under continuous grass and arable were split to establish grass, arable and bare-fallow treatments within each. We focused on the continuing long-term grass, arable, and bare fallow treatments for this research.

We used an extract-based fluorimetric microplate assay (Criquet et al. 1999) with methylumbelliferone (MUB) as a fluorescence indicator to measure the activities of GLU, NAG, and PHO using the substrates 4-MUB-β-D-Glucoside, 4-MUB-N-acetyl-β-glucosaminidase, and 4-MUB-phosphate, respectively. Fluorescence was determined on a microplate reader (Fluostar Omega, BMG Labtech, Ortenberg, Germany) excitation wavelength at 365 nm, and emission wavelength at 450 nm.

Figure 1: The Highfield Ley-Arable Experiment at Harpenden. The experiment contains treatments under long-term grass and arable (since 1949), and bare fallow (since 1959).

References:

- Acosta-Martinez, V., Perez-Guzman, L., & Johnson, J. M. (2019). Simultaneous determination of β-glucosidase, acid phosphomonoesterase, and arylsllfatase in a soil sample for a biogeochemical cycling index. Applied Soil Ecology, 142, 72– 80.
- Bowls, T. M., Acosta-Martinez, V., Calderon, F., & Jackson, L. E. (2014). Soil enzyme activities, microbial communities, and carbon nitrogen availability in organic agrosystems across an intensively managed agricultural landscape. Soil Biology and Biochemistry, 68, 252– 262.
- Criquet, S., Tagger, S., Vogt, G., Lacazio, G., & Le Petit, J. (1999). . Soil Biology and Biochemistry, 31(9), 1239-1244.

## RESULTS

*NAG was associated with increased C availability and was positively correlated with total N, total C, and inorganic P in the soil. We also see clear treatment differences, NAG had higher activity in grass treatments but was not able to further separate, statistically, the arable and fallow treatments. (Figure 2). This could be due to the application of fertilisers and water which can enhance crop yields but reduce enzyme activities (Bowls et al, 2014).*

*GLU and NAG activity had a greater correlation to chemical properties compared to PHO which had fewer correlations to total C and N in the soil. Furthermore, enzyme activities were correlated to each other, however, NAG and GLU activities were more related to soil properties and showed greater differences in land uses than PHO activities.*

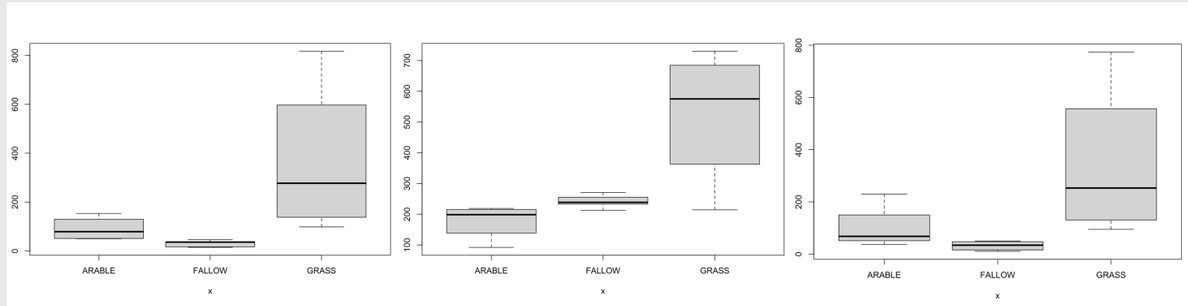



Figure 2: Boxplots showing NAG, GLU, and PHO enzymatic activities respectively.

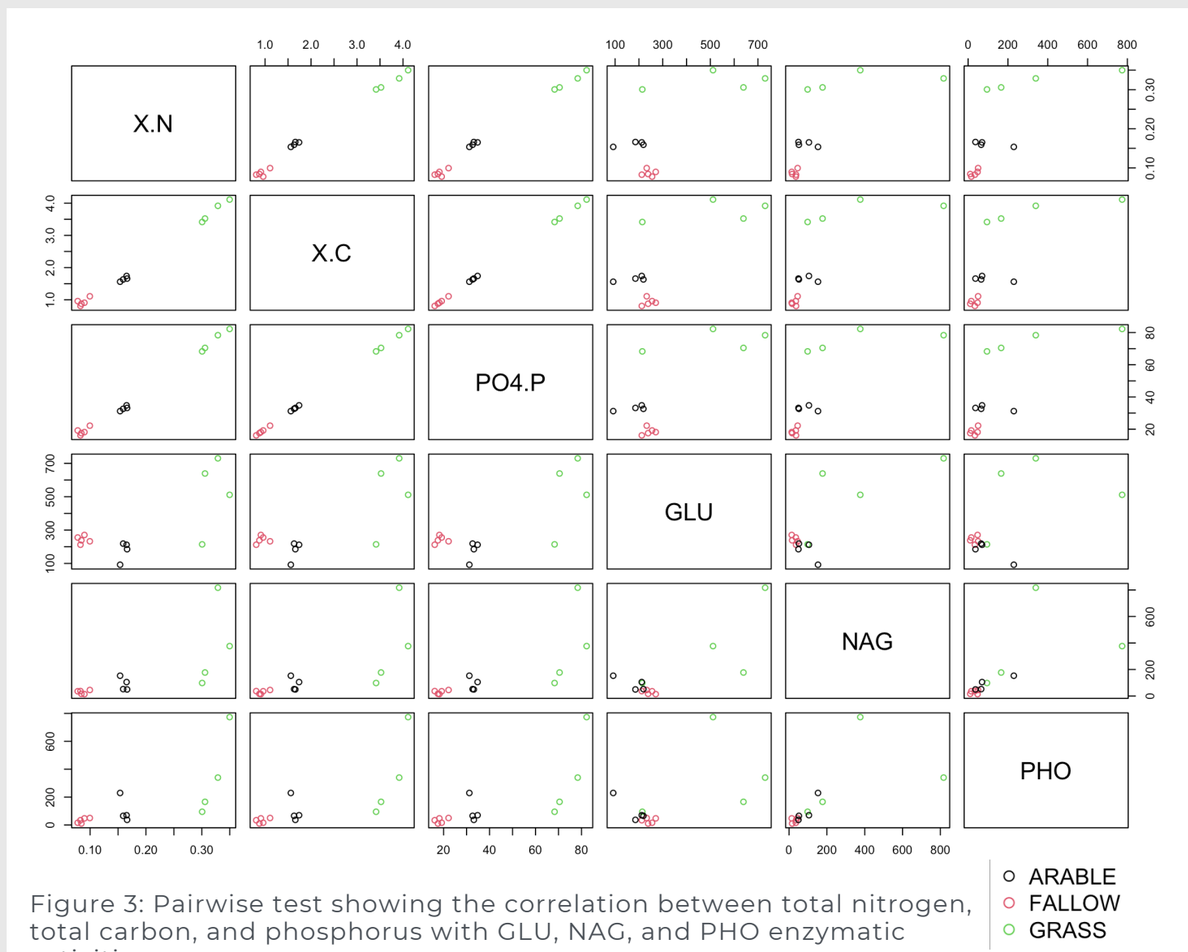



Figure 3: Pairwise test showing the correlation between total nitrogen, total carbon, and phosphorus with GLU, NAG, and PHO enzymatic activities.

## CONCLUSION

*NAG and GLU could be used as soil health indicators due to their ability to differentiate between different soil management practices and their correlation with SOM content. Studies on long-term experiments have helped us to understand the interactions of important enzymes with SOC and soil characteristics and thus the health of our soils.*

*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.*

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

**Luana Aparecida Menegaz Meneghetti, UFR - Federal University of Rondonópolis, Brazil (luana_m.meneghetti@hotmail.com)**
**Edna Maria Bonfim-Silva, UFR - Federal University of Rondonópolis, Brazil (embonfim@hotmail.com)**
**Tonny José Araújo Da Silva, UFR - Federal University of Rondonópolis, Brazil (tonnyjasilva@gmail.com)**

## INTRODUCTION

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.

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.

This research aimed to evaluate different fertilizers associated with liming in Oxisol under chrysanthemum cultivation.

## MATERIAL AND METHODS

The study was developed at the Federal University of Rondonópolis, Brazil. This region is characterized by Tropical Climate (Aw) according to Köppen & Geiger classification.

The experimental design was in randomized blocks, in a 5 x 2 factorial scheme, with 5 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.

## RESULTS

The Calcium (Ca) variable was statistically significant for fertilization and liming separately. The treatments of incubated biomass ash (3.31 $cmol_c\ dm^{-3}$), non-incubated biomass ash (3.31 $cmol_c\ dm^{-3}$), and organomineral (2.81 $cmol_c\ dm^{-3}$) were the ones that obtained the highest calcium contents (Figure 1A). As a function of liming, greater values of calcium were observed in the treatments that had liming application (Figure 1B).

The Magnesium (Mg) variable was statistically significant for the interaction between fertilization and liming factors. The interaction of fertilization with liming (100% of the recommendation) showed that the fertilizations containing biomass ash in the composition did not differ from the mineral fertilization concerning the magnesium content. The interaction of fertilizers without the application of liming showed a difference, with higher magnesium values for the treatments with incubated biomass ash (1.13 $cmol_c\ dm^{-3}$), non-incubated biomass ash (1.08 $cmol_c\ dm^{-3}$) and organomineral (0.90 $cmol_c\ dm^{-3}$) (Figure 2).

The Aluminium variable was statistically significant for the interaction of fertilization factor with no liming (Figure 3). Fertilization of incubated and non-incubated biomass ash and organomineral annulled the aluminum toxicity in the soil.

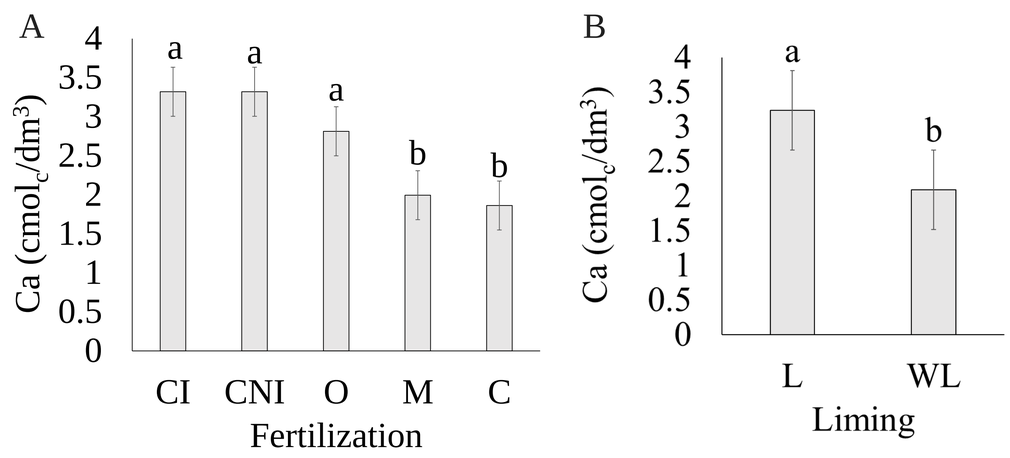



**FIGURE 1.** Calcium ($cmol_c\ dm^{-3}$) as a function of fertilization types in chrysanthemum cultivation on Oxisol (A); and calcium ($cmol_c\ dm^{-3}$) as a function of liming values (B). CI: Incubated biomass ash; CNI: Non-incubated biomass ash; O: Organomineral; M: Mineral; C: Control; L: Liming (100% of the recommendation); WL: Without liming. Vertical bars represent the confidence intervals for the mean ($p \leq 0.05$). Means followed by the same letters are not statistically different according to Tukey's test ($p \leq 0.05$).

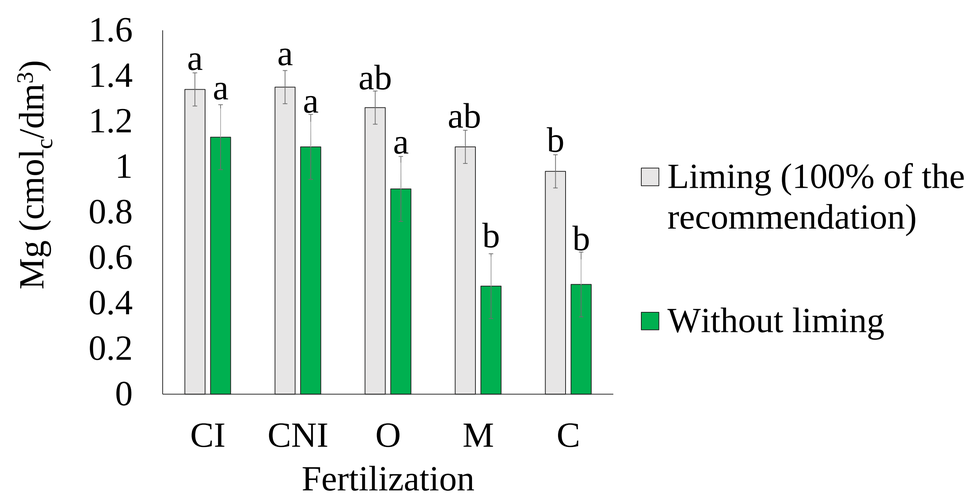



**FIGURE 2.** Magnesium ($cmol_c\ dm^{-3}$) as a function of fertilization types associated with liming values. CI: Incubated biomass ash; CNI: Non-incubated biomass ash; O: Organomineral; M: Mineral; C: Control. Vertical bars represent the confidence intervals for the mean ($p \leq 0.05$). Means followed by the same letters are not statistically different according to Tukey's test ($p \leq 0.05$).

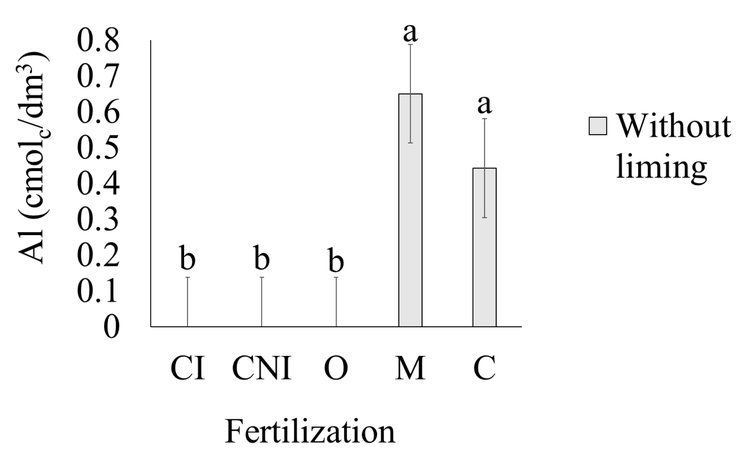



**FIGURE 3.** Aluminium ($cmol_c\ dm^{-3}$) as a function of fertilization types with the absence of liming in chrysanthemum cultivation on Oxisol. CI: Incubated biomass ash; CNI: Non-incubated biomass ash; O: Organomineral; M: Mineral; C: Control. Vertical bars represent the confidence intervals for the mean ($p \leq 0.05$). Means followed by the same letters are not statistically different according to Tukey's test ($p \leq 0.05$).

## CONCLUSIONS

Fertilizers that have biomass ash in their composition, such as the organomineral fertilizer, eliminated the aluminium 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.

# COMBINATION OF ORGANIC AND MINERAL FERTILIZATION ON SOIL ACIDITY PARAMETERS AFTER *Panicum maximum*

**Niclene Ponce Rodrigues de Oliveira[*1], Edna Maria Bonfim-Silva[**1], Luana Aparecida Menegaz Meneghetti[2], Rosana Andréia da Silva Rocha[2], Alisson Silva Costa Custódio[2] and Tonny José Araújo da Silva[1]**

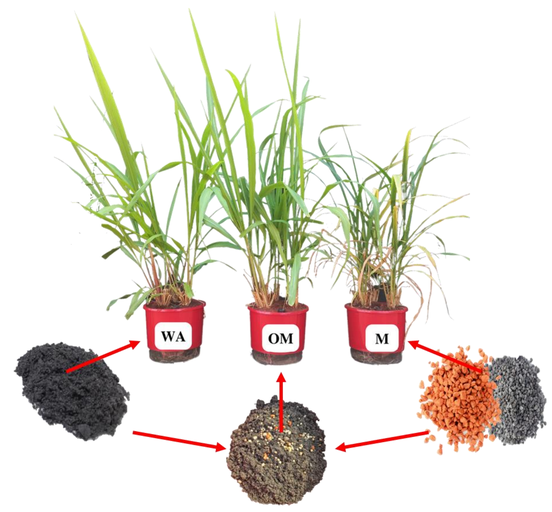
**[1]UFR - Federal University of Rondonópolis, Brazil**
**[2]UFMT – Federal University of Mato Grosso, Brazil**
***niclene_ponce@hotmail.com**
****embonfim@hotmail.com**

## INTRODUCTION

The need to seek alternative sources of fertilizers and soil amendments due to rising fertilizer costs. The use of organomineral fertilizer stands out, which is a combination of organic and mineral inputs, capable of providing a wider variety of nutrients compared to industrial mineral fertilizers. The objective was to evaluate the effect of the combination of wood ash and mineral fertilizer associated with base saturation levels on soil acidity parameters after *Panicum maximum* cultivation.

## MATERIAL AND METHODS

The experiment was carried out in a greenhouse at the Federal University of Rondonópolis, Mato Grosso, Brazil. A randomized block design in a factorial scheme (3 x 3) was used with three types of fertilization (wood ash, organomineral and mineral) and three base saturation levels (control, 25% and 50%), totaling 36 experimental units. The variables of interest were sum of bases, cation exchange capacity, base saturation and aluminium saturation after 90 days of cultivation of *Panicum maximum* cv. BRS Zuri.




## RESULTS

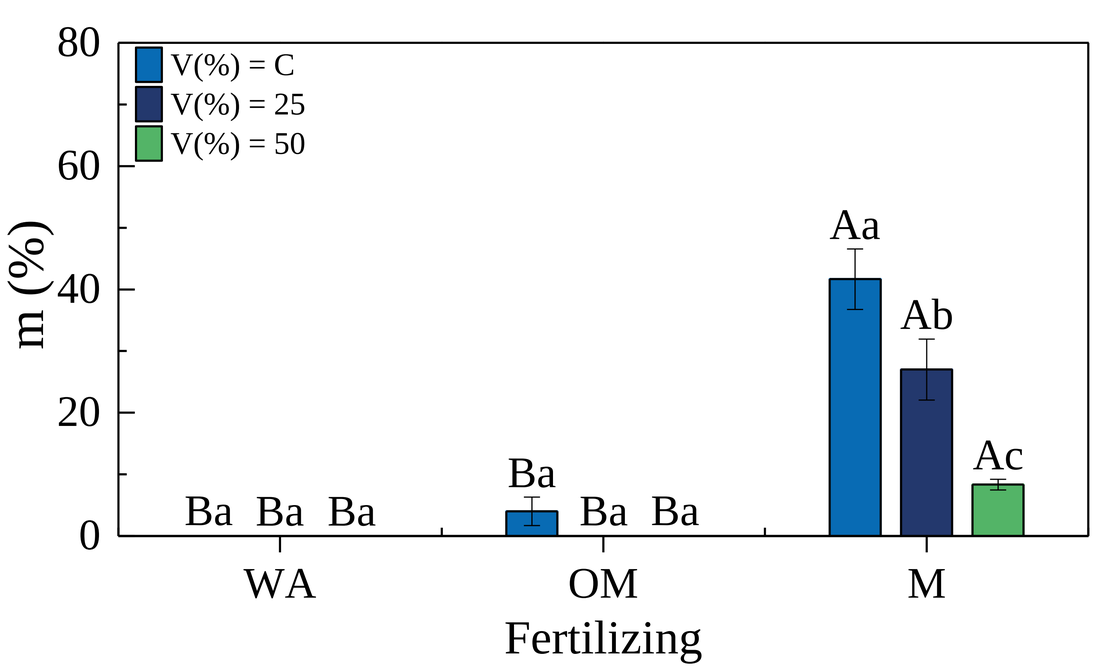



**FIGURE 1.** Aluminium saturation (m%) ($cmol_c\ dm^{-3}$) present in the soil for the interaction between the factor types of fertilization and base saturation level after 90 days of cultivation of *Panicum maximum* cv. BRS Zuri. WA: wood ash; OM: Organomineral; M: Mineral. V(%)= C: Control – natural base saturation; V(%)= 25 and 50: Soil base saturation raised to 25% and 50%, respectively. Means followed by equal letters do not differ statistically by the Scott-Knott test ($p \leq 0.05$).

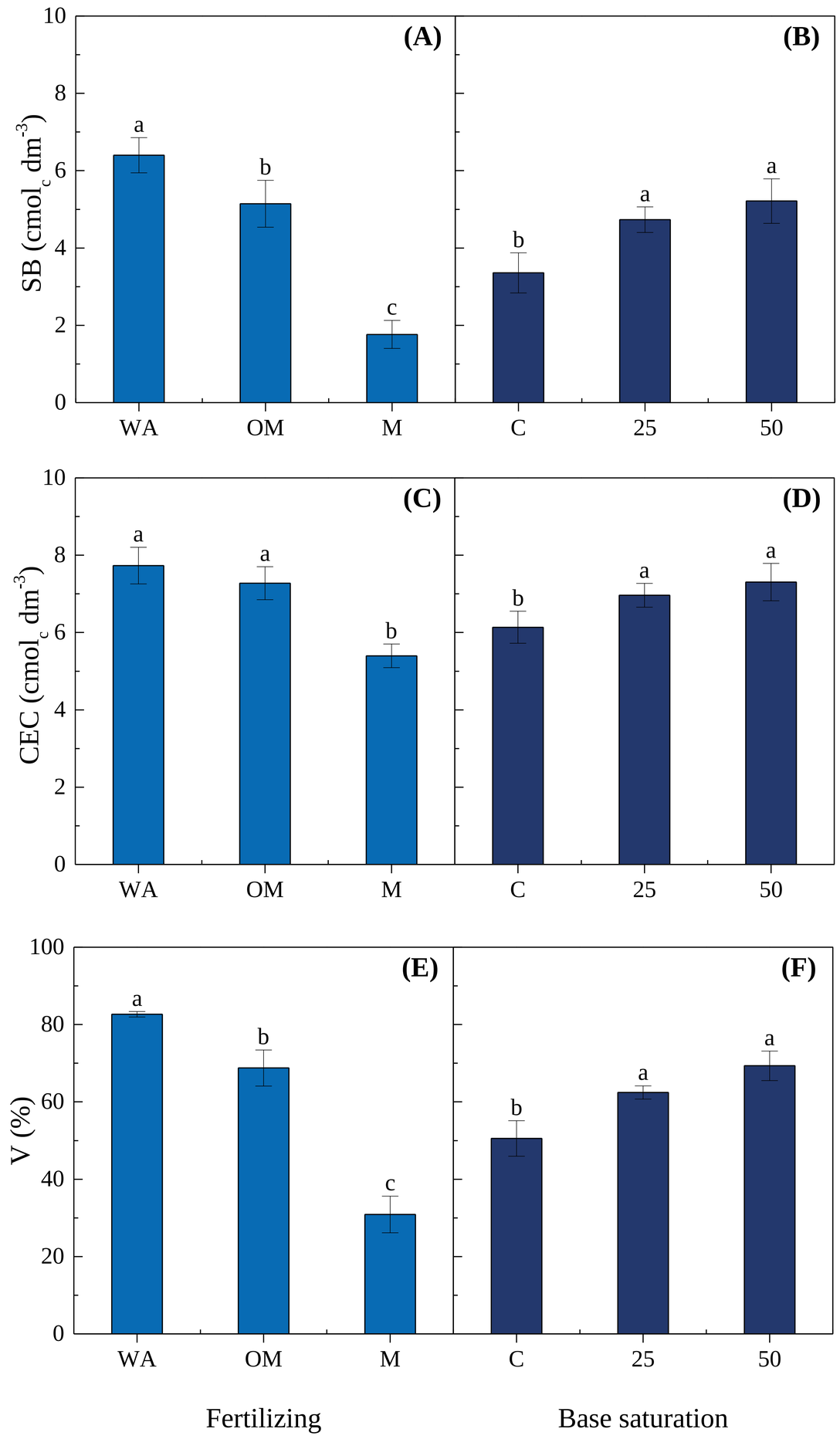



**FIGURE 2.** Sum of bases (SB) ($cmol_c\ dm^{-3}$), Cation exchange capacity (CEC) ($cmol_c\ dm^{-3}$) and Soil base saturation (V%) present in the soil for the interaction between the factor types of fertilization (A, C and E) and base saturation level (B, D and F) after 90 days of cultivation of *Panicum maximum* cv. BRS Zuri, respectively. WA: wood ash; OM: Organomineral; M: Mineral. V(%)= C: Control – natural base saturation of the soil; V(%)= 25 and 50: Soil base saturation raised to 25% and 50%, respectively. Means followed by equal letters do not differ statistically by the Scott-Knott test ($p \leq 0.05$).

## CONCLUSIONS

The combination of wood ash and mineral fertilizer is recommended as an alternative to exclusively mineral fertilizers. The organomineral fertilizer increases the sum of bases, cation exchange capacity and reduces aluminium saturation. Liming is not required for this cultivar when wood ash is used in combination with mineral fertilizer.

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

**Livija Zarina[1], Liga Zarina[2]**

*[1]Institute of Agricultural Resources and Economics, [2] Latvia University of Life Sciences and Technologies*

## Introduction

Fertilizers are important for a productive agriculture. However, these nutrient inputs come with high environmental impacts as wel (Spiertz, 2010). First of all, fertilization can directly or indirectly change the properties of the soil. In various agro-ecological conditions, the impact manifests itself in different ways. To clarify the impact of long term mineral fertiliser use on soil chemical properties, there were in 1958 long term experimental field in Priekuli Research Centre of the Institute of Agricultural Resources and Economics (57o19'N, 25o20'E) established.

## The objective of study:

to clarify the impact of long term mineral fertiliser use on the basic soil chemical properties: **soil pH**, content of **$P_2O_5$** and **$K_2O$** depending crop rotation.

## Materials and methods

**Site**: Latvia, Priekuli Plant Breeding Institute (*57°19'N, 25°20'E*)

**Soil agrochemical characteristics**

| 1958 (In the year of establishing): | 2008 (Depending fertilisation) |
|---|---|
| pH $K_{KCl}$ 5.8–6.1 | pH $_{HCl}$ 4.9–5.8 |
| SOM 2.1 | SOM 1.1–2.0 |
| $P_2O_5$ 80–00 mg kg $^{-1}$ | $P_2O_5$ 61–387 mg kg $^{-1}$ |
| $K_2O$ 100–120 mg kg $^{-1}$ | $K_2O$ 56–468 mg kg $^{-1}$ |

**The rates of fertilisers**

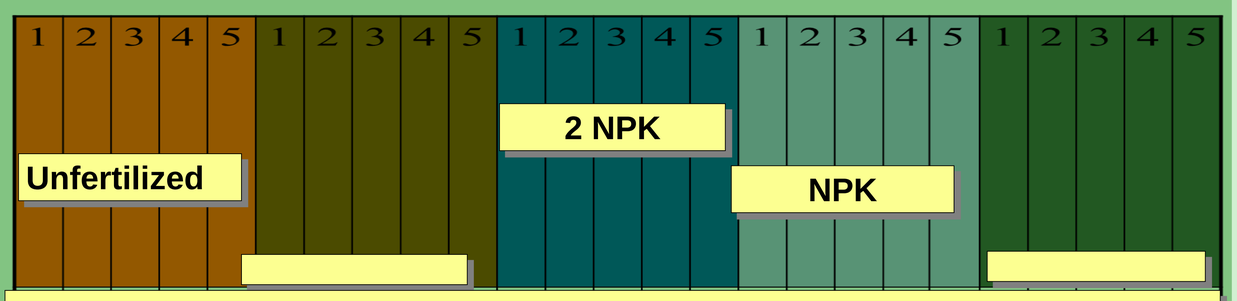
NPK
N–66, P–90, K–135 kg ha$^{-1}$

2 NPK
N–132, P–180, K–270 kg ha$^{-1}$

**Soil tillage technology** –
based on the traditional in Latvia manners – ploughing in the autumn and cultivation after spreading of mineral fertilisers.

**A measurements**
of soil pH and nutrient content was performed every year.

**Statistical analysis**
Descriptive statistics, different graphs evaluation, comperative analysis, correlation analysis
Histograms, P–P plot, Q–Q plot, for data with normal distribution: ANOVA, t-test, F-test.



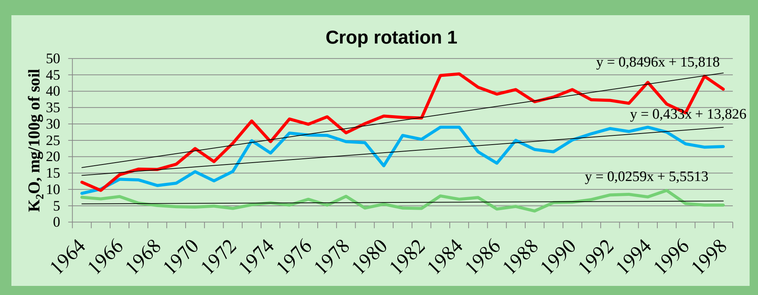

**Crop rotations:**

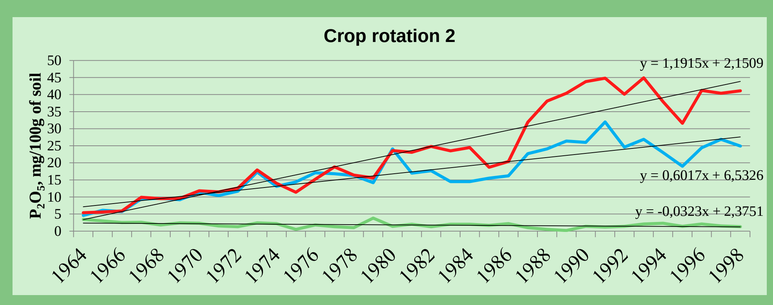
**1. Barley-potato-barley; 2. Barley-clover/grass-rye-potato; 3. Barley-clover/grass-barley-rye-barley-potato; 4. Barley-clover/grass-potato; 5. Barley-clover/grass-clover/grass-rye-barley-potato**

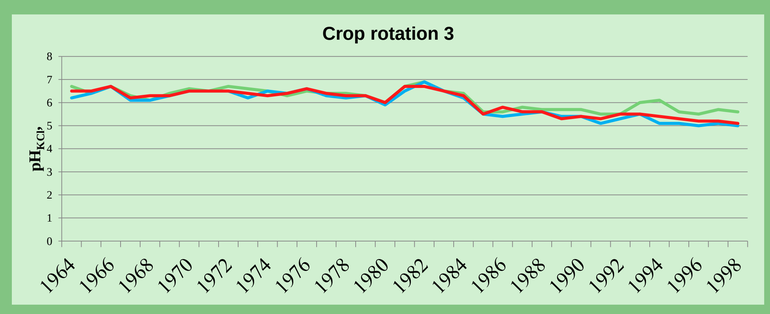
# Results

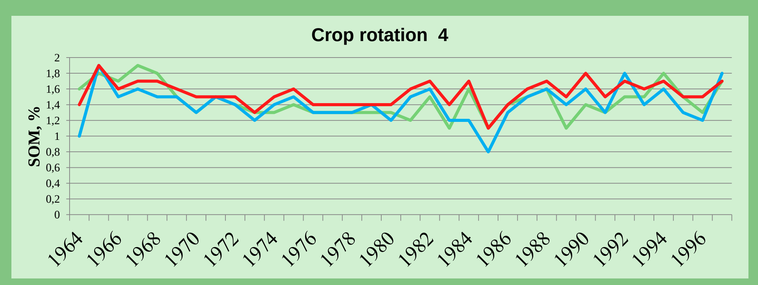
### Tendencies of trends of change of soil chatacteristics comparing impact of the use of fertiliser in different crop rotations

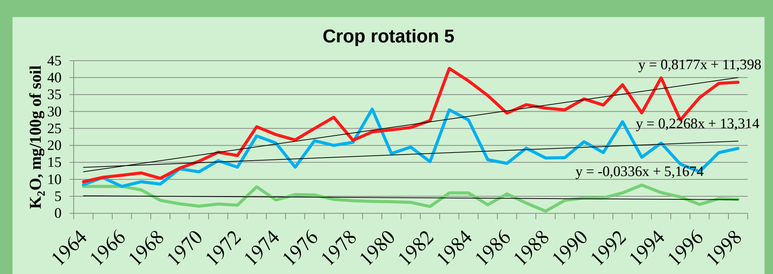
In all fertilization regimes the statistical analysis shows the dependance of **SOM** and **pH** acording year. In fertilization regime 2NPK such dependance can be detected also for soil characteristics **$P_2O_5$** and **$K_2O$**.



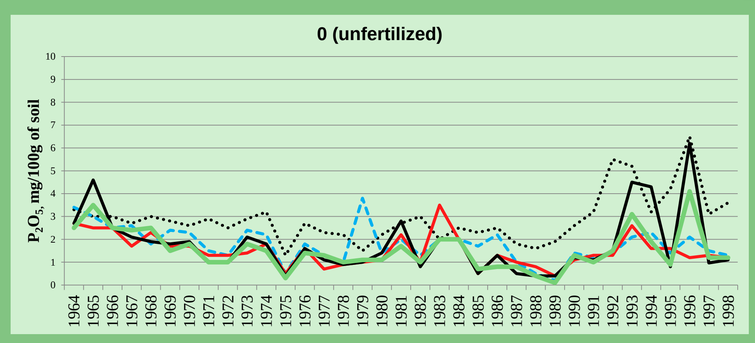



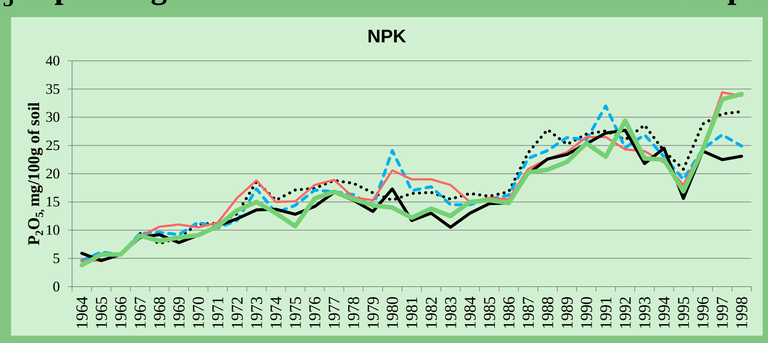



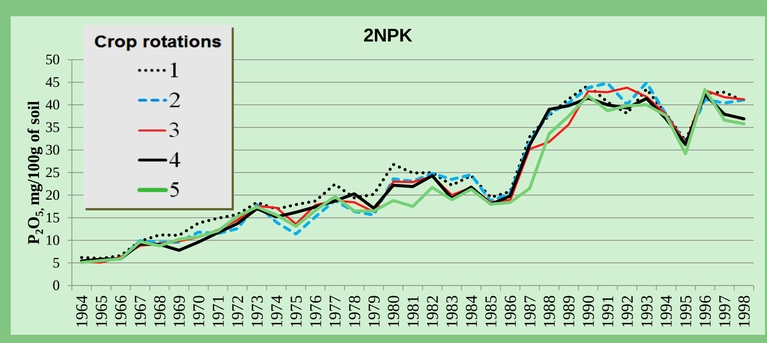



Similar tendences under fertilizer rate N–56, P– 48, K–60 kg ha$^{-1}$ on a clay loam soils were found also by other authors (Maiksteniene et al, (2008).

### $P_2O_5$ depending on different fertilization in different crop rotations




Strong and moderete correlations corelation (α=0.05) between soil charasteristics in different crop rotations using fertiliser rate 2NPK.

| 1 | $K_2O$ | $P_2O_5$ |
|---|---|---|
| $K_2O$ | 1 | |
| $P_2O_5$ | 0.717 | 1 |
| SOM | 0.073 | 0.124 |
| $pH_{KCl}$ | -0.37 | -0.8 |

| 2 | $K_2O$ | $P_2O_5$ |
|---|---|---|
| $K_2O$ | 1 | |
| $P_2O_5$ | 0.703 | 1 |
| SOM | 0.019 | 0.29 |
| $pH_{KCl}$ | -0.4 | -0.81 |

| 3 | $K_2O$ | $P_2O_5$ |
|---|---|---|
| $K_2O$ | 1 | |
| $P_2O_5$ | 0.627 | 1 |
| SOM | -0.06 | 0.259 |
| $pH_{KCl}$ | -0.27 | -0.69 |

| 4 | $K_2O$ | $P_2O_5$ |
|---|---|---|
| $K_2O$ | 1 | |
| $P_2O_5$ | 0.533 | 1 |
| SOM | -0.16 | 0.132 |
| $pH_{KCl}$ | -0.27 | -0.81 |

| 5 | $K_2O$ | $P_2O_5$ |
|---|---|---|
| $K_2O$ | 1 | |
| $P_2O_5$ | 0.406 | 1 |
| SOM | -0.04 | 0.055 |
| $pH_{KCl}$ | -0.05 | -0.77 |

## Conclusions

An increased dose of mineral fertilizers in a long period worsens the agrochemical parameters of the soil.
The inclusion in rotation of clover reduces the negative effects of mineral fertilizers.

**References**

Maiksteniene S., Kristaponyte I., Masilionyte L. (2008). Effect if long-term application of different fertilization on the fertility of gleyic cambisol. Latvian Journal of Agronomy, No.11, 244-249.

SPIERTZ, H. (2010). Food production, crops and sustainability: Restoring confidence in science and technology. Current Opinion in Environmental Sustainability, 2, 439-443.

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

Rittl, T. F.[1]; Pommeresche, R. [1]; and Løes, A.-K.[1]

[1]Norwegian Centre for Organic Agriculture (NORSØK)

## Background

Anaerobic digestion of animal manure can help farmers to produce renewable energy and reduce greenhouse gas emissions. Compared to non-digested slurry, digested slurry has a reduced content of organic matter, which may affect the soil fertility and crop productivity in the long-term. Hence, a field experiment with two slurry-application levels was established in 2011 to study how application of anaerobic digested slurry versus untreated dairy cattle slurry affects soil characteristics and crop yields. The field experiment was established in a grass-clover ley and comprised two fertilizer treatments applied at two rates of total N compared with a non-fertilised control.

***Fig.1.*** *Slurry application and harvest of the grass-clover ley.*

## Materials and Methods

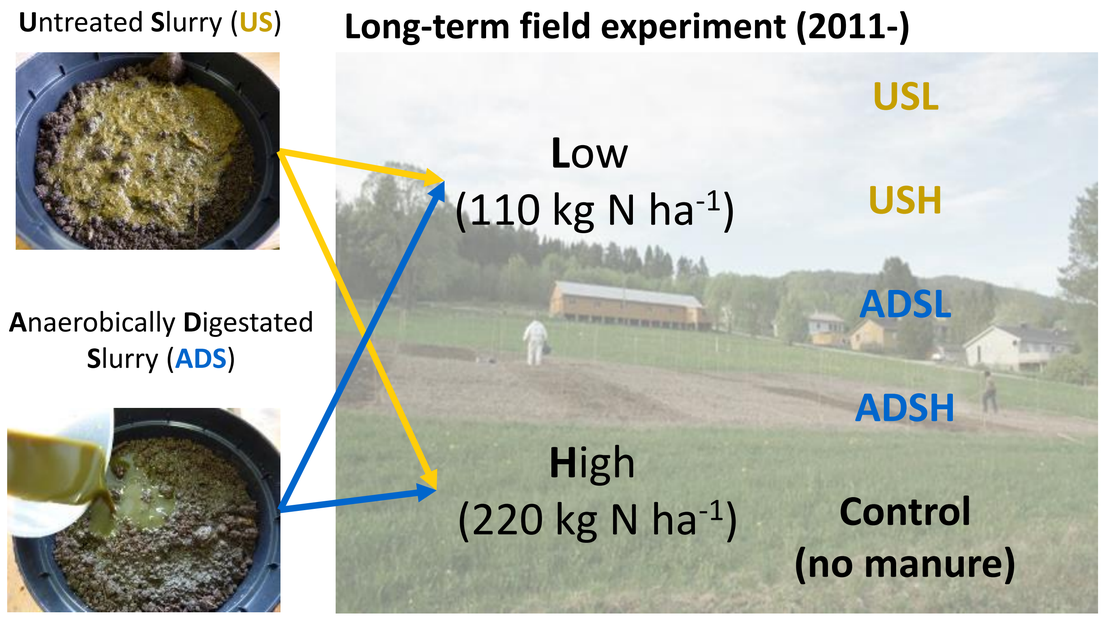



***Fig.2.*** *Treatments of the SoilEffects long-term field experiment.*

## Results

***Tab.1.*** *Average values (2011-2021) of the chemical composition of non-digested slurry (US) and anaerobically digested slurry (ADS)*

| Chemical composition | US | ADS |
|---|---|---|
| Dry matter (%) | 5.3 | 3.4 |
| Loss ignition (%) | 1.2 | 0.9 |
| Tot-N (g kg $DM^{-1}$) | 50.0 | 71.0 |
| $NH_4$-N (g kg $DM^{-1}$) | 31.7 | 42.1 |
| $NH_4$-N (% of total N) | 60.6 | 65.2 |
| pH | 7.4 | 7.7 |
| P (g kg $DM^{-1}$) | 9.4 | 10.9 |
| Ca (g kg $DM^{-1}$) | 30.6 | 35.5 |
| Mg (g kg $DM^{-1}$) | 8.5 | 10.3 |
| S (g kg $DM^{-1}$) | 5.1 | 5.5 |
| K (g kg $DM^{-1}$) | 63.6 | 81.4 |

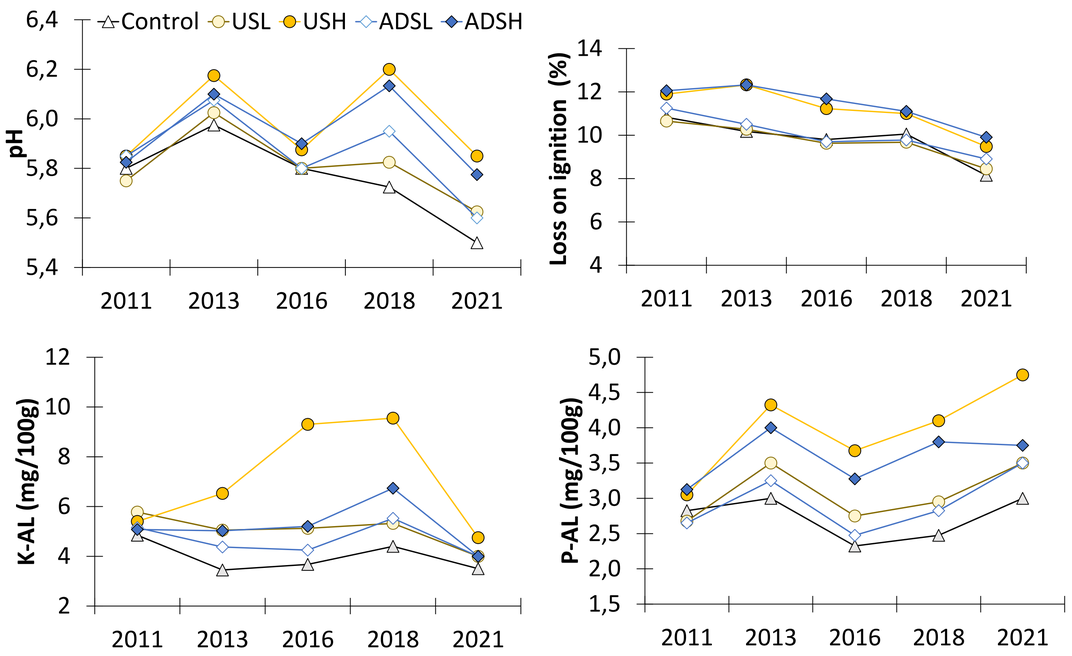



***Fig.3*** *Changes in soil pH, organic matter (LOI) and P-AL and K-AL in the SoilEffects long-term field experiment, spring samples. Non-digested slurry (US) and anaerobically digested slurry (ADS).*

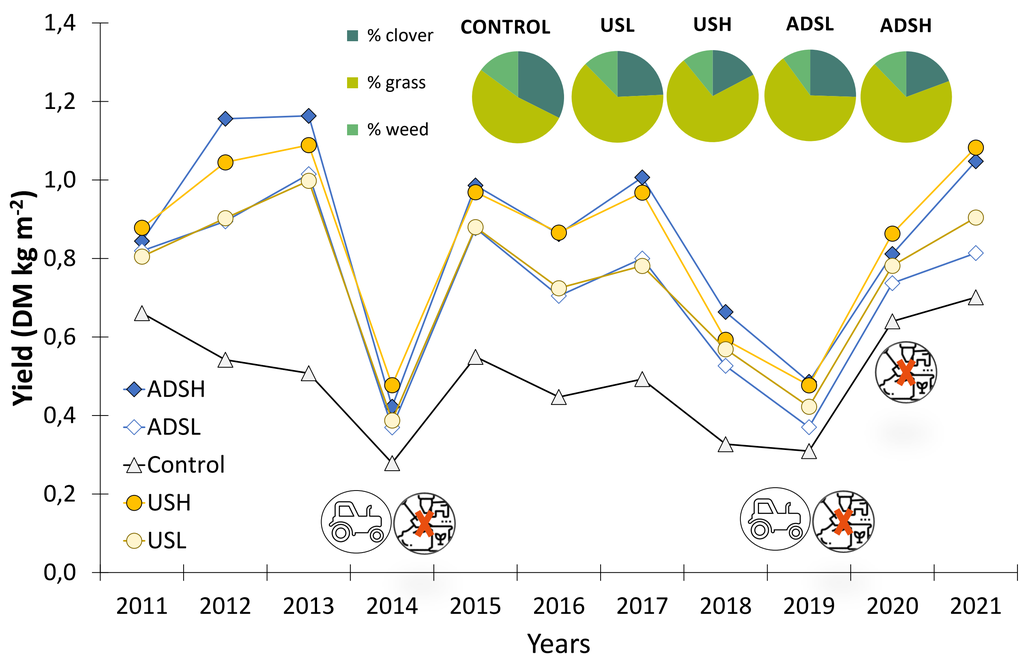



***Fig.4****. Summarized mean DM yields (sum of 1st and 2nd cuts) of grass-clover ley in a field experiment 2011-2021. Inserted graphic is the average in percentage of clover, grass and weed in each treatment over the years. = re-establishment of the ley with green fodder; no manure application. Non-digested slurry (US) and anaerobically digested slurry (ADS).*

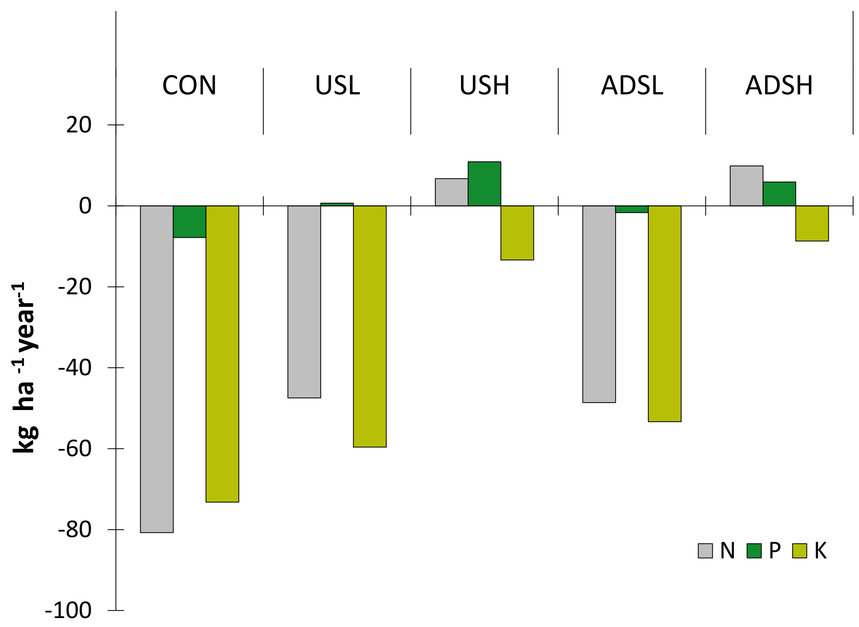



***Fig.5.*** *Nutrient (NPK) budgets (manure minus yields, kg $ha^{-1}$ $year^{-1}$) in the SoilEffects long-field experiment. Non-digested slurry (US) and anaerobically digested slurry (ADS).*

## Conclusions

This study confirmed that anaerobically digested slurry has a low content of organic matter. The long-term effect of application of ADS vs. US to soil did not affect SOM, soil fertility or crop yields. Surprisingly, we found that the application of organic fertilizers did not increase SOM, and a decline in SOM was observed in all treatments. This may be due to the high initial content of SOM and soil drainage. As expected, higher rates of manure reduced the proportion of clover. Higher manure application resulted in slight surpluses of N and P in nutrient budgets. Even in the treatments with low application rate, the total P deficit was minimal. For N and K, low rates of manure application led to significant deficit of these nutrients. Under the given conditions, we found that the benefits of extracting energy from the slurry by AD will not compromise grassland productivity or soil quality in the long run.

**www.norsok.no**

**NORSØK**
Norsk senter for økologisk landbruk
Gunnars veg 6, NO-6630 Tingvoll

Tatiana F. Rittl
tatiana.rittl@norsok.no

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

INÉS SANTÍN, FRANCISCO JAVIER SÁNCHEZ, JOSÉ LUIS TENORIO

*INIA-CSIC, Madrid, Spain*

## CASE OF STUDY:

Conservation Agriculture Long-term experiment (1994- )

Alcalá de Henares, Madrid, Spain
40°32'N, 3°20'W
600 m asl

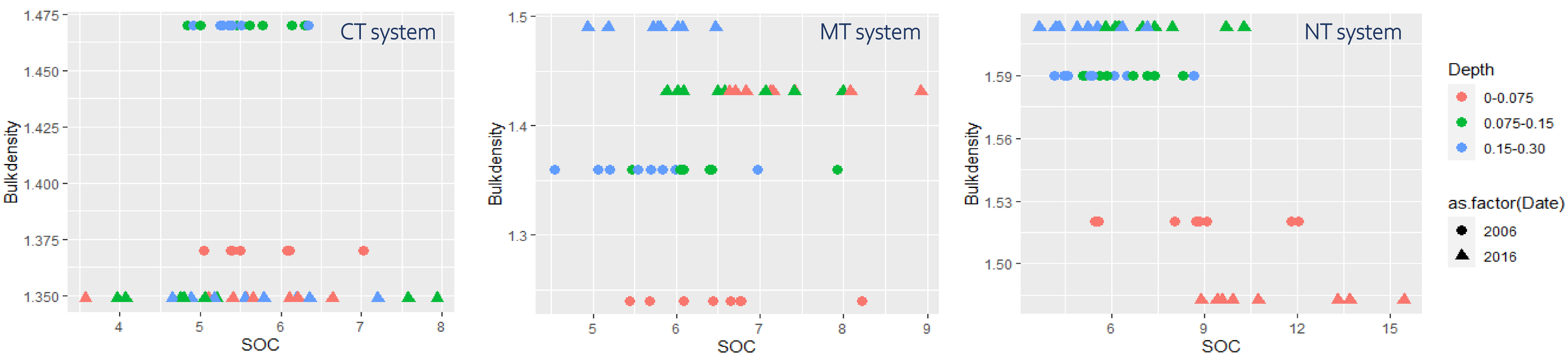
- **Soil type:** Calcic Haploxeralf (Soil Survey Staff, 2014)
- **Mediterranean semiarid conditions:**
  - Bsk type in Köppen-Geiger scale (Peel et al. 2007)
  - 353 mm year$^{-1}$
  - 4.4 °C January to 21.5 °C June (monthly average)
- **Split-plot design with 4 replicates:**
  - **3 Tillage intensities:**
    - CT (Conventional Tillage)
    - MT (Minimum Tillage)
    - NT (No-tillage)
  - **2 Cropping systems:**
    - Wheat monoculture
    - 4-year rotation (Fallow-Wheat-Vetch-Barley)
  - **Total of 60 plots** (25 x 10 m)

## MATERIAL AND METHODS:

- Years : 2006 and 2016 (November)
- Soil measurements:
  - SOC (Mg kg$^{-1}$)
  - Bulk density (Mg m$^{-3}$)
- Soil depths:
  - 0-0.075 m
  - 0.075-0.15 m
  - 0.15-0.30 m
- Data Analysis (Date x Tillage x Depth)

## RESULTS:

- Significant increase in soil bulk density after the ten-year period:
  - MT showed a significant increase in bulk density
  - NT had the highest values of bulk density at high depth
- Increase in SOC after the ten-year study:
  - in NT system
  - Highest increase in SOC observed in the topsoil layer




**LTEs facilitate monitoring soil properties over extended periods, providing robust and reliable results**

Acknowledgments

This study has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695. EJP Soil Programme SoilCompaC: www.ejpsoil.eu/soil-research/soilcompac

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

Bohdana Makaova, Volodymyr Tyshchenko
Agronomy Department, Poltava State Agrarian University, 36003, Ukraine

## Background

The genetic potential of winter wheat plants is fully realized only when optimal sowing times are used. However, climate changes make adjustments in determining the optimal sowing date. In recent years, the optimal date of sowing has shifted by 2 weeks, and today the optimal date of sowing winter wheat is 15-30th September.

## Objective

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.

The experiment design allows for the analysis of many traits, which helps to assess the level of adaptability of winter wheat accessions.

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.

During the years of the experiment, valuable data regarding the yield level and its fluctuations depending on the weather conditions were obtained.

During the field experiment, no fertilizers or plant protection agents are used, which makes it possible to assess the natural level of soil fertility, the suitability of the agro-climatic conditions of the region, and the genetic level of yield and stability of winter wheat samples.

## Monitored variables

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.

Every year, more than **100 genotypes** of different geographical origins are analyzed in a field experiment.

The experiment design allows for the analysis of many economic-valuable traits (yield related traits).

This helps to assess not only the **yield level** of winter wheat samples at different sowing dates, but also to compare the same variety at different sowing dates.

The use of this selection method allows to evaluate the winter wheat varieties according to the reaction to the length of the light day (**Ppd** - photoperiodic sensitivity genes) and the duration of the vernalization period (**Vrn** genes). It was found that high winter resistance is due to sensitivity to the photoperiod (they do not grow in the autumn period) and an extended period of vernalization (resistant to winter thaws and to the return of cold weather).

In addition, an analysis of **genetic correlations** of productivity with other quantitative features of the generative part of the plant is carrying out.

## Obtained results

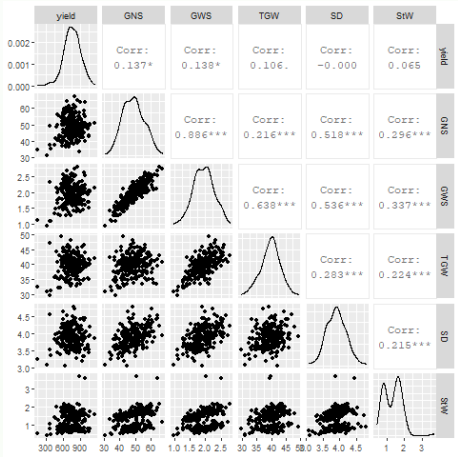



Figure 1
Multiyear results correlation at yield components and morphology parts

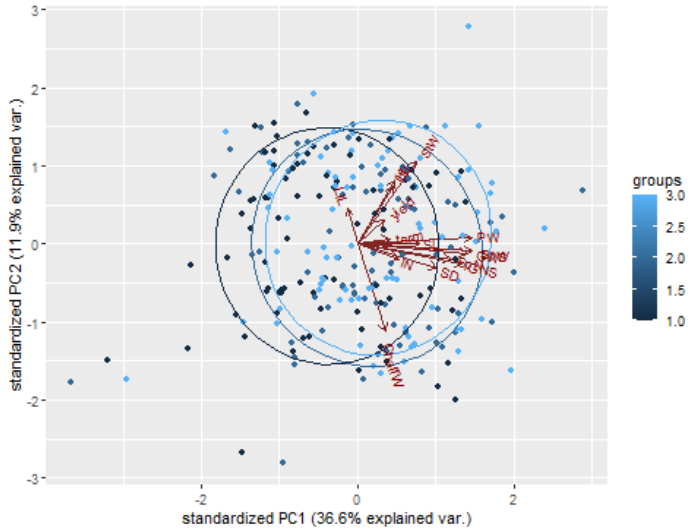
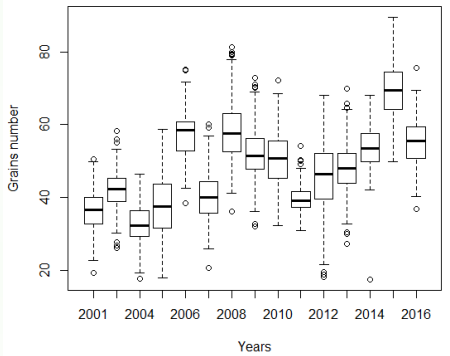
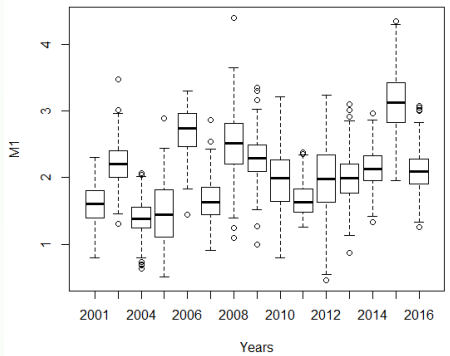



Figure 2
PCA of monitored variables devided by sowing terms

Figure 3 and Figure 4
Multiyear grain number and grain weight per plant variation



# Rothamsted Long-Term Experiments: e-RA
# Historic Data for Current and Future Challenges

S.A.M. Perryman, M.J. Glendining, N.I.D. Castells & R.J. Ostler

**The electronic Rothamsted Archive (e-RA)** is a unique internet resource, providing FAIR Open Access data from Rothamsted's Classical & long-term experiments (LTEs), meteorological records and associated metadata…

### Soil data
- Soil Organic Carbon
- Nitrogen
- Plant-available P (Olsen P )
- pH
- Total P
- Exchangeable cations
- Bulk density & weights

### Crop data
Nutrients in grain & straw -
- Broadbalk wheat & rotational crops since 1968
- Hoosfield Barley since 1852
- Long-term liming arable crops since 1962

Grain Quality -
- TGW
- Hadberg Falling Number
- Hectolitre weights

### Yield data
- Broadbalk wheat since 1843 & rotational crops since 1968
- Park Grass hay since 1856
- Hoosfield Barley since 1852
- Exhaustion Land since 1856
- Alternate Wheat & Fallow since 1856
- Woburn Ley Arable since 1938
- Wilderness biomass since 1880s
- Long-Term Liming since 1962-1996
- and others…

### Plants & Disease Survey data
- Broadbalk weeds section 8 no herbicides
- Broadbalk take-all and eyespot disease
- Park Grass botanical composition
- Broadbalk & Geescroft Wilderness vegetation

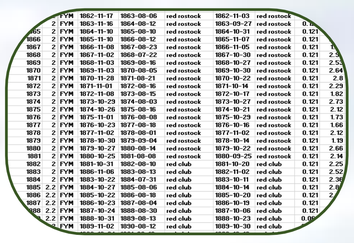
### Agronomic metadata
- Plans
- Cropping
- Fertiliser treatments
- Cultivars
- Management dates

### Meteorological data
- Rothamsted since 1853
- Woburn since 1928
- Brooms Barn since 1982

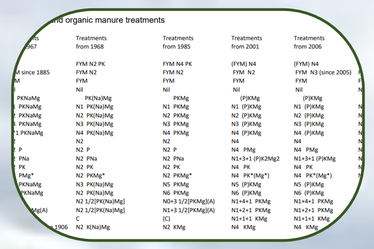
Daily data for temperature, rain, wind, sun hours, soil temperature, radiation and derived variables

**Get the data here: www.era.rothamsted.ac.uk | era@rothamsted.ac.uk | @eRACurator**

## FAIR Data



## Experiment details



## Publication database

Connecting with scientists in the UK and around the world

e-RA provides

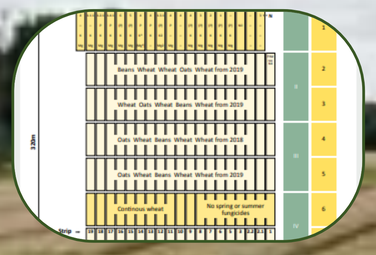
Knowledge Transfer & Outreach

Dedicated FAIR data curation

Support & guidance to data-users

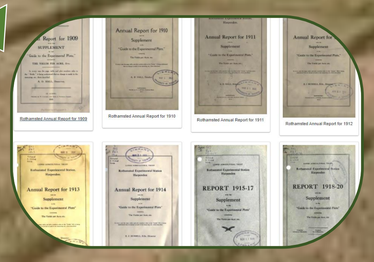
Comprehensive website

**Schools Activities**



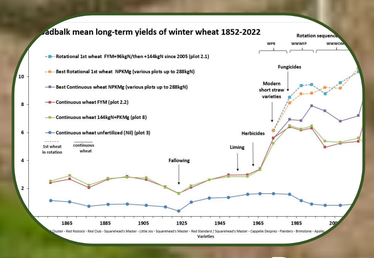
**Maps & plans**

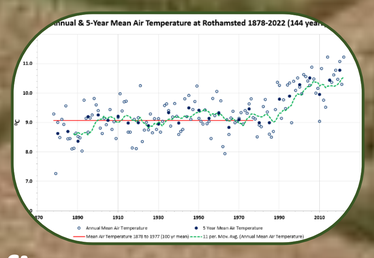
**Historical & current photos**



**e-RAdoc digital documents**

There are over 1900 publications in the e-RA Bibliography relating to the Long-Term Experiments & Met data





**Prepared figures**

Since 2017, 830 requests from scientists of 35 countries around the world have used knowledge, data & metadata from e-RA

## e-RA enables exciting opportunities for scientists worldwide to explore new ideas & future challenges…

**CLIMATE CHANGE**
Using Broadbalk yields, Park Grass yields & Rothamsted met data
Addy et. al. (2021) showed differences in cereal and permanent grassland yield changes in relation to agricultural climate in South-Eastern England from 1892 to 2016
doi.org/10.1098/rsif.2022.0361

**SUSTAINABLE AGRICULTURE**
Using Broadbalk yields and other LTE data from Europe & Africa
Maclaren et.al. (2022) conducted a metanalysis and provided Long-term evidence for ecological intensification as a pathway to sustainable agriculture
doi.org/10.1038/s41893-022-00911-x

**SOIL HEALTH**
Using SOC data from Broadbalk Wheat, The Wilderness's, Ley Arable & other world-wide data Powlson et.al. (2022) addressed whether it is possible to attain the same soil organic matter content in arable agricultural soils as under natural vegetation
doi.org/10.1177/00307270221082113

**HUMAN NUTRITION**
Using Broadbalk yields & wheat samples from the Sample Archive, Rothamsted meteorological data & other world-wide data
Ben Mariem et.al. (2020) assessed the evolution of wheat grain traits during the last 166 years
doi.org/10.1038/s41598-020-78504-x

The Rothamsted Long-term Experiments-National Bioscience Research Infrastructure is funded by the UK Biotechnology and Biological Sciences Research Council (BB/CCG2280/1).

# FARMERS AND ROTHAMSTED SCIENTISTS WORKING TOGETHER ON A NEW LONG-TERM EXPERIMENT: THE DEVON SILVOPASTURE NETWORK

C. SEGURA [1], R.M. DUNN [1], M. WRIGHT [1], C. MORTEN [1], M.S.A. BLACKWELL [1], B. GRIFFITH [1], A.E. MILNE [2], H. ANDREWS [3], S. BULLINGHAM [3], H. CURTIS [3], A. GRAY [3], S. POWELL [3], C. RICHARDS [3] and L. CARDENAS [1]

[1] Rothamsted Research North Wyke, EX20 2SB UK, [2] Rothamsted Research Harpenden, AL5 2JQ UK, [3] Farmers from The Devon Silvopasture Network, UK

## WHO WE ARE

The Devon Silvopasture Network is an innovative, farmer-led research project established in 2020. Our aim is to assess the long-term benefits of introducing trees into grassland and arable fields for soils, biodiversity, animal welfare and farm socioeconomics.

Six commercial farms and one research farm in Devon, southwest UK

Key research areas identified by farmers

Supported by FWAG South-West, The Woodland Trust, The Soil Association, Innovative Farmers, Rothamsted Research, and the Organic Research Centre

KNOW US

## METHODS

**Winter 2020-2021**: **baseline soil sampling at the seven farms** following a stratified random sampling design (FAO, 2020).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Fields for planting | 3 | 5 | 6 | 4 | 1 | 7 | 3 |
| Planting designs | 3 | 1 | 3 | 1 | 1 | 2 | 2 |
| Controls | 1 | 1 | 2 | 1 | 1 | 2 | 1 |
| Fields sampled | 4 | 3 | 5 | 2 | 2 | 4 | 3 |
| Samples per depth | 72 | 54 | 90 | 36 | 36 | 72 | 54 |

Fig 1. Planting sites and samples for soil organic carbon (SOC), total nitrogen, bulk density and texture determination. Each field was divided into three sampling units. In each sampling unit, two depths sampled (0-10, 10-30 cm).

**March 2021: tree planting**. 43 ha, 500 plants/ha: 100 standard trees, 100 shrubs and 300 thorns following three designs (Table 1; Fig. 2).

Species composition in A, B and C

| Tree Species | % | Shrub Species | % |
|---|---|---|---|
| Oak (*Quercus robur*) | 20 | Willow (*Salix caprea*) | 15 |
| Downy birch (*Betula pubescens* ) | 10 | Elm (*Ulmus glabra*) | 10 |
| Field maple (*Acer campestre*) | 5 | Hazel (*Corylus avellana*) | 10 |
| Scots pine (*Pinus sylvestris*) | 5 | Elder (*Sambucus nigra*) | 5 |
| Alder (*Alnus glutinosa*) | 5 | Holly (*Ilex aquifolium*) | 5 |
| Aspen (*Populus tremula*) | 5 | Spindle (*Euonymus europaeus*) | 5 |

Fig 2. Planting designs: wood pasture (A), shelterbelt (B) and regularly spaced rows (C). Area around base of all plants kept weed-free to reduce competition. Planted species and total proportion are the same in each farm. Livestock excluded for 5 years.

**Productivity** (sward heights) **and botanical surveys** (plant species in quadrats 2 x 2 m, % cover and frequency) regularly measured.

## RESULTS

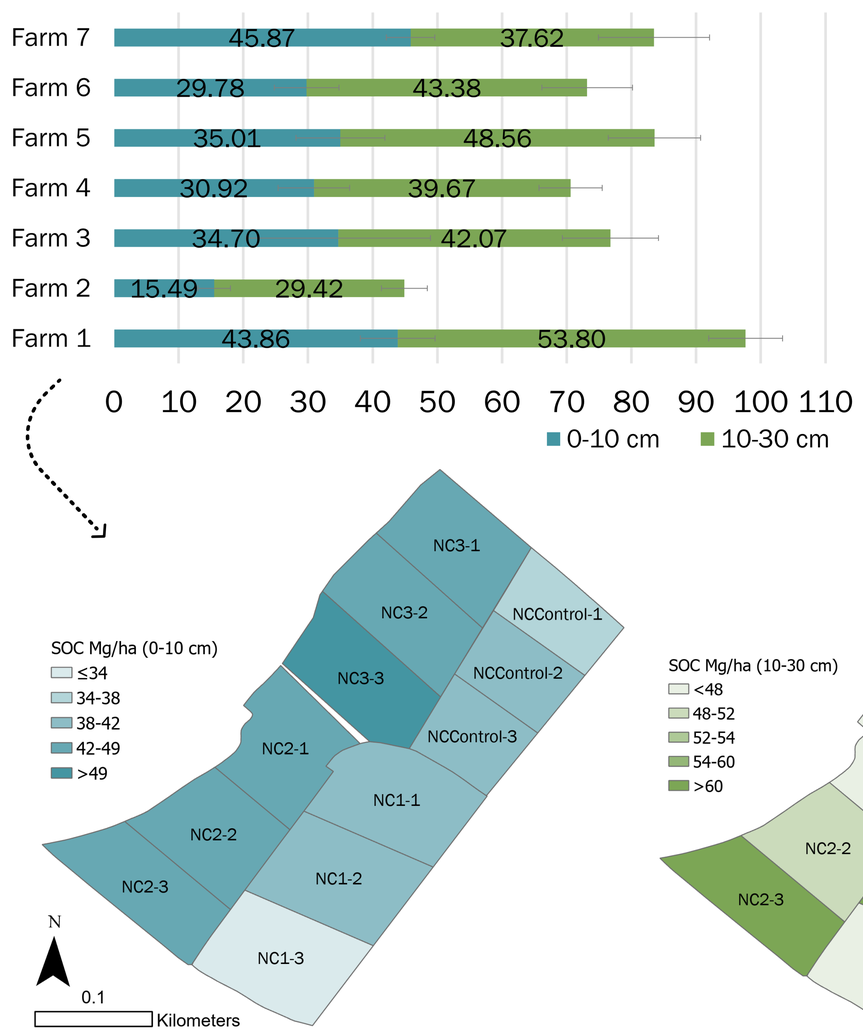



Fig 3. Mean SOC (Mg C ha$^{-1}$) in each farm and SOC variability per each sampling unit in the Rothamsted site included in the Network (Nethercott, NC). 1_1,1_2,1_3 etc. refers to the units in each field containing 6 sampling points (1 composite sample).

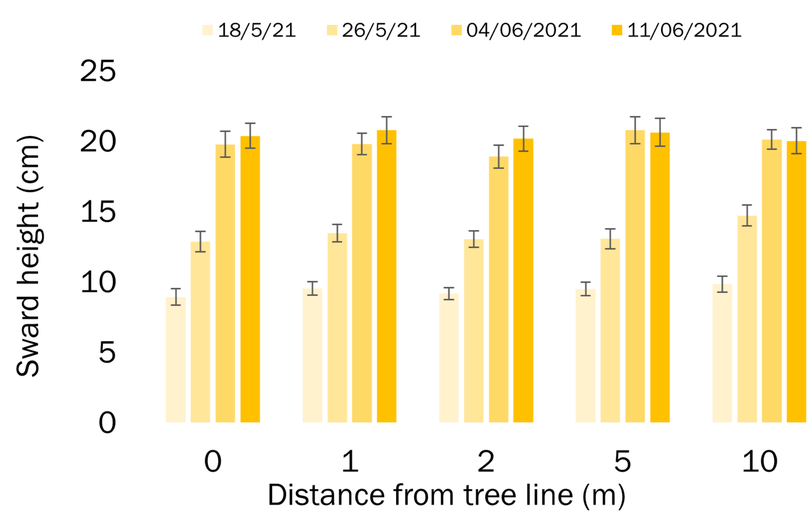



Fig 4. Sward heights measured in the regularly spaced rows at Nethercott over Summer 2021. The planting of trees had no effect on sward heights at this early stage of establishment. The plant community was MG6a (*Lolium perenne-Cynosurus cristatus* grassland Typical sub-community), irrespective of planting design or sampling distance from the trees.

## NEXT?

- Soil surveys each four years
- Biodiversity monitoring (productivity and botanical surveys, bats, beetles)
- Greenhouse gas emissions
- Animal welfare
- Socioeconomics

**References**

Soil Association, 2019. The Agroforestry Handbook: Agroforestry for the UK.
FAO, 2020. A protocol for measurement, monitoring, reporting and verification of soil organic carbon in agricultural landscapes – GSOC-MRV Protocol.

**Acknowledgements**

Rothamsted work funded by Soils to Nutrition (BBS/E/C/000I0320) and Growing Health (BB/X010953/1) programs. Funding for the design and establishment of the silvopasture trials was provided by the Innovative Farmers programme and the Woodland Trust's *Trees for your farm* scheme.

ROTHAMSTED RESEARCH

Biotechnology and Biological Sciences Research Council

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

| Subject | Nr. of LTEs | Researching… |
|---|---|---|
| Plant nutrition and soil fertility | 24 | ...the effect off liming, mineral fertilisers, organic amendments, and management practices on long-term soil fertility, soil organic matter and soil biology. |
| Cropping systems | 6 | …the efficiency of different cropping systems, and improving the ability of crop models to simulate production and yield levels as a function of changes in climate and cropping practices. |
| Cropping systems in Northern Sweden | 4 | … the impact from monocultures and crop rotations on yield and quality of the most important crops in Northern Sweden. |
| Landscape ecology | 3 | …how extended buffer zones along field edges (planted with bushes and undersown with arable crops and wild meadow plants) develop and impact invertebrates. |
| Weed ecology | 1 | …changes in weed populations and the effects of cropping practices, weather and ecological interactions. |
| Water quality management | 9 | …impacts of different management practices and crop rotations on nutrient flows in crops, soil and drainage water. |
| Agricultural water management | 6 | …different types of land drainage on mineral soils, and subsidence and GHG emissions on organic soils. |
| Soil tillage | 7 | …whether energy demanding conventional tilling can be replaced with reduced tillage or no-till farming. |

The frame trial at Ultuna Campus, Uppsala, was designed to study changes in soil carbon and microbial community. Different organic amendments such as straw, peat and sewage sludge have been added since 1956.

## ACCESS TO DATA, SAMPELS AND SITES

Researchers are allowed to study the LTEs or use archived data and material, as long as the proposed activity does not cause large difficulties for SLU staff or diminish the future value of the field experiments. The LTE coordinator (Sabina Braun) can help you find and access a suitable LTE for you purposes.

## REASEARCH STATIONS

Many of the LTEs are located at SLU's four research stations, Röbäcksdalen (Umeå), Lövsta (Uppsala), Lanna (Skara), and Lönnstorp (Alnarp). These stations can also host short- and mid-term experiments, and have infrastructure such as specialised farming equipment, individually drained plots, drones, and experienced field technicians.

**Sabina Braun, PhD**
LTE coordinator
sabina.braun@slu.se

**Funding**
The SLU Agricultural Long-Term Experiments are funded by the Faculty of Natural Resources and Agricultural Sciences (NJ)

LTE WEBPAGE

SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE

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

**T. D'Hose[1]**, G. Blanchy[1], K. Klumpp[2], L. Makoschitz[3], A. Spiegel[3], R. Murugan[4], T. Sandéen[3], L. O'Sullivan[5], C. Donmez[5], C. Hoffmann[5], N. Svoboda[5], G. Ruysschaert[1] & S. Zechmeister-Boltenstern[4]

*[1] ILVO, [2] INRAe, [3] AGES, [4] BOKU, [5] Teagasc, [6] ZALF*

## Introduction

**Long-term field experiments (LTE)** are crucial sources of knowledge on the long-term sustainability and productivity of agricultural management practices. Besides, they can provide long-term datasets for calibration and validation of mathematical models. As they are fairly costly to maintain them, efforts aiming at more extensive and cooperative use of long-term field experiments and their corresponding (meta)data should be encouraged. Within the European Joint Program SOIL (EJP SOIL) **metadata of running European field experiments were collected.** This metadataset could also serve as a **match-making platform between researchers and LTE owners**, enabling interested users to make bi-lateral arrangements with LTE-owners to exchange experimental data or physical soil/crop samples.

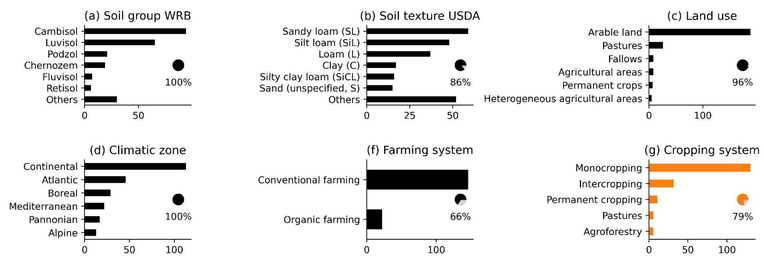
## Database construction

To collect metadata about the selected LTEs, an excel template was developed. The terms used in the template are based upon the keywords tree of the Knowledge Library of the BonaRes project (https://klibrary.bonares.de), controlled vocabulary from FAO AGROVOC thesaurus (http://www.fao.org/agrovoc/) and Corine Land Cover.

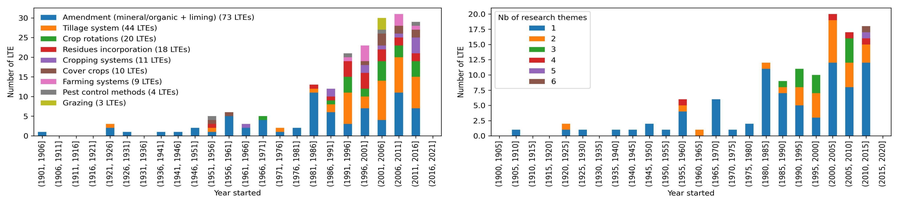
As much as possible, a controlled vocabulary was enforced by the use of drop-down menus while keeping the flexibility for the user to add new terms if needed. the template was divided into different tables (equivalent to sheets or tabs). The use of indices enabled the link between the different tables to be defined, transforming the template into a relational metadataset.

## Database exploration

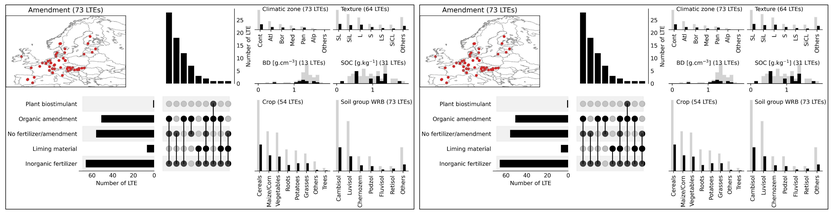
In total, metadata from **240 different LTEs from 21 countries** across Europe were collected. The main pedo-climatic variables and management practices are summarized below*.




9 research themes were identified within the database and the number of themes that was investigated within one LTEs was determined.



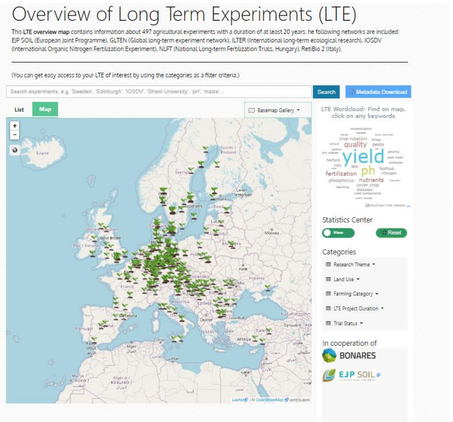

Information about specific agricultural management practices investigated by the LTEs was presented in a dashboard (e.g. type of amendments and tillage type). The left part of the dashboard consists of an intersection figure, so-called Upset plot, that enables us to visualize the interactions between the different levels of the factor. Additional bar charts are depicted in each dashboard to provide an overview of the pedo-climatic context of those LTEs.




Both the template as the database are published online (Blanchy et al. 2023).

## Online accessible database

In collaboration with the team of the Bonares project, all information about LTE collected within EJP and previous LTE already in Bonares are also displayed on an interactive map.




* Blanchy et al. An open-source metadataset of running European mid- and long-term agricultural field experiments (*under review*)

Donmez et al. 2022

Blanchy et al. 2023

EJP SOIL European Joint Programme

BONARES Centre for Soil Research

ILVO Flanders Research Institute for Agriculture, Fisheries and Food

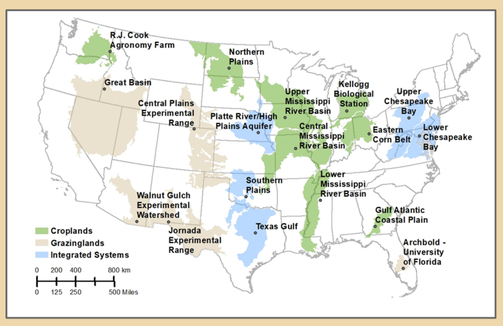
# Network Strategies and Studies to Advance Science for Climate-Smart Agriculture in the LTAR Network

Lindsey Witthaus[1], Phil Heilman[2], Lori Abendroth[3], Betsey Boughton[4], Michel Cavigelli[5], Mark Liebig[6], Jude Maul[5], Adam Schreiner-McGraw[3]

[1]USDA-ARS National Sedimentation Laboratory, [2]USDA-ARS Southwest Watershed Research Center, [3]USDA-ARS Cropping Systems and Water Quality Research Unit, [4]Archbold Biological Station, [5]USDA-ARS Sustainable Agricultural Systems Laboratory, [6]USDA-ARS Northern Great Plains Research Laboratory

## The USDA Long Term Agroecosystem Network (LTAR)

The LTAR network is led by the United States Department of Agriculture (USDA) Agricultural Research Service (ARS), with collaboration from several US universities and non-profit organizations.




The network is comprised of 18 different sites spread across the US. Agroecosystems include croplands, grazinglands, or integrated systems with both cropping and animal production. The diversity of LTAR sites is both a strength and challenge of the network.

LTAR sites are situated across a range of extreme climates from very cold (Northern Plains) to hot and humid (Lower Mississippi). This range allows climate smart practices to be evaluated across conditions and agroecosystem types.

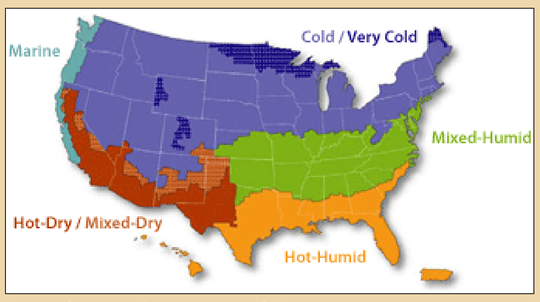



Image from the Department of Energy
https://www.energy.gov/eere/buildings/building-america-climate-specific-guidance-image-map

## How does Climate-Smart Agriculture fit into LTAR Strategic Initiatives?

The 7 strategic initiatives to address core challenges and opportunities. Blue squares are research initiatives; green squares are organizational initiatives. The CSA related initiatives are highlighted with a tan border.

Climate Smart Agriculture (CSA) is a critical focus for the scientific work in LTAR, both within the common experiment and the network observatories.

The common experiment compares prevailing management with innovative practices in a paired-experiment at each site. Systems of new and existing practices are co-produced with stakeholders and evaluated for mitigation and adaptation to climate change, including resilience to climate extremes.

Network observatories with long term records of social, production, and environmental-related variables can provide benchmarks to assess local rates of change related to climate and other drivers.

## Current Climate Smart Research in the LTAR Network

Common Experiment:

*Cropland Adaptation Practices*

Many cropland sites are studying cover crop systems, minimal tillage, and precision or adaptive nutrient/pest/water management. Cover crops are being assessed for both climate adaptation and mitigation benefits. Increased soil cover throughout the year due to green plants or residue is hypothesized to reduce erosion from extreme events and improve water retention to withstand drier growing seasons. The image on the right demonstrate a diverse cover crop mix in a corn-soybean-wheat rotations in Central Missouri.

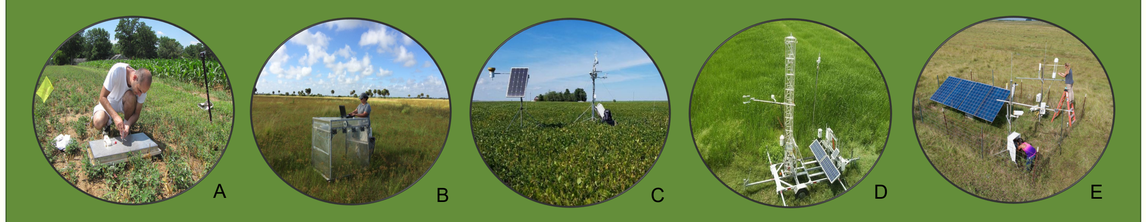
*Grazingland Adaptation Practices*

Grazingland sites are evaluating optimized grazing, pasture improvement, restoration of grasslands, and climate resilient cattle species, like the Criollo cattle with greater heat tolerance and parasite resistance compared to commercial beef cattle breeds (image on right; Jornada).

*Climate Mitigation*

All sites measure soil carbon changes over time, as well as greenhouse gas (GHG) fluxes at various scales. Efforts are underway to coordinate measurements and analysis across sites to evaluate:

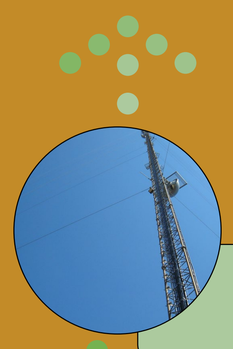
1) If innovative systems of cropland practices increase resiliency to extreme events using eddy-covariance (EC) tower data (led by Adam Schreiner-McGraw);
2) Carbon regulating services of LTAR grazingland sites using EC and chamber flux measurements (led by Betsey Boughton and Maria Silveira).




A) crop plot-scale chamber measurements at the Lower Chesapeake site (CR: Michel Cavigelli); B) chamber measurements in a pasture in Florida (CR: Betsey Boughton, Archbold); C) EC tower in a soybean field in North Dakota; D) EC tower in miscanthus field in Georgia (CR: SE Watershed Research Laboratory); E) EC tower in pasture in Florida (CR: Betsey Boughton, Archbold).

## Future Directions and Aspirations

The network aims to expand current greenhouse gas (GHG) measurements to include tall towers with sensors for regional trace gas measurements, and then integrate measurements across scales, from the plot, field, landscape to regional levels.



Tall towers for regional hotspot monitoring

Eddy-covariance field to landscape high-resolution data

Plot to field-level GHG sampling

Another goal is to use network experimental and observational datasets to improve model simulations and assessments of climate smart practices. With inherent uncertainty surrounding future climate conditions, modeling tools are invaluable resources to test potential situations, evaluate relationships, and highlight gaps in current knowledge.
Proposed models to assess agroecosystems:

SWAT Soil & Water Assessment Tool | DSSAT | APEX

Questions or ideas for collaborating – please email Lindsey: Lindsey.Witthaus@usda.gov

To learn more about the LTAR network, please scan this QR code to visit our website.

# Re-evaluating the fertiliser nitrogen use efficiency using Swiss long term experiments

**Carole Alice Epper*, Shiva Ghiasi, Frank Liebisch and Jochen Mayer**
Agroscope, 8046 Zurich, Switzerland; www.agroscope.ch
*carole.epper@agroscope.admin.ch

## How to investigate the **temporal** fertiliser nitrogen (N) cycling dynamics and N use efficiency (NUE) trends using LTEs?

### 1. Selection of long-term field experiments (LTEs) based on defined criteria (a – d)

a) Swiss pedo-climatic conditions
b) control plot without fertiliser application
c) mineral and organic fertiliser treatments
d) crop rotation

**AESCH** (FiBL)
Duration: 2010 – ongoing
Design: split-plot, four replicates
Factors: fertiliser type and amount, tillage
Fertiliser treatments: NPK, cattle slurry

**DEMO** (Agroscope)
Duration: 1989 – ongoing
Design: not-replicated, seven parallel crops
Factors: fertiliser
Fertiliser treatments: NPK, NPK + Ca, PK, NP, cattle slurry, cattle farmyard manure

**DOK** (Agroscope, FiBL)
Duration: 1978 – ongoing
Design: strip-split-plot, four replicates
Factors: farming system, fertiliser type and amount
Fertiliser treatments: NPK, cattle slurry, cattle farmyard manure

**P24A** (Agroscope)
Duration: 1976 – ongoing
Design: split-plot, four replicates
Factors: fertiliser type and amount
Fertiliser treatments: NPK, green manure, cereal straw, cattle farmyard manure, cattle slurry and selected combinations of organic and mineral fertilisers

**ZOFE** (Agroscope)
Duration: 1949 – ongoing
Design: systematic block, five replicates
Factors: fertiliser
Fertiliser treatments: NPK, PK, farmyard manure, compost, sewage sludge, peat and selected combinations of organic and mineral fertilisers

### 2. Intensive data wrangling sessions to build a database

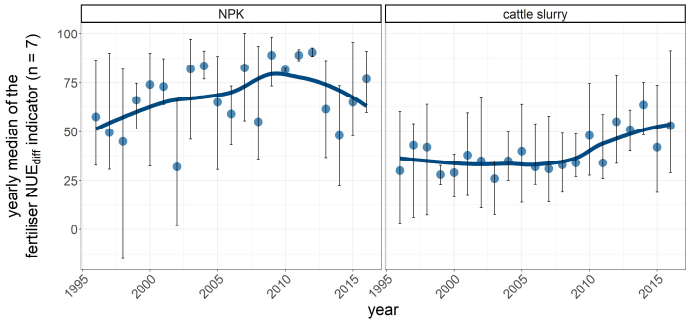
### 3. Calculation and results normalisation of selected indicators for each trial and fertiliser type

$$Approx.\ soil\ system\ N\ balance\ (kg\ N\ ha^{-1}\ y^{-1}) = \\ = Nseeds + Nfertiliser + Nfixation + Ndeposition - \\ - (Nuptake + \triangle NsoilStock)$$

$$fertiliserNUE_{\text{diff.}}\ (\%) = \frac{Nuptake_{\text{t}} - Nuptake_{\text{c}}}{Nfertiliser_{\text{t}}} * 100$$

*t*: plot with fertiliser treatment
*c*: control plot without fertiliser

### 4. Trials comparisons to find an overall NUE range per fertiliser type




Preliminary results of the *fertiliser NUE* development in the DEMO trial using the $NUE_{diff}$ indicator

## Outlook

- Use case-study farms to quantify the implications of our findings in practice
- Expand the LTEs selection to validate method under other pedo-climatic conditions

## Sounds easy: but why is this so challenging?

- Finding LTEs fitting the selection criteria
- Comparing LTEs with different duration, design, crop rotation, fertiliser amounts, management history
- Data sharing and data harmonisation
- To which extent can we generalise these findings for the specific fertiliser type?

**Acknowledgements for data sharing**
AESCH trial: Meike Grosse et al. (FiBL),
P24A trial : Thomas Guillaume (Agroscope)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Federal Department of Economic Affairs, Education and Research EAER
Agroscope
Agroscope good food, healthy environment

Meike Grosse, Mareike Weiner, Michael Thompson, Alfred Berner, Röbi Frei, Monika Messmer, Frédéric Perrochet, Paul Mäder, Maike Krauss

# Costs and Benefits of Reduced Tillage in Organic Farming
## Results of a Long-term Experiment on Loess Soil in Switzerland

## Introduction

Reduced tillage (RT) has soil conservation benefits compared to conventional ploughing (CT) (Krauss et al. 2021), but can lead to lower yields in organic farming. The aim of the current analyes of a long-term experiment (LTE) is to provide a holistic assessment of both methods, including profitability and environmental impact.

## Material and Methods

- **Start of the LTE:** 2010
- **Site:** organic farm Schlatthof, Aesch BL, Switzerland (349 m asl, 785 mm, 9.6°C)
- **Soil type:** Luvisol, **Textur:** silty loam
- **Experimental design:** two factorial split-plot with fertiliser type and amount and tillage (Fig. 1)
- **Analyses:** soil organic carbon (SOC), microbial biomass carbon and nitrogen (MBC, MBN), yield and nutrient contents
- **Calculations:** Life Cycle Assessment approach for the comparison of global warming potential and energy consumption of the treatments

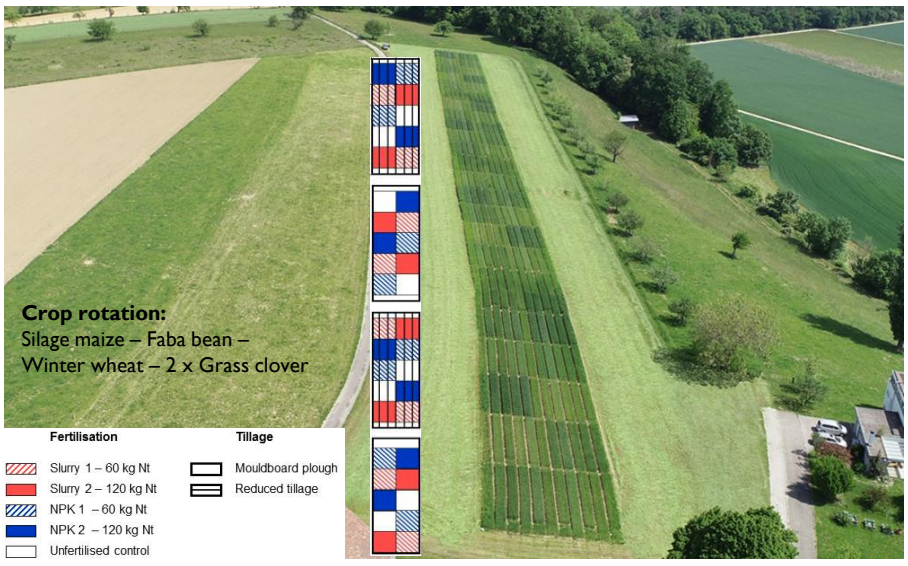



Fig. 1: Experimental design of the long-term experiment «Schlatthof»

## Results

- Mean yield (2010-2022): -4 % with RT compared to CT (range from minus 14 % for grass-clover 2014 to plus 11 % for grass-clover 2022) (Fig. 2)
- SOC stocks and MBC: in the layer 0-10 cm development to higher contents, in 10-20 cm lower contents with RT (Fig. 3 a-d)
- Life Cycle Assessment 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 Slurry 1 they were similar to CT, with Slurry 2 they were 9% lower than with CT. 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.

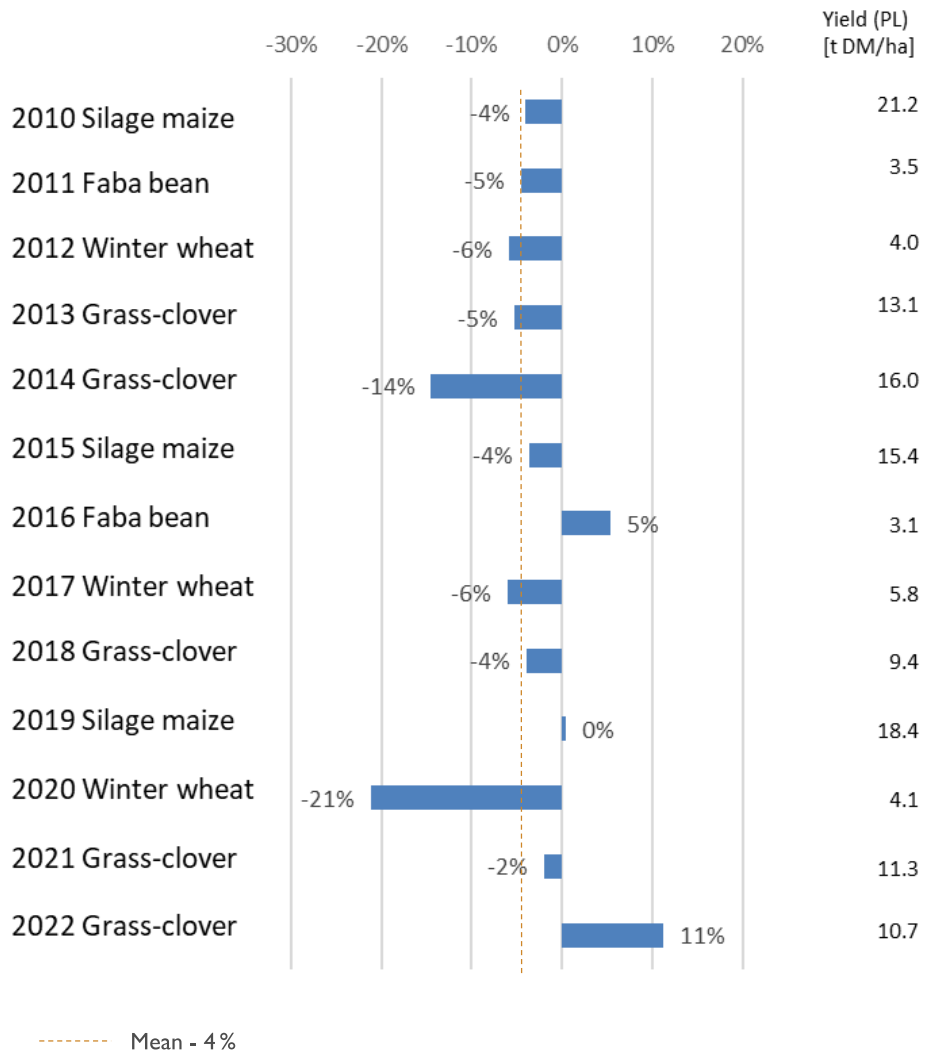



Fig. 2: Relativ yield with reduced tillage *versus* ploughing

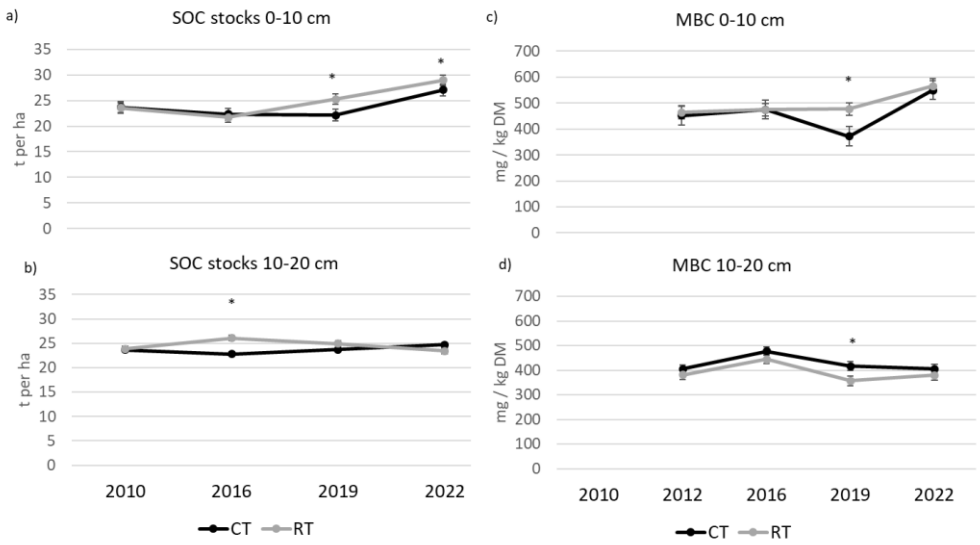



Fig. 3 a) and b): Mean ±SE of SOC stocks (a,b) and MBC (c,d) with reduced tillage (RT) and ploughing (CT). * marks significant differences (p≤0.01)

## Conclusions

With RT, the yield losses at this location are low compared to CT and RT contributes to climate protection and the saving of fossil fuels.

In Switzerland, RT is partly profitable with subsidies only, which underlines the importance of subsidies for this system to compensate for environmental performance in the assessed categories of climate change and energy consumption.

**References**
M. Krauss, M. Wiesmeier, A. Don, et al. (2022).
Reduced tillage in organic farming affects soil organic carbon stocks in temperate Europe, Soil and Tillage Research, 216
https://doi.org/10.1016/j.still.2021.105262

© FiBL 2023