Comparing organic and conventional agricultural cropping systems - What can be learned from the DOK and other long-term trials?

Congressi Stefano Franscini, Monte Verità, Ascona, Switzerland

6-10 October, 2019

DOK Excursion 11 October, 2019

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PROGRAM AND ABSTRACT BOOK

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The Organizing Committee gratefully acknowledges the financial support of:

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Thomas Nemecek, Agroscope, Switzerland

Kate Scow, University of California Davis, USA

Henrik G. Smith, Lund University, Sweden

Doris Vetterlein, Helmoltz Center for Environmental Research, Germany

General Information

The conference takes place at the Congressi Stefano Franscini (CSF), the conference center of ETH Zurich, located at Monte Verità, Ascona, Switzerland. The conference facilities, the restaurant and the bar are located in the main building called Bauhaus Building.
For further information on Monte Verità and on connections to Ascona, please refer to the white CSF folder included in your conference bag.

Conference rooms

All lectures will take place in the Auditorium on the ground floor of the Bauhaus Building. All posters will be displayed from Monday to Thursday in the Balint Room, located on the first floor of the Bauhaus Building. We kindly ask you to take your poster down on Thursday morning and bring it home with you. Posters left at the venue after departure of the group will be discarded.

Oral Presentations

All talks are in plenary and are presented via Power Point or pdf slideshow on either a Windows or a Mac computer available in the Auditorium. The beamer has an additional third channel, so the use of your own computer is possible, but compatibility with the video system should be tested ahead of time. Members of the organizing committee will be available to assist you in uploading and testing your presentation.
Chairpersons will monitor that the speakers stay within their allotted time.

Poster Presentations

Dimensions of poster boards are 180 cm (width) x 120 cm (height) and can fit A0-sized posters printed in both portrait or landscape format. Please refer to the numbered posters list in this book to find the assigned board for your poster.
Two poster viewing sessions are planned: one on Monday and one on Wednesday, both from 17.30 to 19.00. Authors of posters listed in Session I are asked to stand by their posters on Monday, authors in Session II on Wednesday afternoon.

"CSF Award"

The *CSF Award* has been established in 2009 by the director and the scientific board of the Congressi Stefano Franscini. The Award will be conferred to the best platform presentation given by a young scientist during the conference, after review by a jury of jury members specifically appointed by the conference organizers. The *CSF Award* ceremony is scheduled at the end of the program on Thursday morning.

Wireless and computer room

There is a free wireless network in the Bauhaus Building and in the Semiramis Building. Please refer to the CSF folder you have received at registration for further information on the use of the wireless (password, settings, etc.).
A computer room (equipped with Windows and Mac computers and one printer) is available for you 24 hours a day. The room is located at the ground floor level of the main building, just a few steps behind the Monte Verità hotel front desk.

Meals and refreshments

Lunches and dinners (from Sunday dinner till Thursday lunch) will be served at the Monte Verità Restaurant, on the first floor of the Bauhaus building. Please refer to the timing indicated in the program for meals and arrive on time at the dining room.
All coffee breaks will be served at the Bar Roccia, on the first floor of the Bauhaus Building. The Bar Roccia will also be open for you every evening from 21.00 to midnight.
Only the participants who have booked the meals package in advance from the online Monte Verità's platform can join the group for lunches and dinners.

Excursion and conference dinner

On Tuesday 8 October after lunch there will be a visit to two organic farms in the Magadino plain, followed by the conference dinner at the restaurant Castelgrande in Bellinzona.
The farms are: (i) *Demanio Cantonale*, an organic farm owned by the Canton Ticino with 60 ha of arable crops, various experiments of No-Till and seed mixtures well adapted for dry conditions and newly planted orchard of chestnut trees for intensive production; (ii) *Mäder Kräuter*, a branch of Mäder Kräuter in Boppelsen (Canton Zurich), an organic farm with fresh herbs produced for supermarkets on 13 ha and a recently built glasshouse of 4 ha.
We will depart from Monte Verità around 14.00 with 2 buses; the visits are planned to last approximately from 15.00 to ca. 18.00, and then we will reach the restaurant around 19.00 (directly after the visits, without going back to Ascona). We expect to return to Ascona around 22-22.30.
We advise proper clothing depending on the weather forecast (we expect to spend 2.5 to 3 hours outdoor) and comfortable shoes for some easy walking on mostly flat terrain.

DOK Excursion, Friday 11 October

On Friday morning the two responsible scientists, Paul Mäder and Jochen Mayer, and colleagues will guide you through the DOK field experiment, where bio-dynamic, bio-organic and conventional cropping systems are compared in a four-fold replicated field experiment in 96 plots since 1978. It is located in the valley Leimen, a region characterized by loamy soil developed on deep deposits of alluvial Loess. An overview on associated ongoing or recently closed projects will be given (e.g., on drought stress, soil quality indicators, N_2O emissions, N and C rhizodeposition, root carbon turnover, Deuterium studies, P-cycling). Principle investigators and PhDs will present new projects on soil organic matter quality and soil metagenomics. We will also discuss future research questions and potential collaboration with visitors.

Disclaimer

The conference organizers cannot accept any liability for personal injuries sustained, or for loss or damage to property belonging to congress participants (or their accompanying persons), either during or as a result of the congress.
Registration fees do not include insurance.

Program

Sunday, 6 October

From 15.00 Arrival, registration

16.00 – 17.00 Welcome drink

Introductory session

Chair: Jochen Mayer

17.00 Welcome addresses
Bernard Lehmann, former DG Federal Office for Agriculture, Switzerland
Eva Reinhard, Head Agroscope, Switzerland
Urs Niggli, Director FiBL, Switzerland

17.30 – 18.15 **Keynote lecture**
Kate Scow, University of California Davis, USA
Longterm impacts of management on soil Carbon, soil life, and agricultural resilience in Mediterranean agroecosystems

18.15 – 19.00 **Keynote lecture**
Paul Mäder, FiBL, Switzerland
The DOK long-term experiment – lessons learned from 40 years of interdisciplinary research

19.15 Dinner

Monday, 7 October

8.45	Congressi Stefano Franscini and Fondazione Monte Verità Welcome address

Yield and yield development

<u>Chair: Erik Steen Jensen</u>

9.00 – 9.30	**Keynote lecture** **Jochen Mayer**, Agroscope, Switzerland The performance of yields in organic and conventional cropping systems
9.30 – 9.45	**Andrew Macdonald,** Rothamsted Research, UK The Rothamsted Long-term Experiments
9.45 – 10.00	**Bettina Leschhorn,** Justus Liebig University Giessen, Germany Long-term effects of different farming and fertilization systems on biomass yields and nitrogen uptake of crops in the LTE "IOSDV" Rauischholzhausen
10.00 – 10.15	**Evelin Loit,** Estonian University of Life Sciences, Estonia Yield stability and nutrient use efficiency in wheat, barley, potato and field pea when comparing organic and conventional crop management from 2008-2017
10.15 – 10.30	**Jaroslaw Stalenga,** State Research Institute, Poland Environmental and yield performance of organic and conventional crop production systems in long-term experiment in Puławy (Poland)
10.30 – 11.00	*Coffee break*

Nutrient flows and nutrient use efficiency

<u>Chair: Else K. Bünemann</u>

11.00 – 11.30	**Keynote lecture** **Erik Steen Jensen**, Swedish University of Agricultural Sciences, Sweden Determining nutrient flows and nutrient use efficiency in long-term cropping systems experiments – Advantages and challenges
11.30 – 11.45	**Bettina Eichler-Löbermann,** University of Rostock, Germany Yield development and soil fertility – results of different phosphorus fertilizer practices over 20 years
11.45 – 12.00	**Klaus Jarosch,** University of Bern, Switzerland Soil phosphorus (P) budgets, P availability and P use efficiencies in conventional and organic cropping systems of the DOK trial
12.00 – 12.15	**Astrid Oberson**, ETH Zurich, Switzerland Nitrogen budgets and soil nitrogen stocks of organic and conventional cropping systems: how reconcile efficiency and sustainability of nitrogen use?

12.15 – 12.30	**Xiaojin Zou**, Liaoning Academy of Agricultural Sciences, Shenyang, China Interspecific root interactions enhance nitrogen acquisition, symbiotic N_2 fixation, and N transfer in foxtail millet/peanut intercropping
12.30	*Lunch*

Soil quality

Chair: Andreas Gattinger

14.00 – 14.30	**Keynote lecture** **Else K. Bünemann**, FiBL, Switzerland Soil quality: a critical review and a look into the future
14.30 – 14.45	**Andreas Fliessbach,** FiBL, Switzerland Change of biological soil quality in organic and conventional farming systems of the DOK trial
14.45 – 15.00	**Noelia Garcia Franco,** Technische Universität München, Germany Beneficial effects of reduced tillage on soil aggregation and stabilization of organic carbon in an irrigated semiarid Mediterranean ecosystem
15.00 – 15.15	**Kyle Mason-Jones,** Netherlands Institute of Ecology, The Netherlands Vital Soils for Sustainable Intensification of Agriculture: A chronosequence approach to organic agricultural research
15.15 – 15.30	**Erin Silva,** University of Wisconsin-Madison, USA Influence of long-term organic and conventional cropping systems on soil microbial population size and structure
15.30 – 16.00	*Coffee break*
16.00 – 17.30	Workshops Themes 1-3
17.30 – 19.00	Poster session 1
19.00	*Dinner* *Supported by Biovision–Foundation for Ecological Development*

Tuesday, 8 October

Rhizosphere processes

<u>Chair: Jochen Mayer</u>

9.00 – 9.30	**Keynote lecture** **Doris Vetterlein,** Helmoltz Center for Environmental Research, Germany Relevance of rhizosphere processes at field scale – a road map based on imaging techniques
9.30 – 9.45	**Maria Finckh,** University of Kassel, Germany Long-term root adaptation to organic and conventional farming in heterogeneous wheat populations
9.45 – 10.00	**Andreas Hammelehle,** Agroscope, Switzerland New insights in below ground nitrogen of clover-grass mixtures
10.00 – 10.15	**Juliane Hirte,** Agroscope, Switzerland Fertilization intensity and the fate of root carbon in soil within two years after harvest
10.15 – 10.30	**Fritz Oehl,** Agroscope, Switzerland Diversity of arbuscular mycorrhizal fungi in agricultural systems
10.30 – 11.00	*Coffee break*

Climate change adaptation and mitigation

<u>Chair: Andreas Fliessbach</u>

11.00 – 11.30	**Keynote lecture** **Ana Iglesias,** Universidad Politecnica de Madrid, Spain Effect of agricultural management practices on soil ecosystem services
11.30 – 11.45	**Philipp Koal,** University of Rostock, Germany The role of agronomic management practices on greenhouse gas emissions in a long-term field trial
11.45 – 12.00	**Nicolas Beaudoin,** INRA Laon, France Can organic cropping systems mitigate nitrogen losses and improve GHG balance? Results from a 19-yr experiment in Northern France
12.00 – 12.15	**Andreas Gattinger,** University of Giessen, Germany Soil-derived greenhouse gas emissions as influenced by farming management
12.15 – 12.30	**Emily Miranda Oliveira,** Agroscope, Switzerland Resilience of organic and conventional cropping systems to drought and climate change
12.30	*Lunch*
14.00 – 22.30	Excursion to two innovative farms in the Magadino plain and conference dinner at the Restaurant Castel Grande in Bellinzona (UNESCO World Heritage)

Wednesday, 9 October

Nutritional quality

Chair: Astrid Oberson

9.00 – 9.30	**Keynote lecture** **Carlo Leifert,** Southern Cross University, Australia Effect of agronomic practices on food quality and human health – the need to understand complex interactions
9.30 – 9.45	**Emmanuel Frossard,** ETH Zurich, Switzerland Long-term organic matter application reduces cadmium but not zinc concentrations in wheat
9.45 – 10.00	**Juan Herrera,** Agroscope, Switzerland Genetic progress and genotype (G) × environment (E) interactions effects on winter wheat under organic, conventional low-inputs and conventional high-inputs production systems: insights from 20 years of studies
10.00 – 10.15	**Georg Langenkämper,** Max Rubner-Institut, Germany Profiling techniques and targeted analyses in the quest for differentiation of organic versus conventional DOK wheat
10.15 – 10.30	**Leonidas Rempelos,** University of Newcastle, UK Nafferton Factorial Systems Comparison trials: What we have learned from the first 18 years of experiments
10.30 – 11.00	*Coffee break*

Sustainability assessment

Chair: Jan Bengtsson

11.00 – 11.30	**Keynote lecture** **Thomas Nemecek,** Agroscope, Switzerland Environmental impacts of cropping systems: lessons learnt from LCA studies
11.30 – 11.45	**Mariam Soma,** Institut de l'Environnement et de Recherches Agricoles, Burkina Faso History, lessons and challenges of the long term field trial of Saria
11.45 – 12.00	**Martin Entz,** University of Manitoba, Canada The Glenlea long-term study illuminates the ecosystem health – crop productivity nexus in Canadian Prairie organic production
12.00 – 12.15	**Long Li,** China Agricultural University, China Crop diversity enhances agroecosystem sustainability via improving soil fertility
12.15 – 12.30	**Andrew Mead,** Rothamsted Research, UK A meta-analysis approach for assessing the sustainability of cropping systems using data from multiple global LTEs
12.30	*Lunch*

Biodiversity in agroecosystems

Chair: Klaus Birkhofer

14.00 – 14.30	**Keynote lecture** **Henrik G. Smith,** Lund University, Sweden Landscape-scale studies capture effects of organic farming across scales on mobile organisms and their services
14.30 – 14.45	**Klaus Birkhofer,** Brandenburg University of Technology, Germany Effects of farming system and simulated drought on biodiversity, food webs and ecosystem functions in the DOK trial
14.45 – 15.00	**Martina Lori,** FiBL, Switzerland Nitrogen transformations and its underlying microbial communities in differently managed soils under future projected rainfall variability
15.00 – 15.15	**Francisco Xavier Sans Serra,** Universitat de Barcelona, Spain Effects of farming system on weed seed bank and on invasibility in arable fields: evidences from the long-term DOK trial
15.15 – 15.30	**Marjetka Suhadolc,** University of Ljubljana, Slovenia Transition of long term Conservation Tillage experiment from Conventional to Organic system – effects on soil quality and weed infestation
15.30 – 16.00	*Coffee break*
16.00 – 17.30	Workshops Themes 4-6
17.30 – 19.00	Poster session 2
19.00	*Dinner* *Supported by Bio Suisse*

Thursday, 10 October

Sustainable production within planetary boundaries

Chair: Paul Mäder

9.00 – 9.30	**Keynote lecture** **Hermann Lotze-Campen,** Potsdam Institute for Climate Impact Research (PIK), Germany Agricultural production in line with the Sustainable Development Goals and within Planetary Boundaries
9.30 – 9.45	**Gurbir Bhullar,** FiBL, Switzerland Can organic agriculture contribute to sustainable development in the tropics?
9.45 – 10.00	**Pietro Barbieri,** Bordeaux Sciences Agro, France Simulating the effects of nitrogen availability on organic production at the global scale
10.00 – 10.15	**Jan Bengtsson,** SLU, Sweden Long-term field trials are fine but insufficient for understanding landscape impacts of farming systems on ecosystem services and biodiversity
10.15 – 10.30	**Michael Mielewczik,** Rothamsted Research, UK TSARA (Targets for sustainable and resilient agriculture) – efficiency
10.30 – 11.00	*Coffee break*

Research need and new perspectives of long-term experiments

Chair: Emmanuel Frossard

11.00 – 11.30	**Keynote lecture** **Paolo Barberi,** Sant'Anna School of Advanced Studies, Italy Applying the Efficiency-Substitution-Redesign transitional framework to ensure the sustainability of long-term experiments
11.30 – 11.45	**Maike Krauss,** FiBL, Switzerland Organic conservation tillage – evidence from more than 15 years of research
11.45 – 12.00	**Janjo de Haan,** Wageningen University and Research, The Netherlands (What is) The best methodology to compare organic and conventional agricultural cropping systems
12.00 – 12.15	**Sara König,** Helmholtz-Zentrum für Umweltforschung GmbH, Germany The importance of long-term field experiments for modelling soil functions in agricultural systems
12.15 – 12.30	**Christine Watson,** SRUC Aberdeen, UK A comparison of four contrasting experimental rotations: reflections on an organically managed rotational LTE started in 1991
12.30 – 12.45	CSF Award ceremony and closing remarks
12.45	*Lunch and departure*

Poster session 1

Monday, 17.30 – 19.00

1. Amelie Carriere, Arvalis, France
Fertility losses in organic agriculture systems

2. Leo Condron, Lincoln University, New Zealand
Impacts of long-term input cessation and biomass management on soil nutrient dynamics in a New Zealand grassland

3. Anne-Laure de Cordoue, ARVALIS Institute, France
Multi-performances of an organic cropping system led without external fertilizer, in the northern part of France, in arable crops: comparison with a conventional cropping system

4. Keyvan Esmaeilzadeh Salestani, Estonian University of Life Sciences, Estonia
Impact of long-term conventional and organic farming systems on barley

5. Noelia Garcia Franco, Technische Universität München, Germany
Seasonal climate conditions, pedogenic-topographic factors and management practices as main drivers of long-term carbon dynamics (1989-2016) in grassland soils of Bavaria

6. Veronika Hansen, Copenhagen University, Denmark
Green manure crops for low fertility soils

7. Valentin Klaus, ETH Zurich, Switzerland
The ServiceGrass project: Effects of organic farming on ecosystem services and grassland multifunctionality

8. Bärbel Kroschewski, Humboldt-Universität zu Berlin, Germany
Analysis of a long-term nitrogen fertilization experiment on fen grassland and presentation of the results

9. Tatiana Rittl, Norwegian Centre for Organic Agriculture, Norway
Perennial leys for dairy cows: soil and plant attributes, yield and botanical composition with long-term low and high N input

10. Francisco Xavier Sans Serra, Universitat de Barcelona, Spain
The Gallecs trial, a mid-term experiment on reduced tillage, fertilisation and green manure in Mediterranean dryland arable cropping systems

11. Franz Schulz, University of Giessen, Germany
(presented by **Andreas Gattinger**, University of Giessen, Germany)
Organic arable farming experiment Gladbacherhof - productivity and soil parameters of different farm types and various soil tillage systems

12. Markus Steffens, FiBL, Switzerland
(presented by **Hans Martin Krause**, FiBL, Switzerland)
Carbon sequestration and stabilization in a 40-year agronomic long-term experiment

13. Liina Talgre, Estonian University of Life Sciences, Estonia
Organic cropping systems with winter cover crops in combination with composted manure significantly improve soil properties

14. Huyen Thai, Leibniz Centre for Agricultural Landscape Research (ZALF) e.V., Germany
Effect of long-term fertilizer management on spring and winter cereals on sandy soil in Northeast Germany

15. Yavar Vaziritabar, Justus Liebig University Giessen, Germany
Long-term effects of different previous crops and NPK fertilization on soil parameters and biomass yields of subsequent crops in the LTE “BSG” Giessen

16. Martin Wiesmeier, Bavarian State Research Center for Agriculture, Germany
Soil carbon dynamics in croplands under conventional and organic management in Bavaria

Poster session 2

Wednesday, 17.30 – 19.00

17. Daniele Antichi, University of Pisa, Italy
(presented by **Erik Steen Jensen,** Swedish University of Agricultural Sciences, Sweden)
Building a network of long-term experiments on agroecology and organic farming

18. Gilles Gagné, CETAB, Canada
Establishing a long-term experiment to study the effect of organic cropping systems on GHG emissions, carbon and nitrogen cycles and environmental efficiency

19. Meike Grosse, Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V., Germany
The BonaRes Repository: overview of long-term field experiments and provision of research data

20. Dominika Kundel, FiBL, Switzerland
Profiling soil microbial communities influenced by reduced summer precipitation and farming system history

21. Frank Liebisch, Agroscope, Switzerland
Phenotyping – a link between field experiments and agricultural practice?

22. Chloe MacLaren, Rothamsted Research, UK
Combining long-term experiments to quantify the contribution of crop diversity to sustainability

23. Jakob Magid, Copenhagen University, Denmark
What are the limits for recycling from society to organic agriculture?

24. Indrek Melts, Estonian University of Life Sciences, Estonia
Estonian semi-natural grasslands in historical perspective

25. Richard Ostler, Rothamsted Research, UK
The Global Long-term Experiments Network Metadata Portal

26. Vladimir Romanenkov, Lomonosov Moscow State University, Russia
Long-term timescale for implementation 4per1000 initiative: comparison organic and mineral fertilization

27. Colin Skinner, FiBL/University of Basel, Switzerland
Determination of greenhouse gas sources and sinks in Swiss arable soils under organic and non-organic management

28. Laura Summerauer, ETH Zurich, Switzerland
(presented by Astrid Oberson, ETH Zurich, Switzerland)
Influence of long-term fertilization and crop rotation on the 13C and 15N natural abundance of soils from the Saria soil fertility experiment

29. Odette Weedon, Universität Kassel, Germany
(presented by **Maria Finckh**, Universität Kassel, Germany)
Exploring agronomic performance of heterogeneous winter wheat populations under organic and conventional agricultural cropping systems in a long-term trial

Thematic workshop topics

Monday, 16.00 – 17.30

WS 1 Productivity, stability and resource use efficiency

WS 2 Nitrogen and phosphorus sources and use efficiency in the North and the South?

WS 3 Climate change and climate smart agriculture

Wednesday, 16.00 – 17.30

WS 4 Economics and life cycle assessment

WS 5 Biodiversity

WS 6 Future research needs and new designs of long-term experiments

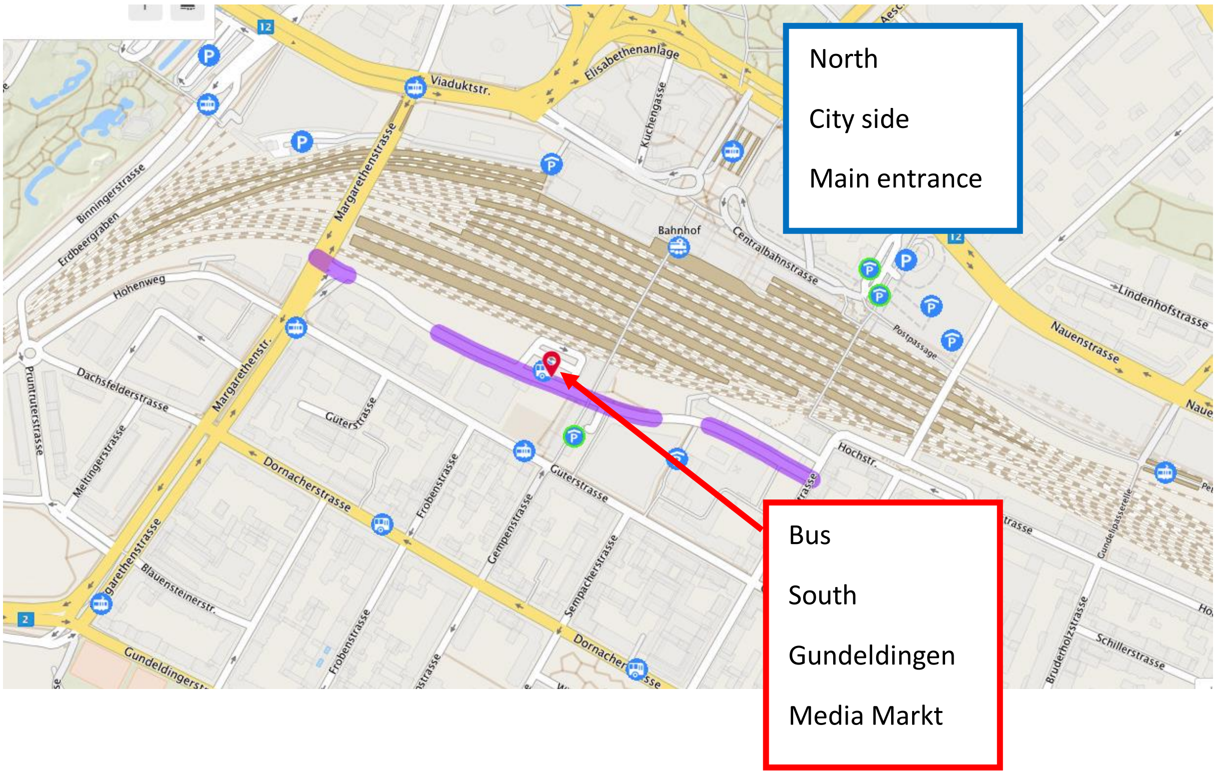
DOK Excursion Friday 11. October 2019

Address of the DOK trial: Birsmattehof in Therwil (7 km south of Basel)

In the morning of Friday Oct. 11, Paul Mäder and Jochen Mayer, the two responsible scientists and other staff members will guide you through the DOK field experiment, where bio-dynamic, bio-organic and conventional cropping systems are compared in a replicated field experiment since 1978. It is located in the Leymen valley, a region characterized by loamy soil developed on deep deposits of alluvial loess. An overview on associated ongoing or recently closed projects will be given (e.g., on drought stress, soil quality indicators, N_2O emissions, N and C rhizodeposition, root carbon turnover, Deuterium studies, P-cycling). Principle investigators and PhDs will present new projects on soil organic matter quality and soil metagenomics. We will also discuss future research questions and potential collaboration with visitors.

A bus is waiting for you at Basel SBB main station to bring you to the DOK site in Therwil and return to the station afterwards. The bus will leave on Oct. 11, 2019 at 8.30 am and return after the excursion before 12 pm. Departure and arrival are at Meret Oppenheim Strasse at the southern side (Gundeldingen) of Basel SBB station. You reach the Meret Oppenheim Strasse by entering the main hall of the SBB train station (northern side, city) and crossing the rail tracks on the walkway direction Gundeldingen (Media Markt). Before reaching the southern end of the walkway, turn left to a stairway that brings you down to Meret Oppenheim Strasse.

In case of any problems contact Paul Mäder +41 79 346 18 86 (mobile).



Abstracts

Abstracts of the oral presentations are sorted chronologically according to the program. Presenting authors are listed in bold.

Poster abstracts are sorted according to the numbered posters list in this book. Presenting authors are listed in bold.

Abstracts have been edited in style and formatting, but not in their contents, which remain the responsibility of the authors.

Longterm impacts of management on soil Carbon, soil life, and agricultural resilience in Mediterranean agroecosystems

Kate Scow, N. Tautges, M. Li and A. Gaudin

Russell Ranch Sustainable Agriculture Facility, Agricultural Sustainability Institute, University of California Davis, USA

Management practices that target soil health as well as crop yield maximization, increase the resilience of agriculture to pressures of drought, high temperatures, and climate unpredictability, while providing ecosystem services and other benefits to support agricultural sustainability. Long-term, replicated ecological experiments provide unique testbeds for investigating questions about climate change adaptation and mitigation over decadal time scales. At the University of California Davis's Russell Ranch Sustainable Agriculture Facility, the 100-year "Century Experiment" is a large-scale replicated study of 11 management systems with both vegetable- (tomato/maize and tomato/maize/alfalfa) and small grains- based systems, managed using conventional, organic, or hybrid management practices. Systems were designed along a gradient of input (e.g., irrigation water, carbon, and nitrogen fertilizer and pesticide use) intensity. We measure long-term trends in yield, water and energy use efficiency, soil health, and environmental impact. After 26 years, we find that crop yields, yield stability, soil microbial communities, and carbon sequestration differ substantially across different management systems. Long term benefits of adding inputs such as compost, but not biochar, were reflected in soil microbial communities, soil structure, nutrient cycling and carbon storage. Including winter cover crops into tomato-maize rotations decreased rather than increased deep soil carbon in conventional systems and did not benefit yields in the long term. RRSAF's rich historical data set, and data plan for decades to come, will help elucidate some of the mechanisms driving short- and long-term environmental responses to climate change, and provide support for agricultural management solutions needed to respond to the challenges that lie ahead

The DOK long-term experiment – lessons learned from 40 years of interdisciplinary research

Paul Mäder[a], H.-M. Krause[a], A. Fliessbach[a], K. Jarosch[b,c,d], A. Oberson[c], A. Gattinger[a,e], K. Birkhofer[f], S. Knapp[b,g], E. Frossard[c], U. Niggli[a] and J. Mayer[b]

[a] *Department of Soil Sciences, Research Institute of Organic Agriculture (FiBL), Frick, Switzerland*
[b] *Agroscope, Department Agroecology and Environment, Nutrient Flows, Zurich, Switzerland*
[c] *Institute of Agricultural Sciences, Plant Nutrition, Department of Environmental Systems Science, ETH Zurich, Switzerland*
[d] *Institute of Geography, Soil Science, University of Bern, Switzerland*
[e] *Organic Farming with focus on Sustainable Soil Use, Justus-Liebig University Giessen, Germany*
[f] *Brandenburg University of Technology, Germany*
[g] *Technical University of Munich, Chair for Plant Nutrition, Germany*

The world's growing population calls for sustainable food production within the limits of planetary boundaries. With respect to nitrogen and phosphorus cycling, the loss of biodiversity, land use change and the emission of greenhouse gases, four of these boundaries have been crossed already. Although fragmented knowledge of effects of different cropping systems on these focal planetary boundaries exists, there is a lack of comprehensive data from comparative cropping system experiments over the long run. Four decades back, farmers and researchers co-designed a system comparison experiment, located in Therwil (Basel-Land) Switzerland, comprising a seven-year ley crop rotation. Two conventional (with and without manure), and two organic systems (biodynamic and bioorganic) are compared. This experiment has served as a platform for national and international interdisciplinary research teams in the field of agronomy, soil quality, biodiversity, plant nutrition, food quality, sustainability assessment and modelling. Results of the 40years old DOK experiment show that organic systems, receiving distinctly less external inputs (chemical N, P, K and pesticides), maintained a higher biodiversity and produced lower greenhouse gas emissions. Yield averages over 40 years were 20% lower in organic systems across all crops. A nitrogen balance, including biological nitrogen fixation and stock changes of soil nitrogen, revealed a surplus for all manured systems, whereas the conventional system with sole mineral fertiliser was well balanced. Soil nitrogen stocks only increased slightly in the biodynamic system receiving composted manure. The biodynamic soil showed also increased soil organic carbon stocks, while the conventional soil receiving only mineral fertilizer acted as source for atmospheric CO_2. A climate impact analyses encountering nitrous oxide, methane and soil organic matter changes resulted in lower CO_2eq emissions in organic compared to the conventional systems, both area and yield scaled. Biodiversity and especially biomass of invertebrate fauna and plant seeds was enhanced in the organically managed systems. Our results demonstrate that organic cropping systems can contribute to a more sustainable production with respect to key planetary boundaries. To further improve system performance, yield gaps between organic and conventional systems need to be reduced by adapted cultivars, more effective organic plant protection and by closing urban and rural nutrient cycles.

The performance of yields in organic and conventional cropping systems

Jochen Mayer[a], L. Gunst[a], P. Mäder[b] and S. Knapp[a,c]

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Sufficient and stable crop yields are the basis for feeding a growing world population. Limited cropland, climate change, loss of soil quality and biodiversity coupled with excessive use of non-renewable resources require new solutions for future cropping systems beyond existing management practices. Here we compare the yield performance of organic and conventional cropping systems.

Average yields of organic cropping systems achieve 80% of conventional systems. However, large differences exist between crop types. Organic non-legumes yields achieve 75%, but legumes 90% of the conventional level. In high yielding regions where *potential yields* are approximately achieved the yield gap can be much greater. Organic systems achieved only 50% of cereal and 55% of potato farm yields in Germany. Also within the group of non-legumes, the yield gap differs largely. An evaluation of long-term cropping system experiments with a duration of more than 15 years show that wheat achieved about 70 %, potatoes 75%, but maize 82% of conventional yields.

Beside sufficient yield levels, a key question is how crop yield development performs in the long-term in different cropping systems. In addition, temporal yield stability is crucial for regional food security. Organic cropping systems show here, per unit yield, a 15% lower temporal static stability. Fertilisation, mainly nitrogen, is the main driver for the yield gap between the systems. However, results from the DOK experiment show that for the yield level, crop protection and fertilisation was important, stability was mainly determined by crop protection and not by fertilisation. An evaluation of the yield gap clearly showed that a high gap was caused by lower organic yields and comparatively constant conventional yields.

Yield trend analysis in the DOK experiment reveal positive or stagnating trends in all systems for wheat and maize over a data series of 40 years. Surprisingly the clover-grass ley yields tended to decrease over time in all systems and at different fertilisation levels. Neither a significant increase nor decrease in yield gap between organic and conventional systems could be observed. This finding is confirmed by the yield trends in organic-conventional long-term comparisons (≥ 15 years), which show in most cases constant or slightly increasing yields under organic management. However, also farm yields of wheat and maize under conventional management showed no positive yield development in regions with high yield levels like Central and North Europe since the 1990ies.

The future challenge will be to reduce the yield gap between organic and conventional systems by a substantial yield increase in organic systems without trade-offs between productivity and sustainability of agricultural management. The comparison of the regular fertilised mixed cropping systems in the DOK experiment with reduced fertilisation (50% of regular) clearly demonstrates the reasons for yield limitations of organic systems. The conventional system with reduced fertilisation gained higher or similar yields over all crops compared to the regular fertilised organic systems but it received less absolute amounts of nutrients with fertilisers. However, the conventional system received a higher amount of mineral nitrogen forms and it was treated with pesticides. Hence, the main drivers to reduce the yield gap are an improvement of nitrogen availability and a synchronisation between supply and crop demand. Further improvements in weed control by new technologies and crop protection by cultivars that are more resistant or by crop diversification will be a key measure of future management.

The Rothamsted long-term experiments

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Agricultural research began at Rothamsted in 1843 when the first of the "Classical" field experiments were established by Lawes and Gilbert. They are now widely recognised as the oldest continuing agricultural field experiments in the world. Most of the early experiments were located at Rothamsted Experimental Farm (Hertfordshire, UK), but later, other long-term experiments were established at Rothamsted and at Woburn Experimental Farm (78 ha), 40 km north of Rothamsted.

The early work on the Classical experiments focussed on the effects of fertilisers and manures on crop yields. These aims were achieved relatively quickly, but subsequently the experiments have been modified to include the use of lime, pesticides and new crop varieties to ensure that they remain relevant to current agricultural issues, whilst maintaining their long-term integrity. Consequently, today they are a unique platform for researching sustainable crop production using mineral fertilisers and other new synthetic inputs.

Two of the most widely known Classical experiments are the Broadbalk Wheat Experiment and the Hoosfield Barley Experiment. On Broadbalk, yields of winter wheat in rotation, receiving farmyard manure (FYM) or mineral fertiliser (but now with lime and pesticides and the latest short-strawed, high-yielding variety), continue to increase after 175 years of cropping; best yields now exceed 13 t ha^{-1} for wheat in rotation. On the Hoosfield Barley Experiment, yields of spring-sown barley also responded to the change to short-strawed cultivars in 1970, larger amounts of N and the use of fungicides since 1978. However, in contrast to autumn-sown wheat on Broadbalk, maximum yields are only obtained where soil organic carbon (SOC) has been increased through applications of FYM. This illustrates the importance of SOC to good soil structure and the rapid root growth needed by spring-sown crops to acquire water and nutrients.

About 300,000 samples of dried plant and soil material, collected from the long-term experiments since the 1840's, are stored in the Rothamsted Sample Archive and data collected from the experiments are stored in the electronic Rothamsted Archive (e-RA, http://www.era.rothamsted.ac.uk/). The long-term experiments together with the sample and data archives form the Rothamsted Long-Term Experiments National Capability. The experiments and associated resources have contributed to research in many areas of agro-ecology, specific examples include:

- Sustainable crop production
- Modelling soil carbon turnover
- Micronutrient deficiency in wheat
- Crop pathogen diversity and atmospheric sulphur deposition
- Fungicide resistance in plant pathogens
- Soil metagenomics

Details of some of the Rothamsted Long-term Experiments and examples of their contribution to agricultural research will be presented.

Long-term effects of different farming and fertilization systems on biomass yields and nitrogen uptake of crops in the LTE “IOSDV” Rauischholzhausen

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The International Organic Nitrogen Fertilisation Experiment, which is called as IOSDV was established at the Justus Liebig University Giessen (Research Station Rauischholzhausen) in 1983. This LTE (Long-Term-Experiment) is part of the IOSDV network that includes in total 15 LTE´s in several European countries and is being coordinated by the section of Agronomy of the Justus Liebig University Giessen. The general aim of this LTE is to investigate and to compare different farming systems (arable farming with/without organic fertilization or livestock farming) in relation to its effects on soil parameters and biomass yields for a long time.
The IOSDV Rauischholzhausen includes three factors (A: crops, B: N fertilization, C: organic fertilization) consisting of 45 variants (3 x 5 x 3) and was established as complete randomized design with three replications. The factors and variants can be characterized as follows: A (crops): silage maize (until 2008: sugar beet), winter wheat and winter barley, grown every year, B (mineral N fertilization): five treatments including control and C (organic fertilization): without organic fertilization, with farmyard manure, with straw plus green manure plus fermentation residues.
The presentation highlights selected results from the IOSDV Rauischholzhausen over the last twenty years. In particular, the plant parameters like biomass yields, harvest indices, N uptake and grain quality as well as the carbon and nitrogen contents of the soil will be presented. The existing results express clear impact of the farming and fertilization systems on soil fertility and biomass yields of the used crops.

Yield stability and nutrient use efficiency in wheat, barley, potato and field pea when comparing organic and conventional crop management from 2008-2017

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The aim of agriculture is to produce food of high nutritional quality in sufficient quantity. The sustainable crop management and soil protection is necessary in same time.
The aim of this study was to compare and analyse the impact of organic and conventional growing system to the yield, quality and efficiency of barley, winter wheat, field pea and potato.
The field experiment was established on 2008 on the experimental fields of the Estonian University of Life Sciences (58o 22´ N, 26o40´E) and the data was collected during the period of 2008- 2017 (two full rotations). Soil type was Stagnic Luvisol (sandy loam surface texture, C1,38% and N 0,13%, pHKCL 6,0). The experiment was set up in systematic block design with four replicates of each treatment and plot size was 60 m2. The field was divided by nitrogen treatments: three different treatment in organic plots (M0, MI with cover crops, and MII with cover crops and manure) and four different treatments in conventional plots (N0, Nlow, N100average, and Nhigh). The five-field crop rotation based on following order of the crops: barley (Hordeum vulgare L.) with undersown red clover, red clover (Trifolium pratense L.), winter wheat (Triticum aestivum L.), pea (Pisum sativum L.), potato (Solanum tuberosum L.).
The average yield in organic system was lower compared to conventional system. Winter wheat and barley yield was up to 50% higher in conventional farming and the 1000 kernel weight and protein content were significantly higher. Yield of field pea varied from 20-35% between farming systems. Thousand kernel weight was not influenced by the farming system, but protein content was the highest in the Nhigh conventional treatment. Potato yield was at least 30% higher in the conventional system, also contributing to the higher yield of larger tubers. However, the difference of yield in different farming systems varied from year to year. Nitrogen uptake followed the same trend for mineral and organic fertilizers.

Environmental and yield performance of organic and conventional crop production systems in long-term experiment in Puławy (Poland)

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In 1994 a special field experiment aimed to compare different crop production systems (organic, integrated, conventional and winter wheat monoculture) was established at the Experimental Station of the Institute of Soil Science and Plant Cultivation (IUNG) in Osiny (Lublin Voivodeship, Poland). Different crop rotations and crop managements were designed for particular systems. Organic system has been established as a 5-field crop rotation including: potato-spring barley (spring wheat since 2005) + undersown clover/grass mixture used for 2 years-winter wheat with a catch crop. As far as fertilization is concerned only manure (30 t/ha) was applied in this system. The conventional system (winter rape – winter wheat – spring wheat) has been run as an intensive crop production management, whereas the integrated one (potato - spring wheat – grain legume - winter wheat + catch crop) was designed as its less intensive variant. The area of each field in all systems was about 1 ha.

Research topics undertaken over the 25 years of the experiment's maintenance included, among others, evaluation of: crop productivity, energy efficiency, competitiveness with weeds, nitrogen and SOM dynamic in soil, stem base and root system and leaf infestation by fungal pathogens, usefulness of different modern and old cultivars of cereals and potato for organic farming, nutrient status of crops, performance of Leaf Area Index (LAI), crop quality and biodiversity of selected groups of invertebrates.

The average yield of winter wheat in the organic system for the last 20 years amounted to 4.4 t/ha and was by 30-34% smaller than in the integrated and conventional systems and 10% smaller than in monoculture of winter wheat. Smaller yields in the organic system were mainly caused by lower density of crop canopy. The average yield of potato in the organic system amounted to 25 t/ha and was by ca. 30% smaller than in the integrated one, mainly due to higher infestation of leaves by potato blight in the organic system.

In organic system due to diversified crop rotation and intensive application of special mechanical weed control it was possible to effectively avoid high weed infestation.

The majority of the compared winter and spring wheat cultivars showed only a few signs of fungal diseases on the root system and stem base, which was a result of a very favourable crop rotation. The key problem identified was the infestation of leaves by fungal pathogens. Old winter and spring wheat cultivars were stronger infested by pathogens than modern ones and as a result they yielded by ca. 1.5 t/ha less.

There were significantly more invertebrate taxa in winter wheat in the organic system than in its monoculture. Spring cereals were characterized by worse values of diversity indices than winter forms. The largest biomass of earthworms was found in the organic system, with their highest number under winter wheat and grass-clover mixtures, whereas in the integrated and conventional systems the biomass of earthworms was ca. 50% lower.

In organic system a decrease of potassium and phosphorus content is soil has been observed, however due to better recycling and application of appropriate natural fertilizers contents of these nutrients increased to sufficient levels. In conventional system and in monoculture a decrease of SOM content has been observed in last years.

Determining nutrient flows and nutrient use efficiency in long-term cropping systems experiments – Advantages and challenges

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Farmers must maintain the triple balance of 1) ensuring sufficient nutrients for sustainable crop production, 2) ensuring long-term soil fertility and 3) prevent nutrients in the cropping system from polluting the environment. While the farmer may be able to determine/estimate the input of nutrients from fertilizers and animal manure, it is much more difficult to estimate the amount of nutrient input from other sources, such as deposition, symbiotic N_2-fixation and weathering of parent rock materials. Similar it may be possible to determine the export of nutrient with the harvested crop, but much more complicate to determine nutrients lost by leaching, erosion and gaseous emission and the internal flows and nutrient cycle processes leading to plant nutrient availability or losses from the cropping system. Long-term cropping systems experiments (LTEs) are useful in obtaining knowledge on nutrient cycle processes over shorter or longer periods, e.g. when converting from conventional to biodynamic farming. The measurements in LTEs of nutrient inputs, cycle processes, exports and losses may strengthen the farmer ability to management the triple balance and sustainability of the cropping system. It is essential to bear in mind that LTEs may differ from real practical cropping systems, which are influenced by many factors such as soil type, local climate, farmer values and management. I will discuss advantages and challenges of nutrient budgeting and determination of nutrient cycle processes in long-term cropping systems experiments and some future challenges for nutrient management in organic farming systems.

Yield development and soil fertility – results of different phosphorus fertilizer practices over 20 years

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Results of long-term experiments are important for the interpretation of soil nutrients tests, yield performances and can give an extensive overview about the effectiveness of fertilizer strategies. At the Rostock long-term field experiment the effects of single and combined organic and inorganic phosphorus (P) treatments on soil P pools and plant nutrition are investigated since 1998: I) Control without any P, II) Triplesuper P (TSP), III) biomass ash (ash), IV) Cattle manure (manure), V) Manure x TSP, VI) Manure x ash, VII) Biowaste compost (compost), VIII) Compost x TSP, and IX) Compost x ash. Crop yields and soil characteristics were analyzed each year. For standard soil tests soil samples were taken of the top soil (0 – 30 cm) twice each year in spring and after the harvest of the crops. Additionally, for selected treatments further soil characteristics like enzyme activity and organic and inorganic P fractions were determined. Soil P pools were also analyzed from the subsoil 1 (30-60 cm) and subsoil 2 (60-90 cm).

Crop yields depended only partly on P supply and even after many years without P supply (control) yields must not be lower than in the P treatments with a P surplus. Differences regarding their sensitivity to P supply were found with lowest sensitivity for winter cereals and highest sensitivity for maize and potatoes. The P treatments influenced the soil P pools at which considerable differences could occur in dependence of the sampling date. The amount of P applied had a greater effect soil P pools in the top soil than the type of the P source, and no differences between organic and inorganic P treatments were found. The P budgets could not fully explain changes of soil test P in the topsoil over time. Beside vertical movements of P we also expect surface run-off and transformation of soil P fractions.

In the subsoil 1 the labile and moderate labile fractions (P-water, P-lactate, P-$NaHCO_3$, P-NaOH) were mainly increased after TSP application and the stabile fractions (P-H_2SO_4, P-residual) were mainly increased in the combined treatments with high P surplus. Also in subsoil 2 higher P concentrations in the labile P fractions were found in the treatments with TSP application. In the control the subsoil 2 contained about 20% of the bio-available P in the soil profile (0-90 cm). In the combined treatments this portion was lower with about 15% which indicates an accumulation of P supplied mainly in the upper soil layers.

Application of organic fertilizers increased the activity of enzymes in soil (phosphatases and dehydrogenase). However, these activities were also found to be affected by crops resulting in highest activities under mixed cropping system where a monocot crop was combined with a legume crop (maize + phaseolus bean or sorghum + Andean lupin).

Results of this long-term experiment showed, that fertilizer practices only partly affected crop yields. For soil characteristics the fertilizer effects were more pronounced. Crops also may have a considerable effect on soil characteristics, even after only one vegetation period.

Soil phosphorus (P) budgets, P availability and P use efficiencies in conventional and organic cropping systems of the DOK trial

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

We used data obtained from the DOK (dynamisch, organisch, konventionell) long term field trial obtained during a 35-year period. The trial was established in 1978 near Basel (Switzerland) and consists of four different cropping systems using different sources of P fertilizer: BIODYN: biodynamic (composted farmyard manure and aerated slurry), BIOORG: bioorganic (rotted manure and slurry), CONFYM: conventional with farmyard manure and slurry, complemented with mineral fertilizer and CONMIN: conventional with mineral fertilizer only. Rates of fertilizers application equal 1.2 livestock units (increase to 1.4 at the 3rd crop rotation period of 7 years each). All cropping systems except CONMIN are also maintained at a reduced (i.e. halved) fertilization level. We calculated a soil surface P budget considering all relevant P inputs (fertilization, seeds) and outputs (removal by crops) on a plot level (12 plots per cropping system). At commence and at the end of each crop rotation, plant P availability was estimated by soil P extraction with carbon dioxide saturated water as well as by determining isotopically exchangeable P.

Phosphorus inputs surpassed the outputs in conventional cropping systems CONFYM and CONMIN, resulting in a positive P-budget between +3 and +6 kg P / ha * yr in average. The trend was reversed in organically managed cropping systems BIODYN and BIOORG, having negative P-budgets between -3 and -6 kg P / ha * yr in average. Additionally, all cropping systems with reduced fertilization levels had a negative P budget as well (-11 to -13 kg P / ha * yr). Plant P availability generally decreased within the first crop rotation period in all cropping systems, likely as a result of depleting high soil P stocks that were established before the start of the field trial. Plant available P continued to decrease since then in cropping systems with reduced fertilization, while it stabilised in the more balanced cropping systems.

In summary, while conventional cropping systems risk to apply P at rates higher than actual plant removal, a P limitation for crops in organically managed cropping systems may establish in the long run if current fertilization recommendations are pursued. The results of the P budget will be further discussed including data on soil P stock changes, evaluations on P availability to crops (derived from isotopically exchangeable P) and estimates on fertilizer use efficiencies in different cropping systems.

Nitrogen budgets and soil nitrogen stocks of organic and conventional cropping systems: how reconcile efficiency and sustainability of nitrogen use?

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Organic and conventional cropping systems differ in the nature and amounts of nitrogen (N) inputs, which may affect efficiency and sustainability of N use. In the DOK (bio-Dynamic, bio-Organic, Konventionell) field experiment, organic and conventional cropping systems have been compared since 1978 at two fertilization levels (with level 2 being typical for the respective system and level 1 receiving half of this dose). Nitrogen inputs via manure and/or mineral fertilizers and N exports from plots with harvested products have throughout been recorded. For all treatments, N outputs with harvests have exceeded the inputs with fertilizers. Over the past years, symbiotic N_2 fixation by soybean and clover grown in the trial has additionally been assessed using ^{15}N isotope techniques. The estimates indicate average annual inputs from about 90 to 120 kg ha^{-1} yr^{-1} of N fixed from the atmosphere, depending on the treatment. Soil surface budgets opposing N inputs via fertilization, symbiotic fixation, seeds and deposition to N outputs via harvested products have been computed at the plot level for the duration from 1985 to 2012. The resulting balances range from negative values of about -20 kg N ha^{-1} yr^{-1} (in the non-fertilized control where outputs exceed the sum of said N inputs) to surpluses of about +55 kg N ha^{-1} yr^{-1} in the conventional treatment with mixed organic-mineral fertilization. The budget based N use efficiency (NUE; N output via harvested products divided by sum of N inputs) in the case of negative balances suggests irrationally high NUE (>100%), while positive balances are related to lower NUE for treatments with inputs exceeding outputs. Negative budgets indicate soil N mining, while surpluses point to a risk of N losses and/or N accumulation in the soil. Estimation of soil N stock changes based on yearly total N concentration measurements in the topsoil layer are ongoing. Preliminary results suggest that soil N stocks in the topsoil decreased under all treatments more than expected from the N balance and that positive N balances are needed to maintain topsoil N stocks. No increase in soil N concentration was observed in any of the treatments. In conclusion, the results indicate an efficiency-sustainability trade-off. Soil N stocks decrease more in treatments with a higher NUE than those with a lower NUE. At the same time, treatments with lower NUE suggest higher N losses from the studied crop-topsoil system. The presentation will address the role of the different fertilizer N forms and doses and will expand the budget based NUE with difference method based NUE estimates, so as to discuss on how to best reconcile N use efficiency, N losses and maintenance of soil N stocks.

Interspecific root interactions enhance nitrogen acquisition, symbiotic N2 fixation, and N transfer in foxtail millet/peanut intercropping

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Intercropping is commonly practiced worldwide because of its benefits to plant productivity and nutrient use efficiency, especially for cereal/legume combinations. However, there is little knowledge available on the mechanisms involved in the increased N acquisition of the intercropping systems. Thus, this study was performed to quantify the yields and nutrient uptake of component species in millet/peanut intercropping systems in response to root interspecific interactions and to explore the mechanisms underlying the facilitation of the cereal/legume intercropping. A 2-year field study was conducted to investigate the crop productivity and Land equivalent ratio in cereal/peanut intercropping under 4 Nitrogen rates and 3 cropping patterns (mono-millet, mono-peanut and millet/peanut intercropping). And a greenhouse experiment was designed to explore the mechanism of facilitation in the intercropping under three root barriers producing full, partial and zero interspecific root interactions between foxtail millet () and peanut (), and either peanut or soil was labelled with ^{15}N with three replicates. The results of field study showed that the land equivalent ratios (LERs) of intercropping were greater than 1 under all four N application levels, indicating some yield advantages of the intercropping. Nitrogen acquisition of intercropped millet and peanut was also higher than that of correspongding monocultured species across all the N rates. Pot experiment showed similar results, where the yields of millet and peanut in the treatments with full interspecific root interactions were 134–221 % and 167–192 % greater than those with no interspecific root interactions. Nitrogen acquisition of millet and peanut with full interspecific root interactions increased by 64.2–156 %, compared with zero interspecific root interactions. The enhanced dry matter biomass and N acquisition of intercropped millet and peanut were mainly derived from below-ground root interactions in the intercropping systems. Millet was a stronger competitor on soil and fertilizer N, thus had an advantage of N acquisition. At the same time, the N competition of millet resulted in a decrease of soil mineral N concentration in the intercropping. Consequently, peanut, was forced to acquire more nitrogen via symbiotic N2 fixation to meet its nitrogen demand, compared to monocultured peanut. Nitrogen transfer from peanut to millet accounted for 2.53 and 17.6 % of total N acquisition of millet in partial and full interspecific root interactions. Our results shed light on efficient use of nitrogen by enhanced symbiotic N2 fixation in cereals/legumes intercropping, which has potential importance in organic agriculture. .

Soil quality: a critical review and a look into the future

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Soils are complex systems with physical, chemical and biological properties which depend on pedo-climatic conditions as well as previous and current land use. Soil status and use potential is frequently assessed from plot to national scales, using either visual examination or laboratory analysis of samples. However, the choice of relevant soil attributes and interpretation of measurements are not straightforward. In this presentation, we review soil quality and related concepts, in terms of definition, assessment approaches, and indicator selection and interpretation. We identify the most frequently used soil quality indicators under agricultural land use. We also consider novel indicators as evaluated using 10 European long-term field experiments. Explicit evaluation of soil quality with respect to specific soil threats, soil functions and ecosystem services is rare, and few approaches provide clear interpretation schemes of measured indicator values. This limits their adoption by land managers as well as policy. The development of a soil quality assessment procedure that is scientifically sound and supports management and policy decisions that account for the multi-functionality of soil requires the involvement of the pertinent actors, stakeholders and end-users. Several interactive tools that are currently being developed will be shown and can be tested during the field trip of the conference.

Change of biological soil quality in organic and conventional farming systems of the DOK trial

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The DOK trial has started in the 1970ies, when first reports warned us on the consequences of our actions and the limits to growth. Even though farmers and a huge research community know better, we are still not managing our soils in a sustainable way. It seems inevitable that the mainstream agriculture wants to go beyond natural frontiers. Soils have an enormous buffering capacity, but this ends, when ecosystems are collapsing not only at the local, but also at the global level.

If we were to measure sustainable land use and management for the justification of subsidies to farmers from taxpayers' funds, we would certainly look at water quality and biodiversity, supported by ambassadors like sparkling waterfalls, pandas or butterflies to address our feelings. It does not help much towards human stupidity, but soils have no such ambassador, even though earthworms try hard. We are not consuming soils directly and our minds are not confronted with positive images to support the life of soils. However, soils are at stake! Soils harbour a vast diversity of organisms that are carrying out important ecological processes. The decomposition of the organic material produced naturally, but also some of the most complex chemical compounds human minds have developed, can be decomposed if not by one then by the co-metabolism of several organisms.

Soil organic matter and soil organisms are guarantee for maintenance and improvement of the structural stability of the soil and the support of soil functions. Farmers on marginal land in the South are complaining that soils are not responding to fertilizer and they are struggling to improve soil quality since this investment does not pay off after one vegetation phase. Due to the potential of carbon sequestration with co-benefits for food security, climate change adaptation and mitigation, soils are high on the political agenda. Policy measures are about to solicit tax funds, which may motivate farmers and any other soil users to invest in the build-up of SOM. If consistently done, it may not only help the climate.

Organic farmers are setting up their arable systems by organic fertilization strategies that recycle nutrients, but also organic matter at the farm level. Most Swiss farmers produce according to guidelines of label organisations (IP Suisse, Bio Suisse, Demeter) with mixed livestock and arable crop production and use manure as well as multiannual grass-clover leys. This constitutes the typology of the farming systems compared in the DOK-trial.

We will present the chronology of approaches looking for a change in soil quality brought about by land management. We will focus particularly on carbon as the driving element of biological soil processes. In this regard, the differences between the DOK farming systems are due to the amount and quality of the fertilizers and the strategy of plant protection. The soils of the DOK trial represent a perfect platform to evaluate the sensitiveness of soil quality indicators to crop and soil management.

Beneficial effects of reduced tillage on soil aggregation and stabilization of organic carbon in an irrigated semiarid Mediterranean ecosystem

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Arid and semiarid regions represent about 47% of the total land area of the world (UNEP, 1992). At present, there is a priority interest for carbon (C) sequestration in drylands. These soils are considered “hot spots” due to their importance for crop production and human food security. In addition, the promotion and development of the best sustainable land management practices (SLM) for soil conservation and mitigation of climate change and to maintain acceptable levels of soil organic matter and good structure in these environments are ones of the major challenges for scientists.
Long-term effect of three different SLM were studied in a irrigated crop of lemons (Citrus limon, var. Fino and var. Verna) under Cacaric Regosol in Murcia (SE Spain). Since 1970, the habitual soil management in the study area was conventional tillage with flood irrigation (T). In 1987, two different sustainable land management practices (SLM) were applied: (i) reduced tillage (until 10 cm soil depth) plus incorporation of the lemon prunis (RT + P) and (ii) no-tillage plus left lemon prunis on the top soil (NT+P). In 2012, drip irrigation was established in RT+P and NT+P. In addition, this year sheep manure (2.4 kg m^{-2}) was added only in RT + P treatment. Four aggregate size classes were differentiated by wet sieving (large and small macroaggregates, microaggregates, and the silt plus clay fraction.
In addition, in order to derive sensitive SOM pools, a promising physical fractionation method was developed that enables the separation of four different SOM fractions by density, ultrasonication and sieving separation: fine particulate organic matter (fPOM), occluded particulate organic matter (oPOM), mineral associated organic matter (sand and coarse silt, > 20 µm; medium + fine silt and clay, < 20 µm) and carbonates of total soil organic C. In addition, the OC associated to LM (> 2000 µm, large macroaggregates) decrease with soil depth in all treatments. The same was observed in OC associated to m (63-250 µm).

Vital soils for sustainable intensification of agriculture: A chronosequence approach to organic agricultural research

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The project Vital Soils for Sustainable Intensification of Agriculture investigates the dynamic changes in soil properties after conversion from conventional to organic production. Better understanding of these changes would enable accelerated development of productive soil conditions and help to reduce the yield gap between organic and conventional management. A network of 37 operational organic farms has been selected in the Netherlands, on either sandy or clay soils. Each represents a known period of time since conversion and is paired with a nearby conventional field with comparable history and soil. These pairs of farms constitute a novel chronosequence of organic agricultural management spanning a period of 60 years of organic production. Soil was sampled from all the farms, with subsequent chemical, physical and biological analysis as well as functional assays. The chronosequence demonstrates differences in soil microbial communities and nutrient cycling, dependent on time and management. The investigation of operational farms is extended by observations under more controlled conditions at the Vredepeel long-term experimental farm (13-year organic/conventional comparisons) as well as targeted greenhouse and laboratory experiments to support mechanistic interpretation of soil processes and management effects. This presentation provides an overview of the project.

Influence of long-term organic and conventional cropping systems on soil microbial population size and structure

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Organic agricultural systems depend on microbial communities for a variety of agroecological functions, including cycling of nutrients, promoting plant growth and defense mechanisms, and building soil structure and organic matter. The recent inclusion of soil microbial activity as part of commercial farm soil tests demonstrate the growing interest from organic farmers with respect to the impact of their production practices on soil microbial populations. However, a dearth of information exists as to the best management practices that should be employed to optimize soil microbial populations. To better understand the influence of different agricultural management practices on soil microbial communities, we assessed soil biological and chemical properties of different cropping systems representative of Midwestern production systems. The study was conducted at the Wisconsin Integrated Cropping System Trial, a long-term trial (26 years) at the University of Wisconsin Arlington Agricultural Research Station, Columbia County, WI. The trial includes several crop rotation strategies, including a conventional and organic cash grain rotation, a conventional and organic dairy forage rotation, and a low-input pasture. The main differences between those cropping systems include type and amount of fertilizer, tillage regimes, crop rotation and weed management strategies. Soil was sampled in the spring of 2016, after the corn phase of the crop rotations when relevant. Soil DNA extraction was performed, followed by 16S and ITS sequencing, phospholipid fatty acid (PLFA) PLFA profiling, and soil chemical properties assessment. The description of the microbial population at the Operational Taxonomic Unit (OTU) level provided by 16S DNA sequencing showed that the row crop, forage, and pasture systems differ in their soil microbial community profiles. More specifically, while showing the most divergent bacterial population as compared to the other cropping systems characterized, soil microbial populations within the pasture system were more similar to the dairy forage than to the grain system. The comparison of total microbial biomass as well as different microbial guilds as described by PLFA extraction demonstrated similarities in soil microbial composition between pasture and dairy forage system and always differentiated pasture soils from those of the grain systems. The management factors appearing to influence soil microbial communities were presence of legume crop; perennial phases of the rotation; presence and amount of manure applied; and degree of soil disturbance. An analysis of the interactions between soil chemical and biological properties demonstrates that pH and total nitrogen have the highest impact on soil microbial populations.

Relevance of rhizosphere processes at field scale – a road map based on imaging techniques

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Rhizosphere processes potentially enhance water and nutrient acquisition, soil structure and soil carbon storage. In addition, rhizosphere processes shape the microbiome by supplying specific substrates and shaping the habitat. All solutes taken up by plant roots or being released by roots into the soil, pass through this mostly narrow region of soil altered by plant roots designated as rhizosphere. Many of the processes require some investment by the plants, whether it is carbon for root growth itself, for exudate production, production of secondary metabolites or for establishing symbioses with beneficial microbes. This investment potentially pays off in systems in which resources required by plants are sparse or not readily accessible.

Despite a wealth of research we still know little on the efficiency of the whole system, particularly as we lack information on the spatiotemporal organisation of the rhizosphere. I.e. we have little information based on the radial geometry of rhizosphere processes on how far gradients extend from the root surface into the bulk soil, how long such gradients exist in time and how they change along the root system or with root ontology. Many of the ground breaking studies in the past are based on investigation of early growth stages in rhizoboxes or compartment systems i.e. linearized systems or pseudo 2D systems in which roots grow along transparent planes. In addition, we saw in the past an increasing separation of the disciplines as new methods developed and this is detrimental for understanding a system as complex as the rhizosphere.

Spatiotemporal organization of the rhizosphere is a key to understand rhizosphere functions. Major challenges are (i) the integration of spatial patterns for physical, chemical and biological parameters in 2D and 3D for systems reflecting radial root geometry and (ii) bridging the relevant scales of local interaction. The latter, ranging from nm to mm around a single root, and to cm for the root system perspective.

Within the framework of the priority program "spatiotemporal organization of the rhizosphere – a key to rhizosphere functions", funded by the German Research Foundation, a hierarchal sampling approach for the lab and the field scale was developed. The approach aims at the integration of a range of imaging techniques from different disciplines. For the large scale (7 cm ∅) X-ray CT scanning provides temporal and spatially resolved data on root architecture, root age, diffusion lengths/travel distances and soil structure development which integrates information from in situ soil solution samplers, spatially informed sampling of the microbiome, the root gene expression and exudation as well as enzyme activity. At the small scale (1.6 cm ∅ subsamples) X-ray CT scanning enables registration of 2D chemical information from different microscopy and micro-spectroscopy methods, and potentially also information on distribution of microbes, back into the 3D context. By merging the scales root age information is available for both approaches and can be used to explain root-age specific uptake and release patterns. Drivers for pattern formation are corn genotypes differing in root hair formation (WT,) and two different soil textures (sand, loam) differing in transport properties. First results for the central experimental platforms established at field and labscale will be presented.

Long-term root adaptation to organic and conventional farming in heterogeneous wheat populations

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For optimal performance in a given farming system breeding should be done for and within that system. In addition to the system specific breeding, especially in the organic sector breeding for diversification has become popular. In the EU, diversified populations will be allowed in the future for organic farming.

Early vigour is especially important for optimal performance in organic systems in order to compete with weeds. Especially the root development and distribution are of importance for N acquisition and competitive ability. We studied if and how early root development adapts to the growing system in wheat populations evolving either under organic or conventional conditions. Since 2005/2006 (starting with the F_5), three winter wheat composite cross populations (CCPs) have been grown at the University of Kassel, Germany in large enough plots to avoid genetic drift. The CCQ population is based on the crossing of 12 varieties with good baking quality. The CCY population is based on the crossing of 9 high yielding varieties. The third population CCYQ was created through the intercross of the Q and Y parents. The CCPs were split and grown either organic (O) or conventional (C) management and within management system, two non-mixing parallel populations (I and II) were maintained, resulting in a total of 12 populations (6 organic and 6 conventional), allowing for statistical comparsions of the CCPs both within and between systems. Frozen seeds of the F_6, F_{10}, F_{11} and F_{15} seeds were multiplied in one field to eliminate storage effects. The early root and shoot development of these generations was assessed after two weeks under hydroponic conditions. Seedling traits were similar among parallel populations. In both systems, Q and YQ CCPs were more vigorous than Y CCPs, pointing to persisting genetic differences among populations. Shoot length and weight increased in both systems until the F_{11} across farming systems and remained constant thereafter. Over time, seminal root length and root weight of organic CCPs increased and total- and specific- root length decreased significantly compared to the conventional CCPs. A severe winter kill during the season when the F_{11} was growing reduced root lengths in that generation. However, this effect was not persistent as seen in the F_{15}. The change in rooting patterns under organic conditions suggests better ability to reach nutrients in deeper soil layers. Overall, heterogeneous populations appear very plastic and selection pressure was stronger in organic systems. The results show that heterogeneous populations will adapt to the growing system over time.

New insights in below ground nitrogen of clover-grass mixtures

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Estimates of symbiotic nitrogen fixation (SNF) of clover in mixtures usually consider only aboveground clover nitrogen (N). However, belowground inputs of clover N derived from SNF via roots and rhizodeposition and its transfer to associated grass may contribute significantly to the amount of symbiotically fixed clover N. A microplot study with a red clover (L.)-perennial ryegrass (L.) model mixture was conducted within zero fertilised, bio-organic and conventional field plots of the DOK (bio-Dynamic, bio-Organic, Konventionell) long-term experiment during two consecutive years. The DOK experiment has been performed since 1978 in Therwil near Basel (CH). Examined cropping systems were fertilised at the typical level according to the respective regulations and, in addition, at the half level (bio-organic). Fertilisation strategies resulted in a gradient of mineral N input increasing from the zero fertilised control (0 g m^{-2} a^{-1}) to the bio-organic cropping system at half dose (2 g m^{-2} a^{-1}), at full dose (4 g m^{-2} a^{-1}) and to the conventional cropping system (12 g m^{-2} a^{-1}). Clover was multiple ^{15}N urea leaf labelled during two cultivation years. Symbiotic N_2 fixation and the fate of symbiotically fixed N in the soil plant system were examined using a combination of ^{15}N enrichment and natural abundance approaches. Results of the microplot study were scaled up using yield data compiled from field plots of the DOK experiment. The ratio of red clover belowground N to aboveground N was constantly 0.4 to 1 irrespective of the cropping system and the time of cultivation. Forty percent of perennial ryegrass N were transferred from red clover in zero and low N (< 5 g m^{-2} a^{-1}) fertilised cropping systems. Total SFN over the two years period was on average 37 g m^{-2}, with a contribution of 90% to red clover N (conventional system > 80%). On average 19 g m^{-2} clover N and 29 g m^{-2} grass N were harvested during the 2 years of cultivation. At the end of the second year, about 5 % of total SNF were stored in clover roots. During the two years, 50% of total SNF was deposited into the soil and further distributed to soil organic matter pools, microbial and soluble N (15% of total SNF) and to the grass partner (35% of total SNF). At the end of the two years, a residual N potential of SNF of 10 g m^{-2} remained in the field. Residual N consisted of N in clover roots (5% of total SNF), clover stubbles (1% of total SNF), grass stubble and roots (8% of total SNF) and soil N pools (15% of total SNF). Thus, a realistic estimation of SNF of red clover in mixtures should take into account belowground N pools and N transfer.

Fertilization intensity and the fate of root carbon in soil within two years after harvest

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Root carbon (C) allocation below ground contributes substantially to C inputs into soil and the build-up of soil organic matter in agroecosystems. During their life cycle, annual crops steadily accumulate root biomass, which enters senescence at physiological maturity and finally dies off following harvest. Additionally, living roots release a variety of organic compounds into soil, which can account for more than half of net root C inputs to soil at harvest. As an essential energy source for soil biota, root C either gets quickly respired or remains in more persistent soil organic matter pools for some time. Not only is the amount of produced root C determined by a multitude of biological and pedoclimatic factors, but also its residence time in soil. To date, the effects of farming practices such as nutrient supply or soil management on root C production have been studied much more intensively than those on the fate of root C in soil after crop harvest. However, this information is crucial for the assessment of C dynamics in agroecosystems. The aim of the present study was, therefore, (i) to quantify the amount of remaining crop root C in soil after one and two years after harvest on two agricultural sites, (ii) to evaluate the effect of fertilization intensity on C loss rates in the topsoil, and to (iii) determine the distribution of remaining crop root C in different soil layers.

The study was conducted between 2013 and 2015 in two Swiss long-term field experiments: DOK and ZOFE (Zurich Organic Fertilization Experiment). On both sites, treatments with pronounced differences in fertilization intensity (long-term mineral NPK input relative to recommended NPK fertilization) were selected, namely BIOORG1 (0.4), BIOORG2 (0.8), and CONFYM2 (1.2) in DOK and CONTROL (0), MANURE (0.5), N2P1K1 (0.7), and N2P2K2Mg (1.1) in ZOFE. In 2013, maize was grown in microplots and weekly labelled with 99% $^{13}CO_2$ during the entire growing season. After harvest, the microplots were bisected and root biomass and soil were sampled in three layers to 0.75 m depth by excavating one half. The other half was left undisturbed in the field and sampled in spring and autumn 2014 by taking two soil cores, respectively, and in autumn 2015 by excavating the remains. Roots and root fragments were separated from soil by 0.5-mm wet sieving and all pools were analysed for ^{13}C. Total maize root C in the three soil layers was calculated from ^{13}C excess in roots, root fragments, and soil and C loss rates in the topsoil were determined for each treatment.

The amount of remaining total maize root C in soil to 0.75 m depth averaged 53% in DOK and 48% in ZOFE after one year and 47% in DOK and 29% in ZOFE after two years. Thus, C loss was similar on both sites during the first year, but decelerated considerably in DOK while it remained high in ZOFE during the second year. In DOK, roots and root fragments contributed roughly 40% to total maize root C after harvest and less than 20% after one and two years each. In ZOFE, this proportion was larger than 50% after harvest and one year and less than 20% after two years. Treatment differences in loss rates in the topsoil were generally small: Loss rates were similar among treatments in DOK but tended to increase with increasing fertilization intensity in ZOFE. Further data analyses will focus on the depth distribution of the remaining root C in soil.

Diversity of arbuscular mycorrhizal fungi in agricultural systems

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Arbuscular mycorrhizal fungi (AMF; Mucoromyceta) are an important component of fertile soils, as for instance they improve plant growth and health, stabilize soil aggregation and retain macro- and micro nutrients in the upper soil layers. Currently, > 300 species are known worldwide. This number is steadily increasing, since many detected species have not been described, while others have so far remained undetected. During the last 20 years, the diversity of these fungi were studied in a series of natural or agricultural soils in Central Europe, or elsewere, under different climatic conditions, and subjected to different conventional or organic farming and soil tillage practices. It was found that multiple AMF species as well as the overall AMF community structure can be used as powerful indicators in various aspects such as agricultural sustainability, soil fertility, water and nutrient budgets, or soil degradation due to over uses or climate change. About 2-60 species were detected in natural and agricultural soils depending - among other factors - on climate, land use type and intensity, plant species diversity and specific soil parameters. In arid soils, only Glomeraceae, Diversisporaceae or Paraglomeraceae species were detected. Under semi-arid to humid conditions, also others such as Acaulosporaceae, Gigasporaceae and Racocetraceae species occur, but they are generally more sensitive to high fertilization levels than Glomeraceae species, and often they are less common in neutral to alkaline soils. In a wide range of soils types, e.g. Tschernosems, Luvisols, Cambisols and Ferralsols, a high AMF diversity can be found even under intensive agricultural production, as long as the majority of the fungi have suitable living conditions during the vegetation periods. Also herbicide and even repeated fungicide applications might then be only minor factors affecting the overall AMF communities in the soils. Nevertheless, organic farming systems generally show a higher AMF diversity than conventional farming systems. AMF diversity can, however, be dramatically decreased, especially when the plant root and hyphal network is periodically disturbed by harsh tillage practices, or when plants suffer due to increasing drought events. For Central Europe, e.g. *Acaulospora paulinae* and *A. sieverdingii* are useful microbial indicator species for fertile soils and sustainable land use in siliceous soils, while *Rhizoglomus invermaium*, *Dominikia aurea* and *Do. bernensis* can be used as indicators also in calcareous soils, as observed in several long-term field experiments from Germany or Switzerland.

Effect of agricultural management practices on soil ecosystem services

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Agricultural management practices that mitigate soil threats also affect other ecosystem services, such mitigation of climate change. A model to upscale the scientific empirical results at the site level to the wider geographical context is presented, and then applied to Europe and China. The upscaling model is necessarily a simplification of the complex processes that influence and are influenced by soil management at the local level. The central actor in the modelling process is the farmer, who is managing a plot of land where a certain crop is grown under a typical farming system. This plot of land is subject to a physical context, determined by soil type, climate, water availability and other factors that control biophysical processes. The farmer is also immersed in a socio-economic context that influences agricultural policy. Practices of organic agriculture are compared with other management practices. Our results show that even with an additional 10% implementation, the effect of improved management is significant in most European and China regions and all the crops considered in this study.

The role of agronomic management practices on greenhouse gas emissions in a long-term field trial

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Reducing agricultural greenhouse gas emissions (GGE) requires contemporary agronomic management practices. In this regard, organic farming (OF) is considered to help implementing sustainable land use practices. However, the determination and interpretation of GGE in both integrated (IF) and OF systems requires carefully monitored field scale data.
This study explores the effect of tillage (minimum vs. plough) and fertilisation (high vs. low) practices on GGE as currently used in IF and OF. With the analysis of long-term evolving soil properties, this study creates a link between different management systems and GGE as well as the observed cycle of matter. From 1992 to 2015, measurements have been carried out at the research farm Scheyern, located in a relatively fertile Tertiary hilly landscape. Here, field trials of OF and IF have been conducted with the same crop rotation, tillage and fertilisation practices, thereby enabling time series of management impacts on soil of more than 20 years. Since 2012, emissions of CH_4 and N_2O have been monitored for the IF and OF field trial by using an automated system (i.e., motor-driven lid chambers, automated gas sampling unit, on-line gas chromatographic analysis system, control and data logging unit). Precipitation and temperature records exist for each experimental field. Soil properties (e.g. WFPS, SOC, N_{min}, C_{mic}) have been examined in short time intervals and in different depths to aggregate the parameters and processes influencing GGE.
Thus, main outcomes of this study include the temporal and spatial dynamics of GGE with regard to management practices (i.e. fertilisation, crop incorporation, tillage) and meteorological events (i.e. drying-rewetting/freezing-thawing cycles, intense rainfall, dry periods). Results on the comparison between OF and IF show higher N2O emissions in IF for both events and practices, especially drying-rewetting and freezing thawing events on the ploughed plots. Considering the N_2O emissions per harvested product, we investigated the following order: OF minimum (89.5 ng N MJ^{-1}) > OF plough (37.5 ng N MJ^{-1}) > IF minimum (24.2 ng N MJ^{-1}) > IF plough (15.1 ng N MJ^{-1}). In contrast, ecological evaluation show higher SOC and biodiversity for the OF plots. In this way, our study will help to contribute to a set of "best management practices" for decision makers to compromise economic and ecological considerations.

Can organic cropping systems mitigate nitrogen losses and improve GHG balance? Results from a 19-yr experiment in Northern France

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Alternative cropping systems are promoted to reduce nitrogen (N) losses in the environment and mitigate greenhouse gas (GHG) emissions. However, these supposed benefits are rarely studied together and on the long term. We studied the N inputs, N exports, storage of soil organic N (SON), N leaching, gaseous N emissions and GHG balance in a 19-yr field experiment comparing four arable cropping systems without manure fertilization, namely conventional (CON), low-input (LI), conservation agriculture (CA) and organic (ORG).
Systems differed in soil tillage, crop succession and protection, fertilization and crop residues management. The crop rotation of CON and LI was the following: rapeseed, winter wheat, spring pea and winter wheat. Conversely, alfalfa replaced pea and rapeseed in the ORG system. A permanent cover crop, composed of festuca in the first years and alfalfa thereafter, was maintained under the main crop in CA system. Some of the alfalfa cuts were returned to soil, with a proportion of 50% and 67% in CA and ORG systems, respectively.
The N surplus, i.e. the difference between total N inputs and exports, was lowest in LI (43 kg ha^{-1} yr^{-1}), intermediary for CON and ORG with 63 kg ha^{-1} yr^{-1} and highest in CA (163 kg ha^{-1} yr^{-1}). CA and ORG received high amounts of N derived from biological fixation from alfalfa. The annual SON storage rates markedly differed between cropping systems: CA (55 kg ha^{-1} yr^{-1}) > ORG (30) > CON (13) = LI (6). N leaching, calculated using soil mineral N measurements, was 20 kg ha^{-1} yr^{-1} in average and did not significantly differ between treatments. The total gaseous N emissions (volatilization + denitrification), calculated as the difference between N surplus, SON storage and N leaching, ranged from 12 kg ha^{-1} yr^{-1} in ORG to 83 kg ha^{-1} yr^{-1} in CA. N_2O emissions were continuously monitored with automatic chambers during 3.3 years. They were respectively 1.20, 1.50, 2.34, and 4.09 kg ha^{-1} yr^{-1} in LI, ORG, CONV and CA systems and were highly correlated with total gaseous N emissions.
The GHG balance, calculated using soil organic C storage (SOC) and N_2O measurements, varied widely between systems: it was highest in CON and LI, with 2198 and 1763 kg CO_2eq ha^{-1} yr^{-1} respectively. In CA, the GHG balance was much more favourable (306 kg CO_2eq ha_{-1} yr_{-1}), thanks to a compensation between N_2O losses and SOC storage. ORG was the system with the smallest GHG balance (–65 kg CO_2eq ha^{-1} yr^{-1}), acting as a CO_2 sink in the long-term.
The four agricultural systems dissimilarly impacted the N fate. The latter cannot be predicted by the N surplus; which can be considered as an intermediate variable yet. Complementary predictors of N losses and GHG balance are required to obtain a true overview of the C and N environmental impacts of cropping systems. On an operational point of view, these results should lead to investigate the variability of the GHG emissions within each cropping system.

Soil-derived greenhouse gas emissions as influenced by farming management

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Agricultural practices contribute considerably to emissions of greenhouse gases. So far, knowledge on the impact of organic compared to non-organic farming on soil-derived nitrous oxide (N_2O) and methane (CH_4) emissions is rather limited. Meta-studies studies show, that organically managed soils emit less N_2O and take up more CH_4 than those under non-organic management. This in contrast of that what has been found in the laboratory with soil material from the DOK trial. When subjected to the same water-filled pore space (90%) and N fertilization level (40 kg N ha^{-1}), BIOORG showed a higher N2O production potential than CONMIN. This can be related to the higher soil C content and higher microbial activity in BIORG than in CONMIN soil. Production of N_2 was similar in BIOORG and CONMIN and significantly lower in NOFERT, most likely due to significantly decreased pH inhibiting N_2O reduction. This caused the greatest $N_2O/(N_2O + N_2)$ ratios in NOFERT (0.88 ± 0.02) followed by BIOORG (0.79 ± 0.01) and CONMIN (0.68 ± 0.02) ($p < 0.001$).
Furthermore, we investigated N_2O and CH_4 fluxes with manual chambers during 571 days in a grass-clover– silage maize – green manure cropping sequence in the field, making use of the contrasting farming systems of the DOK trial. We compared two organic farming systems – BIODYN and BIOORG with the two non-organic systems CONMIN and CONFYM – all reflecting Swiss farming practices–together with the unfertilised control NOFERT. We observed a 40.2% reduction of N2O emissions per hectare for organic compared to non-organic systems. In contrast to current knowledge, yield-scaled cumulated N2O emissions under silage maize were similar between organic and non-organic systems. Cumulated on area scale we recorded under silage maize a modest CH_4 uptake for BIODYN and CONMIN and high CH_4 emissions for CONFYM. We found that, in addition to N input, quality properties such as pH, soil organic carbon and microbial biomass significantly affected N2O emissions. This study showed that organic farming systems can be a viable measure contributing to greenhouse gas mitigation in the agricultural sector.

Resilience of organic and conventional cropping systems to drought and climate change

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Over the last 30 years, Swiss temperature have increased with an annual average warming rate of 0.35°C per decade. In addition, models project a mean reduction in Swiss summer precipitation by the mid of the century of around 15%. Thus, farming practices have to be developed that ensure food security and enable us to cope with climate change while still providing stable and high quality yields. Yet, it is unclear how different cropping systems will cope with irregular and adverse climatic conditions; and which systems are best to buffer against climate change.

Within the 3 years research project RELOAD (Resilience of Organic and Conventional Production Systems to Drought, Mercator Schweiz Stiftung) we investigate the resistance and resilience of important arable cropping systems to simulated summer drought. For this, we make use of the long-term Farming system and Tillage experiment (FAST) comparing, since 2009, four main cropping systems: conventional cropping with intensive tillage and no tillage and organic cropping with intensive tillage and reduced tillage. Summer drought was simulated in three consecutive years during 10 weeks and for three crops: maize (2017), a pea-barley mixture (2018) and wheat (2019) with rain shelters installed at the plot level. We hypothesized that reduced or no tillage would improve the ability to withstand drought because of improved soil structure and higher water availability. In addition, we predicted that organic management would enhance drought resilience because of a better-developed soil life and improved soil structure. We found that drought reduced crop yield for each of the investigated crops. In contrast to our expectation, first results indicate that all four investigated cropping systems were to the same extend affected by drought. Currently, we identify potential mechanisms that explain differences in resilience to summer drought among different crops, cropping systems and locations within the investigated field. In order to do that we investigated soil physical parameters (e.g. soil structure, pore network) and soil biological diversity using next generation sequences (e.g. microbial community composition, microbiome potential functions). This project follows earlier work in which we assessed soil microbial networks and temporal variation in microbial communities in the different cropping systems of the FAST trial (e.g. see Hartman et al. 2018; Wagg et al. 2018).

The results of this work will contribute to i) a better understanding of important processes taking place at different cropping systems, and ii) formulating pro-active responses to climate change, allowing for gradual and informed adaptation to better meet agricultural goals.

Effect of agronomic practices on food quality and human health – the need to understand complex interactions

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The underlying philosophy of organic, biological or ecological farming is often described as using integrated soil and crop management systems to create "healthy soils" that produce "healthy crops" which the result in "health benefit" for livestock and humans. The presentation will critically review current scientific evidence that support this hypothesis. Results from our long-term, factorial field experiments in the UK and Greece have demonstrated that rotation design, irrigation, tillage, and especially crop protection, fertilisation and variety choice have a substantial impacts on the nutritional composition of feed and food crops. Mineral nitrogen fertiliser use in conventional farming was linked to a reduction in antioxidant/(poly) phenol and increase in nitrate and nitrite concentrations in a range of crops. Higher mineral phosphorus fertiliser inputs in conventional farming was linked to higher cadmium and nickel concentrations in a range of crops. The use of older, longer strawed and new 'organic' wheat varieties was shown to increase phenolic acid, flavonoid and mineral micronutrient concentration in wheat. However, a recent study demonstrated that the genetic potential to express high phenolic acid/flavonoid content is only realised when 'organic' wheat varieties are grown with composted manure instead of mineral N-fertiliser. The use of pesticides results in substantially higher pesticide residues in conventional crops and was also demonstrated to reduce the concentrations of antioxidant and phytochemical in some crops. Long-term factorial field experiments were thus able to identify the main agronomic factor responsible for the nutritional composition differences found between organic and conventional crops in recent systematic literature reviews and meta-analyses. These studies synthesised data from short tern field trials, retail and farm surveys reported and reported that organic crops have on average higher antioxidant activity and higher concentrations of a range of antioxidants and Zn, but lower pesticide, cadmium, nitrate, nitrite and protein concentrations. Using crops produced in factorial field trials as feed in animal dietary intervention studies, showed that higher residues of pesticides and cadmium, and lower lower polyphenol concentrations associated with agrochemical use are the main drivers for the substantial differences in hormonal balances and lymphocyte proliferation (a measure for immune system responsiveness) between rats raised on organically vs conventionally grown feed crops. This presentations will explore the potential of utilising (a) crop composition data and (b) crops from long-term field experiments, in controlled animal and human dietary intervention studies aimed at developing a mechanistic understanding for the results of recent human cohort studies, which reported that organic food consumption is linked to lower risks of overweight/obesity, metabolic syndrome, cancer, pre-eclampsis and hypospadias.

Long-term organic matter application reduces cadmium but not zinc concentrations in wheat

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Wheat is a staple food crop and a major source of both the essential micronutrient zinc (Zn) and the toxic heavy metal cadmium (Cd) for humans. Since Zn and Cd are chemically similar, increasing Zn concentrations in wheat grains (biofortification), while preventing Cd accumulation, is an agronomic challenge. We used two Swiss agricultural long-term field trials, the "Dynamic-Organic-Conventional System Comparison Trial" (DOK) and the "Zurich Organic Fertilization Experiment" (ZOFE), to investigate the impact of long-term organic, mineral and combined fertilizer inputs on total and phytoavailable concentrations of soil Zn and Cd and their accumulation in winter wheat (L.). "Diffusive gradients in thin films" (DGT) and diethylene-triaminepentaacetic acid (DTPA) extraction were used as proxies for plant available soil metals. Compared to unfertilized controls, long-term organic fertilization with composted manure or green waste compost led to higher soil organic carbon, cation exchange capacity and pH, while DGT-available Zn and Cd concentrations were reduced. The DGT method was a strong predictor of shoot and grain Cd, but not Zn concentrations. Shoot and grain Zn concentrations correlated with DTPA-extractable and total soil Zn concentrations in the ZOFE, but not the DOK trial. Long-term compost fertilization led to lower accumulation of Cd in wheat grains, but did not affect grain Zn. Therefore, Zn/Cd ratios in the grains increased. High Zn and Cd inputs with organic fertilizers and high Cd inputs with phosphate fertilizers led to positive Zn and Cd mass balances when taking into account atmospheric deposition and fertilizer inputs. On the other hand, mineral fertilization led to the depletion of soil Zn due to higher yields and thus higher Zn exports than under organic management. The study supports the use of organic fertilizers for reducing Cd concentrations of wheat grains in the long-term, given that the quality of the fertilizers is guaranteed.

Genetic progress and genotype (G) × environment (E) interactions effects on winter wheat under organic, conventional low-inputs and conventional high-inputs production systems: insights from 20 years of studies

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Understanding the effects of genotype (G) × environment (E) × management (M) interactions on grain and protein yield allows identifying the best variety in a given environment. This in turn enables optimization of production systems and minimization of the risks associated with climate variability. It is also essential to set right the efforts dedicated to improve germplasm and agronomic practices.

This study explores the potential synergies that exist between genotypes, production sites and agronomic practices. For this, we analyzed the datasets obtained from three official Swiss trial networks of winter wheat designed to evaluate genotypes under organic, conventional-low-input (150 kg nitrogen (N) ha^{-1} with no fungicide application) and conventional-high-input (180 kg N ha^{-1} with fungicide application) production systems. The trial networks evaluate each year an average of 36 winter wheat genotypes that include released varieties, advanced breeding lines, and Swiss and European lines evaluated for registration in Switzerland. We investigated within each trial network the influence of year, genotype, environment and their interactions on total variation in grain yield and grain N content using variance components analysis. We further applied mixed models with regression features to dissect genetic components due to breeding efforts from non-genetic components, which capture effects of agronomic practices.

The genotype as variance component alone or as a factor interacting with the environment or the year (G × E, G × year, and G × E × year) explained 10% (organic), 16% (conventional-low-input), and 21% (conventional-high-input) of the variance in grain yield, while the corresponding values for grain N content were 27%, 16%, and 28%. Grain yield increased at a yearly rate from 0.09% (conventional) to 0.48% (organic) over the last 20 years. The dissection of grain yield and N content trends into genetic and non-genetic components has given us insights into how to overcome limitations and reduce yield gaps in wheat production and baking quality.

Profiling techniques and targeted analyses in the quest for differentiation of organic *versus* conventional *DOK* wheat

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Organic and conventional wheat grain from several growing seasons of the field trial was investigated using profiling methods and targeted analyses. The aim of the work was to determine, whether there were consistent differences in grain constituents of the various growing systems and, whether these differences could be used to analytically differentiate organic and conventional wheat grain.
Targeted analysis of wheat grain comprised determination of a number of minerals, crude protein content, phosphate levels, antioxidative capacity, levels of phenols, fibre, fructan, oxalate and phytic acid. Levels of these substances fell into a range that is known to occur in other wheat crops, indicating that wheat from the trial was not exceptional. Clear-cut differences were observed for none-fertilised wheat, which was significantly lowest in thousand seed weight, protein and significantly highest in total oxalate. For the majority of the nutritionally important substances analysed, there were no significant differences between bio-dynamic, organic, and conventional growing systems.
Profiling techniques enable the detection of a wide range of substances in biological samples. In combination with bioinformatic evaluation tools a fast and easy comparison of large datasets is possible. Together these techniques are useful for biomarker searching, in extracts of wheat grain. 2D-gel-electrophresis and MALDI-TOF-MS/MS analysis was used for protein profiling of wheat grain extracts. Within a set of several hundred proteins a small number of proteins was identified that had significantly different levels in organic and conventional wheat in individual growing seasons and cultivars. Across cultivars and growing seasons expression differences of individual proteins were not stable. When all identified gliadins and glutenins were viewed as a group of proteins, this group was elevated in conventional wheat. Similarly, a group of α-amylase inhibitors was increased in one growing season in organic wheat.
Metabolite profiles were generated with GC-MS from methanol extracts of finely ground wheat grains. Using this technique approximately 50 metabolites and 250 unidentified metabolites (TAGs) per wheat sample were detected. Monitoring of the cultivar Runal revealed four metabolites that had significantly different concentrations in all three analysed harvest years. Across 11 varieties of the 2007 harvest year, 5 metabolites and 11 TAGs showed significantly different concentrations between the cultivation forms. PCA performed on metabolite data for the individual varieties and for individual growing seasons revealed a clustering according to the cultivation forms. However, PCA of metabolites and TAGs of combined data of all 11 varieties and growing seasons did not result in such a clustering.
For both, analysis of protein and metabolite profiles, it was apparent that cultivar and effects of the growing season were much stronger than the effect of the growing system. On the basis if these results an analytical differentiation of organic and conventional wheat appears very challenging.

Nafferton Factorial Systems Comparison trials: What we have learned from the first 18 years of experiments

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The Nafferton Factorial Systems Comparison (NFSC) trials were established in 2002 as a part of the EU Quality Low Input project to provide a facility for in depth study of different aspects of conventional and organic farming systems. In particular the aims were to identify and quantify the effects and interactions between rotation design (diverse versus cereal intensive), fertilisation (compost versus mineral NPK), crop protection (mechanical versus chemical), and more recently tillage (min tillage versus conventional tillage) and variety choice with respect to yield and the nutritional quality of arable and vegetable crops as well as environmental impact (insect and plant biodiversity; soil health and nitrate leaching) of the above systems. The trial was designed to produce a variety of crops each year from fully organic and conventional systems, as well as “intermediate” systems that used pesticides but no fertilizer, and vice versa.

Results from the first seventeen years of the NFSC trials identified nutrient supply as the major yield limiting factor in organic systems. Organic fertilization reduced yields of wheat and potato by 25%, cabbage by 35%, lettuce by 10% while it didn’t affected onion yields. Results also show that organic crops contain higher levels of antioxidants/poly/phenolics, certain minerals such as zinc and lower levels of many nutritionally undesirable compounds (such as heavy metals, pesticides, and glycoalkaloids). Differences in crop composition were linked primarily to differences in fertilisation (e.g. cadmium, protein, nitrate/nitrite and antioxidant concentrations) and crop protection (e.g. pesticide residues and glycoalkaloid concentrations) regimes between organic and conventional systems, but variety choice and rotation design were also shown to have significant effects in some crops.

The first seventeen years of this trial allowed a comprehensive investigation of the agronomic, nutritional and ecological impacts of organic and conventional cropping systems in northeast England. We are now thinking about the future of the experiments and if any other exciting agronomic or ecological questions that can be answered as well as how we can keep the experiment relevant for sponsors and land managers in the post Brexit era. Some emerging research questions include: (i) What ecosystem services can conservation agriculture approaches deliver?; (ii) How can rotations be designed to optimise Nutrient Use Efficiency?; (iii) What alternative crops can be used to diversify crop rotations and improve economic and ecological resilience?; (iv) What impacts do diverse leys (herb-rich mixes) have on soil properties and ley yields compared to traditional grass/clover mixes?. This is being done while at the same time retaining some of the key original treatments to allow the ongoing study of long-term impacts of organic and conventional crop management.

Environmental impacts of cropping systems: lessons learnt from LCA studies

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Life cycle assessment (LCA) is a method to evaluate the impacts on the environment of human activities such as agriculture. It is characterised by three main features: the consideration of a full life cycle, the assessment of all relevant environmental impact categories, and the calculation of the impact per unit of a reference, a so-called functional unit. The bulk of LCA studies is focussed on single products, such as bread wheat, milk or lettuce in so-called product LCAs. Although there is a clear need for such information on products and production methods, this is not sufficient, as it is difficult or even impossible to capture all relationships between different crops or crops and animals. Therefore, such product LCAs have to be completed with system LCAs, considering whole cropping systems, farming systems, or farms. A number of LCA studies of cropping systems have been carried out during the last two decades. The comparison of organic to integrated or conventional systems has been one of the focus research questions. These LCA studies lead to the following general conclusions: Organic systems tend to have clearly lower impacts per area, while impacts per unit of product depend on the system context and can be similar, lower or higher. Per product unit, different patterns can be identified according to the impact category considered. Due to lower yields, land occupation is higher in organic farming. Fossil energy demand tends to be lower, due to the ban of energy-intensive mineral N fertilisers, while for water consumption, systematic studies are lacking, which prevents a clear conclusion. As to climate change, no systematic difference was found; the global warming potential can be lower, similar or higher. Acidification and eutrophication, driven by loss of nutrients, tend to be higher as they depend largely on practices in animal husbandry and manure management, and organic agriculture uses more manure. Due to the ban of synthetic pesticides, ecotoxicity tends to be clearly lower and biodiversity potentials to be higher. This finding, however, is relativised if other pollutants such as heavy metals are considered, and if the additional land use to produce the same amount of product is considered. Soil quality in organic systems is clearly improved when compared to conventional systems with purely mineral fertilisation.

The eco-efficiency analysis shows that the optimisation of organic farming systems is mainly output-driven, while for integrated and conventional systems it is mainly input-driven. To analyse the environmental impacts of cropping and farming systems, we can rely on three pillars: 1) LCA of experimental cropping and farming systems, such as the DOK trial, 2) LCA of representative, modelled systems based on a combination of various data sources such as statistics, pilot farm networks, extension services, etc., an 3) LCA of pilot farm networks. 1) allows detailed measurements and model validation, 2) enables to calculate representative results, and 3) allows to capture the variability of individual farms and to estimate representative average impacts (given a sufficiently large sample). Only by combining these three pillars in a smart way, we can get a full picture of the environmental impacts, and identify adequate mitigation measures. In particular, we learn from pilot farm networks that a large variability exists among organic farms; this applies even more to integrated and conventional farms. Therefore, a good environmental performance is not only a question of the choice of a farming system like organic or conventional, but of its implementation within the given context and its management.

History, lessons and challenges of the long term field trial of Saria

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The long term field trial of Saria (LTFT-Saria) was established in 1960 in the Centre West of Burkina Faso in West Africa. As other long term field trials in Africa, it continuously provides evidences that changes in soil productivity depend on the management practices and therefore helps in awareness raising and development of solutions to improve agricultural cropping systems. The LTFT-Saria was implemented on a gentle slope of a Ferric Acrisol. This soil has low nutrient contents, less than 1% of organic matter and contains about 60% of sand. The experimental design is set-up on six blocks on a total surface of 9690 m^2. The trial was initially focused on the effect of three fertilizations regimes (control without nutrient addition, mineral and mineral plus organic) and fallow lengths on sorghum productivity but was continuously modified thereafter to meet the evolution of constraints limiting agricultural productivity. So then, crop rotations were introduced from 1965 including sorghum cotton and legumes (groundnut from 1965 to 1974 and cowpea from 1975). Ever since then the LTFT-Saria comprises six main fertilization treatments: control without nutrient addition, low rate of mineral fertilization with a return of sorghum residues, low rate of mineral and organic fertilization, low rate of mineral fertilization, high rate of mineral and organic fertilization and high rate of mineral fertilization. These fertilization treatments are applied on three crop rotation systems: continuous sorghum, sorghum-cowpea and sorghum-cotton. The organic matter is farmyard manure applied every second year, when sorghum is grown on the full trial at a rate of 5 t dry matter ha^{-1} and 40 t dry matter ha^{-1} for the low and high fertilization treatments respectively. In 1978 and 1988, due to soil acidification in the sole mineral fertilization treatments, a lime was added at 1.5 t ha^{-1} in all the plots. The cultivars and the rates of mineral fertilization changed slightly over time. An inter season variability of sorghum yields is observed in all the fertilization treatments and all the rotations partly due to the change of cultivars but mostly due to the variability of rainfall. A yield decrease up to 70% for the same cultivar is observed over time for whatever fertilization regime and the rotation system as a consequence of a degradation of soil properties and/or a pejoration of climatic conditions. This decrease is more pronounced in the control and the sole mineral fertilization treatments and particularly in monoculture of sorghum. The LTFT-Saria clearly shows the limits of sole mineral fertilization and highlights the importance of organic amendment and crop rotations for the long term productivity of the sandy soils. It also highlights the gap between the current popularized rate of organic amendment (5 tha^{-1} every second year) and the higher rate (40 tha^{-1} every second year) regarding soil productivity. The trial is used for capacity building through PhD, MSc theses and also training of farmers through regular commented visits. It is a big challenge to establish a proper and regular archiving system of plant and mostly soil data and to get a perennial source of finance for the trial.

The Glenlea long-term study illuminates the ecosystem health – crop productivity nexus in Canadian Prairie organic production

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The Glenlea long-term crop rotation study, initiated in 1992, is Canada's oldest organic-conventional comparison study. The study includes two, four-year crop rotations (grain-only and forage-grain) conducted under conventional and organic management and 3, 0.4 ha restored Prairie grass plots, one in each replicate. Measurements in the study have focussed on ecosystem function parameters that include net primary productivity; mycorrhizal populations and colonization; bacterial communities; nematode and beetle populations; soil C, N and P stocks; microbial biomass C; soil enzyme activity; aggregate stability; nitrate leaching; and N_2O emissions. Crop production parameters include crop economic yield; energy use and efficiency; crop nutrient concentration; and pests. As expected, the restored Prairie has the most positive ecosystem health scores. It was interesting to observe that two organic systems, both forage-grain rotations, compared favourably with the Prairie for several ecosystem health parameters. The first organic forage-grain system, one that receives "P-replacement" additions of composted manure, is also highly productive in agronomic terms. This observation suggests a positive relationship between ecosystem health and crop productivity. The second organic forage-grain system, one that receives no supplemental nutrients, scored high on several ecosystem health parameters (eg., high microbial biomass C, nematode and beetle populations and phosphatase enzyme activity) but low for crop productivity. This observation suggests a disconnect between ecosystem health measures and agronomic performance; in this case the disconnect appears due to a soil P shortage. The grain-only organic system scored poorly for most ecosystem health parameters (exception: beetle diversity) and agronomic performance. Weeds, which were more abundant in the organic grain only system, were positively correlated with carabid beetle diversity but reduced crop performance. Modification of the organic grain only system (through interrow cultivation for weed control and "replacement" of weeds with grain intercrops and legume cover crops) has improved its agronomic performance; ecosystem function is currently under investigation. In summary, the relationship between ecosystem health and crop productivity has been examined at Glenlea for over 25 years. Results indicate that organic systems can result in high crop productivity and positive ecosystem function. The factors which appeared to play the most important role in a positive ecosystem health– crop productivity nexus are P and N status and plant diversity, including perennials.

Crop diversity enhances agroecosystem sustainability via improving soil fertility

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We face a major challenge feeding an expanding world population with highly degraded soils. Reversing the trend of soil degradation and ensuring food security and a sustainable future have therefore become essential. Although multispecies systems often are productive, the sustainability has been questioned in longer temporal and wider spatial variations as continuous overyielding generally removes more nutrients from soils. In order to address these issues, two field experiments were conducted initially in 2009 at the soils which were reclaimed for 3 years at Hongsipu in Ningxia (Exp. 1) and for 20 years at Jinyuan in Gansu (Exp. 2), China. The Exp. 1 was split-split-plot design, where main plot treatments included inoculation with rhizobium or not, and the sub-plot treatments included five N-application rates (0, 75, 150, 225 and 300 kg N ha^{-1}), and the sub-sub-plot treatments were sole faba bean, maize, and faba bean/maize intercropping. The Exp. 2 was two-factorial design, where main factor was P application rates (0, 40, 80 kg ha^{-1}) and the second factor was cropping systems, including canola/maize, chickpea/maize, faba bean/maize, and soybean/maize intercropping, and their corresponding monocropping. Each treatment has three replications in both field experiments. Productivity, soil physical and chemical properties (bulk density, water-stable aggregates, infiltraction, compactivity, soil organic matter, total N, Olsen-P, Exchangable K, CEC, and pH), and some enzyme activities were measured in 2012 and 2013 in both experiments. Overyielding in intercropping was observed for many years. Results also showed that percentage of water-stable macro-aggregate (> 2.0 mm) was increased by intercropping compared to monocropped faba bean (67.9% vs 56.0%). Soil organic matter and total N were increased significantly by intercropping compared to monocropped maize 6.86 g/kg and 0.27 g/kg vs 6.03 g/kg and 0.22 g/kg) in the Exp. 1. In the Exp. 2, similarly, percentages of soil water-stable macro-aggregate were significantly increased by faba bean/maize, chickpea/maize, canola/maize intercropping, but not by soybean/maize intercropping. Soil organic and total N presented similar trends to Exp. 1. In summary, soil fertility was significantly improved after 4-5 years of intercropping compared with monocropping, especially in rewly-reclaimed desert soil. Our findings highlight that crop diversity not only enhances crop productivity, but also improves soil fertility, and delivers multiple ecosystem functioning and services.

A meta-analysis approach for assessing the sustainability of cropping systems using data from multiple global LTEs

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Sustainable cropping systems meet the needs of the present generation without compromising the needs of future generations. Thus, research on generational timescales is critical to assess what truly constitutes a sustainable system. Long-term experiments (LTEs) provide the depth of data required to explore this, but individual LTEs focused on their own specific questions in their own specific environments have limited potential to provide globally applicable answers. There is much to be gained by combining multiple LTEs from around the world with overlapping and complementary treatments, to understand how different agricultural practices relate to sustainability across a range of systems and environments.

This pilot study, developed as an initial outcome of the Global Long-Term Experiment Network (GLTEN), focussed on three aspects of the performance of cropping systems – crop productivity, maintaining carbon stocks, and the efficient use of N – and on the stability of responses as well as the average response. Using data from four diverse LTEs with a variety of different treatments – Broadbalk (UK, continuous and rotational wheat), LTCCE (Philippines, continuous rice), Pergamino (Argentina, wheat-maize-soybean rotation), Langgewens (South Africa, wheat-based rotations) – the aim of the study was to demonstrate how trade-offs between different aspects of cropping systems could be used to identify cropping practices that lead to more sustainable crop production.

Our approach required considerable initial data preparation, including the identification of standardising transformations to allow comparisons of responses between crops and systems, the use of models to estimate responses in years when direct observations were not made, and the summary of responses across appropriate sets of growing seasons to reflect the impact of different treatment components. For each LTE, the analysis approach uses a Principal Component Analysis (PCA) to explore the relationships amongst the response variables and the grouping of treatment combinations, illustrated using bi-plots to identify the "best" trade-off patterns and hence the most sustainable practices. The meta-analysis of data across multiple LTEs uses both a Procrustes Analysis to compare individual ordinations generated for each LTE separately, and a combined PCA for all 4 experiments, to identify different treatment combinations that appear to lead to similar trade-off patterns.

This talk will describe the initial data preparation steps, and present some results from both the analyses of the individual LTEs and the combined meta-analyses.

Effects of farming system and simulated drought on biodiversity, food webs and ecosystem functions in the DOK trial

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Organic agriculture promotes overall biodiversity in arable fields, with well-documented positive effects on plant and pollinator diversity and abundance. Responses of soil-living decomposers, aboveground herbivores and predators to organic farming are less uniform and not equally well understood. The DOK trial offers ideal conditions to assess the long-term effects of organic compared to conventional farming practices on these above- and belowground invertebrate communities. Organic treatments in the DOK trial have a pronounced effect on abundances, diversity and species composition across taxonomic borders. Application of farmyard manure promotes nematode and earthworm numbers, whereas mineral fertilizers detrimentally affected potworm and fly larvae numbers. Aboveground predators are more abundant under organic agriculture and herbivores show an opposite response. However, effects go beyond simple numeric responses as organic agriculture alters the species composition of local communities significantly.
These changes in taxonomic composition are of particular importance for system comparisons, as they may have pronounced consequences for trophic interactions and levels of ecosystem functions and services. Nutrient mineralization, pest infestation and biological control levels substantially differ between treatments with and without farmyard manure or mineral fertilizer application. The link between the observed natural enemy and pest numbers in organic treatments is not exclusively a consequence of higher predator abundances in organic treatments. Stable isotope analysis of samples from the DOK trial rather indicate, that the observed patterns also partly stem from altered predator-prey interactions under organic agriculture.
Finally, climate change holds the potential to alter the observed effects of organic agriculture on biotic communities and associated ecosystem functions. A recent BiodivERsA EU project (SOILCLIM) simulated severe drought conditions in the DOK trial. Amongst other biotic groups, below- and aboveground arthropods and associated ecosystem functions responded to climatic conditions and organic agriculture. This synthesis summarizes existing results from research on invertebrate communities and associated ecosystem functions in the DOK trial, emphasizing the need for long-term studies and the joint consideration of management and climate effects on biodiversity and ecosystem functions.

Nitrogen transformations and its underlying microbial communities in differently managed soils under future projected rainfall variability

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Soil microbial communities play a fundamental role in maintaining a broad range of soil functions and ecosystem services. Especially nutrient provisioning to cultivated crops are of prime interest in agricultural contexts in order to maintain the production of food, fibre and fuel for the ever increasing human population. Since Nitrogen (N) is the most limiting nutrient in agroecosystem and it's cycling and availability is highly dependent on microbial driven processes, we investigated the impact of farming systems on related ecosystem processes and herein involved soil microbial communities. Considering global climate change, also the potential to withstand rainfall variability was assessed.
Initially, a systematic literature search followed by a meta-analysis identified differences in microbial abundance and activity in contrasting farming systems. Overall, we identified 32 % to 84 % greater microbial biomass carbon, microbial biomass N, total phospholipid fatty-acids, and dehydrogenase, urease and protease activities in organic compared to conventional farming systems. Categorical analysis identified crop rotation, the inclusion of legumes and organic inputs to be important practices positively affecting soil microbial communities.
Next, in order to test whether distinct microbial communities in soil of organic and conventional farming (DOK long-term trial) lead to distinct functioning when facing future projected drought stress, a plant nutrition experiment using a ^{15}N labelled green manure was performed. We identified 30 % higher amounts of N derived from organic fertilizer in ryegrass grown on organically (BIOORG) compared to conventionally (CONMIN) managed soil, but only when subjected to dry conditions. Concomitant with enhanced N provisioning, enhanced stability of proteolytic (*apr* encoding) microbial community diversity and composition was identified in response to drought stress in BIOORG soil. Our results of the DOK indicate proteolytic microbial communities selected under organic farming (BIOORG) to have a better capacity to maintain plant nutrition of a model crop under dry conditions.
Lastly, the effect of management (ecological intensive vs. conventional intensive) on N-related ecosystem processes (forage N uptake and NO_3 leaching) and herein involved microbial communities was assessed in a more natural scenario. Terrestrial model ecosystems (intact soil cores) originating from forage agroecosystems across Europe (Switzerland, Portugal and France) were subjected to altered rain regimes for 263 days. Across countries, we observed strong impacts of rain regimes on N-related ecosystem processes and soil abiotic indicators, but a high resistance of N-related microbial communities. Furthermore, N-related microbial community structure was affected by management across countries and rain regimes, with a positive cascading effect of eco-intensive management on N-related ecosystem services through N-related microbial community composition. Our results based on long-term trials and farm comparison show that distinct farming systems/management shape soil microbial communities and affect their ability to provide ecosystem functioning when facing future projected rainfall variability.

Effects of farming system on weed seed bank and on invasibility in arable fields: evidences from the long-term DOK trial

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Agricultural intensification over last decades has resulted in a great increase of crop yields, but it also had a detrimental impact on biodiversity. The dramatic decline of arable weed diversity is a matter of great concern because weeds have an important ecological function as a key component of the food web of agroecosystems. Weeds are suitable indicators of management effects on wildlife diversity in arable crops because they have high sensitivity to cultivation measures and have a strong relation to other organism groups. Nevertheless, the effect of farming management on weed abundance and diversity will be more reliable on weed seed bank rather than on aboveground weed community because it is the result of processes that have occurred in the past and consequently, it could better reflect the effect of the agricultural practices over the years.

While the negative effect of invader weeds on crop yields have been widely regarded in agroecosystems, few studies, to our knowledge, have devoted to the role of farming system, defined as a complex interaction of factors, on invasion process, although invasion by exotic and native weeds could also dramatically affect biodiversity as occurs in a wide range of ecosystems. The periodical soil disturbance, the large amount of external inputs such as fertilizers and pesticides are the main factors driving invasibility, defined as the inherent susceptibility of an environment to the colonisation and establishment of individuals from species not currently part of the resident community.

The aim of this presentation is to show main results of (1) a study aiming at evaluating the effect of farming systems on weed seed bank abundance and diversity and shifts in assembly of weed communities of the soil seed bank, and (2) another study aiming at analysing if invasibility could be affected by farming system. The first study was carried out in wheat and maize crops under organic and conventional farming practices within a replicated, long-term experiment [DOK biodynamic (D), bioorganic (O), Conventional (K) trial, Therwil, Switzerland], and the second only sin the maize crop.

The long term management on arable fields has significant influence on the size and composition of the weed seed bank. Seed abundance and species richness were higher in the organic systems than in the conventional systems, and weed abundance of species were more evenly distributed in organic farming systems. Functional traits of soil seed bank vary among farming systems, so organic management determined the establishment of more annual and forbs species which reflects the less intensity- The study on invasibility was based on simulated invasion by *Amaranthus retroflexus* through seedling transplant introductions into farming systems. The growth of *A. retroflexus* was significantly higher in conventional systems; the higher mineral fertilisation and its fast release of nutrients lead a greater availability and a more efficient uptake of limiting resources (i.e. N and P). The pre-reproductive mortality was higher in conventional systems due to the higher abundance of slugs in those systems and, in turn, to lower abundance of insects eating slugs. The outcome of the balance between the negative effect of predation by slugs and the positive effect of resources availability on growth *of A. retroflexus* through the different systems reflects that invasibility is enhanced in conventional systems.

Transition of long term conservation tillage experiment from conventional to organic system – effects on soil quality and weed infestation

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Effects of conservation soil management on soil quality were studied in the long term field experiment in Moškanjci, Slovenia, which was established in 1999 and shifted from conventional to organic farming in 2014. Long term conservation (minimum) tillage (MT), with reduced soil disturbances and improved residue management, resulted in stratification of soil organic carbon and nutrients with the highest concentrations in the very topsoil, as opposed to conventional tillage with mouldboard ploughing (CT), which maintained rather uniform distribution down to the ploughing depth. For instance, Corg content in the upper 10 cm layer was higher under conservation treatment (1.60% in 2011; 1.83% in 2017) than conventional (1.45% in 2011, 1.40% in 2017), while no significant differences between the treatments were found in the lower 10-20 cm layer at any sampling time. Similarly, also several other soil properties, such as aggregate stability and water holding capacity, were improved in the upper soil layer of MT in comparison to CT. Microbial biomass was also significantly higher in the topsoil of MT than CT. Furthermore our results indicate an increase of microbial biomass after transition to organic agriculture in both tillage systems. Plant productivity, as an ultimate measure of soil fertility, was generally similar in both soil management systems, with smaller differences between cultures and years, however first year after transition to organic system, yield was highly reduced due to the high weed infestation, especially under MT treatments. Significant effects of crop species on weed infestation was found, the largest average weed cover was measured in maize and soybean of MT treatments (up to 87.8%), while in winter rye of MT it was below 40% in comparison to 20% under CT. Significant effects of both tillage type and crop species was also found on weed soil seed bank abundance; in CT seed bank was generally low whereas on MT (particularly in maize and soybean plots), weed seed density in the top 10 cm soil was very high.

Observed soil quality improvement under MT supports introduction of conservation soil management into both, organic and conventional, agricultural systems as potential measures against erosion, drought, and nutrient losses. However, our results indicate that during the transition from conventional to organic system weed control is critical, particularly when conservation soil tillage is also implemented.

Agricultural production in line with the Sustainable Development Goals and within Planetary Boundaries

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The political process of adopting the sustainable development goals (SDGs) has reached a turning point with the UN Summit in September 2015 and the 2030 Agenda. However, given the ambitious list of 17 SDGs and 169 policy targets, research so far has not provided comprehensive tools and approaches to analyze the interactions, trade-offs, co-benefits and synergies across multiple SDGs in sufficient detail.

Moreover, developing strategies and coherent policy measures to achieve such a complex set of goals at different policy levels (from multi-national to sub-national) and across different policy domains (e.g. across national ministries) remains a huge challenge. In order to operationalize comprehensive SDG research and policy advice, important lessons can be drawn from the IPCC process on climate change impacts, adaptation and mitigation research and policy making.

The food-related SDG 2 (zero hunger) and the climate-related SDG 13 have many interactions with other SDGs, especially with energy (SDG 7), but climate impacts and changes in agricultural production may also affect poverty (SDG 1), water (SDG 6), marine resources (SDG 14) and economic growth (SDG 8). On the other hand, ambitious climate change mitigation may strongly change production and consumption patterns, including food consumption (SDG 12), urban development and infrastructure (SDG 9 and 11), and terrestrial ecosystems (SDG 15) with implications for justice and peace (SDG 16).

The future development of the agricultural sector, with its multiple linkages to other socio-economic sectors as well as most ecosystems, will determine to a large extent, whether and how human society will fulfil the targets of the UN Agenda 2030 and, more generally, stay within the Planetary Boundaries. A mix of coherent policy instruments will be an important component of a sustainable future agricultural development.

Here we propose to advance the well-established Shared Socioeconomic Pathways (SSP) for improved sustainability policy assessments. We will give examples from recent scenario studies, how trade-offs, synergies, and co-benefits between different SDG dimensions can be assessed with integrated computer models. Moreover, global-scale scenarios need to be systematically combined with detailed national assessments.

Can organic agriculture contribute to sustainable development in the tropics?

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The Research Institute of Organic Agriculture (FiBL), Switzerland is running a 'Long-term Farming Systems Comparison in the tropics (SysCom)' programme in Kenya, India and Bolivia, since 2007. The main aim of the SysCom programme is to enhance know-how on potentials and limitations of different agricultural production systems in tropics, thereby contributing to sustainable agriculture. To achieve this aim, sound scientific evidence is obtained primarily from four long-term experiments (LTE) that compare different agricultural production systems (mainly organic and conventional). The scientific findings of SysCom are expected to address global challenges of nutrition security and environmental sustainability by informing the policy process at regional and international level. Started in 2007-08, together with local partner institutions, the LTEs capture long-term changes and monitor the effects of contextual developments through observation of agronomic, economic and ecological parameters over time.

The findings from a decade of experimentation shall be shared in this presentation. Results suggest that organic agriculture and agroforestry systems have considerable potential to enhance sustainability of agricultural systems, especially with regard to soil fertility and biodiversity conservation, while maintaining productivity and profitability in most cases. Higher returns on investment and higher labour productivity make organic and agro-forestry systems interesting for resource poor small-holder farmers. Yet, for full exploitation of the benefits of organic agriculture, major efforts are needed to tackle agronomic/ technological challenges (lack of suitable inputs, pest management), capacity development of farmers (technical know-how) and institutional/governance challenges (markets, agri-business).

Some concrete results in brief are:

- Yields of maize and soybean in Kenya and India are similar in organic and conventional systems.
- Yields of wheat and cotton in India are about 20% lower in organic systems but gross margins are comparable due to lower input costs.
- Yields of vegetables in organic systems (in Kenya) are particularly lower due to pest damage.
- Organic carbon in the soils of organic systems is higher compared to conventional.
- Density and biomass of earthworms in organically managed soils is higher than in conventionally managed soils.
- In cocoa full sun systems yield in conventional is higher than in organic full sun, in agro-forestry systems there is no difference in yield of cocoa nor in total system yield.
- No difference in workload between organic and conventional cocoa growing.
- No difference of economic return per labour day between organic and conventional, in agroforestry systems the economic return per labour day is nearly double than full sun
- Agroforestry systems have higher bird species richness.
- Agroforestry systems offer diverse nutrition and higher total calorie production than monocultures.

Further information and publications available at: https://systems-comparison.fibl.org/

Simulating the effects of nitrogen availability on organic production at the global scale

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Organic agriculture is often proposed as a promising approach to achieve sustainable food systems while minimizing environmental impacts. Its capacity to meet the global food demand remains, however, debatable. Several studies have recently investigated that question and have concluded that organic farming could satisfy the global food demand provided that animal product consumption and food waste are strongly reduced. However, these studies have missed a critical ecological process by not considering the key role that nitrogen (N) cycling plays in sustaining crop yields in organic farming. Indeed, N availability in organic systems might be limited due to the ban of synthetic N fertilisers. Here we estimate organic productivity using GOANIM, a global spatial model simulating cropland soil N cycling in organic farming systems and its feedback on food production at the global scale. The model simulates the productivity of different compartments (organically managed croplands, livestock animals and permanent grasslands) and accounts for the biomass and N flows among these compartments (as grazed biomass, feedstuff, and animal manure) as well as the N flows between cultivated soils and the environment. Our results show that a 100% conversion to organic agriculture would lead to a 38% decrease in global food calorie production compared to the current –i.e. non-organic- baseline. In such a scenario, organic food availability would thus be insufficient to match global food demand (36% production-demand gap). We also show that intermediate scenarios involving lower cropland share under organic farming (up to 60%) in coexistence with conventional farming would be feasible, especially when coupled with demand-side solutions (such as a reduction in food wastage and in per capita energy intake). Our simulations also show that livestock plays a fundamental role in sustaining organic food availability in several global regions by providing manure and by valuing grasslands. We conclude by pointing the limitations of our model and by providing some insights about how long-term, organically managed experiments could contribute to our overall investigation.

Long-term field trials are fine but insufficient for understanding landscape impacts of farming systems on ecosystem services and biodiversity

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While long-term field trials are indeed important for understanding variation in soil and agronomic processes in organic and conventional farming systems, and bringing an important element of scientific credibility to such studies that should not be underestimated, I will argue that such trials – and in fact most agronomic experiments at smaller scales than farms-in-real-landscapes – are not sufficient to examine farming systems effects on biodiversity and ecosystem services. This is because most above-ground ecological processes contributing to biodiversity and ecosystem services, as well as a fair number of below-ground processes, are determined by processes at the landscape spatial scale. Often these landscape processes interact with the local processes studied in field trials in ways that are complex and not always simple to predict. Hence long-term field trials, while an important part of our scientific toolbox, are often less useful to understand and predict the large-scale effects of agricultural practices such as organic farming on ecosystem services and biodiversity. And they are clearly insufficient to provide any evidence whatsoever on the large-scale landscape-wide effects of different farming systems and agricultural intensification on biodiversity and ecosystem services.

I will illustrate this conclusion with results from studies on biodiversity as well as ecosystem services such as biological control, pollination, soil functions and yield. The examples suggest that future research comparing farming systems and sustainability of agricultural production need to increase their spatial scale from experimental plots to natural and well-designed pseudo-experiments on real farms in real landscapes. While this may sacrifice some of the scientific precision of small-scale controlled experiments, it has the advantage to increase scientific generality and relevance for farmers and policymakers, and more directly contribute to reaching the sustainability and biodiversity goals relevant for agriculture.

TSARA (Targets for sustainable and resilient agriculture) – efficiency

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To develop resilient and sustainable strategies for policy makers, scientists and farmers, which proactively address the global challenges of agriculture, requires modern envisioning techniques that make use of systems modelling approaches. Today, humanity is facing the problems that arise from ever increasing decline and degradation of natural resources, while global food demand is increasing. Pollution and climate change are progressing dramatically, and both science and politics are obligated by immense social pressure to provide possible solutions to ensure economic, environmental and social sustainability.

In TSARA, we approached these challenges using a backcasting methodology. The goal was to interact with a diverse group of stakeholders (academics, government officials, industrial actors, farmers, NGOs and others) to develop possible, but ambitious, transformative pathways toward a more resilient and sustainable agriculture by 2030/2050. During stakeholder workshops in the participating countries (UK, NL, FR & NZ), we organized several participatory backcasting exercises, which resulted in 1.) a number of pathways towards a more sustainable future agriculture, focussing on the arable, dairy and livestock sectors, 2.) a wide range of concrete steps along these pathways, 3.) an updated and modified set of indicators for UN SDG 2 with regard to national priorities.

To explore pathways suggested by the outputs from our participatory backcasting approach, we used a multi-objective optimisation algorithm coupled with an agricultural systems model, the Rothamsted Landscape Model (RLM). RLM integrates several underlying models and has been developed and validated on the Rothamsted LTEs. It simulates dynamics of major physical, chemical and biological processes in the topsoil, crop production and environmental interactions. With this tool we simulated the consequences of some of the proposed pathways, implementation steps and possible changes in agricultural land-use and management on both production and the environment. Using a differential evolutionary algorithm, trade-offs between different factors were identified, using a multi-objective set of optimizable SDG indicators, such as food production, profit, GHG emissions, soil organic carbon (SOC) or nitrogen use efficiency. We were thus able to simulate potential consequences of different management options and specific, suggested policy implementations. The latter were tested iteratively over a discrete set and range of control variables, including the amount of fertilizer application and alternate crop rotation systems.

Simulation results show, for example, that the implementation of a Natural Capital System (as suggested during participatory backcasting) can provide support for the improvement of some sustainability indicators. Yet, implementation without additional social transformation might be insufficient. Subsidies for improving the amount of SOC in the top-soil and/or financial penalties on the use of fertiliser show, can reshape trade-offs, but are limited in their efficiency. The reason is that the leverage of those incentives and policies alone is not powerful enough. However, simultaneous changes in agricultural land-use and a focus of optimization strategies on resource use efficiencies might provide attainable pathways towards a more sustainable future agricultural production within planetary boundaries.

Applying the Efficiency-Substitution-Redesign transitional framework to ensure the sustainability of long-term experiments

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The concept of sustainability applied to agricultural and food systems relies on two pillars: (i) a long-term perspective, (ii) a system approach highlighting the interconnectedness of the three sustainability domains (environmental, economic and social). The ongoing discussion on the transition towards more sustainable agri-food systems and on the paradigms that may foster it (e.g. agroecology, sustainable/ecological intensification) increasingly recognises the Efficiency-Substitution-Redesign (ESR) approach, developed by Hill & MacRae in the mid 1990s, as a reference action framework. We argue that the ESR framework could also be useful to ensure the sustainability of long-term experiments (LTEs) – here intended as the adaptation of LTEs to changing research priorities and societal needs. This is of paramount importance to ensure that LTEs continue to provide novel research questions and data as well as to keep their attractiveness to funding agencies. We illustrate the dynamics of changes undergone in the objectives, structure, treatments, research questions and data collection undergone in the MASCOT LTE since its establishment in 2001. MASCOT (Mediterranean Arable Systems COmparison Trial) is located in S. Piero a Grado (Pisa) and compares a conventional and an organic management system for stockless arable crop rotations applicable in the coastal plain of Tuscany (Central Italy), and runs across an overall experimental area of 24 ha. The ESR framework applied to MASCOT includes different adaptation strategies at short, mid and long time scales, based on research outcomes. Short-term adaptation is mainly based on yearly changes in management details aimed to improve the efficacy of single cultural practices (e.g. tillage, fertilisation, direct weed control). Mid-term adaptation is based on the possible substitution of crops and/or cultural practices decided at the end of each rotation cycle. Long-term adaptation implies the redesign of the whole crop rotation – as we did in 2017 – to refresh the appealing of the LTE by taking into account emerging research interests and societal needs. Obviously, long-term adaptation is done only once in a blue moon. One important feature of MASCOT, which makes it a versatile LTE, is that it includes both fields for system comparison (conventional organic) and others (organic 'playground') where different technical solutions based on efficiency or substitution can be trialled at a shorter time scale but still within a system context. As examples of alternative data that could be generated in LTEs and that are appropriate to analyse the dynamics of management practices and policy framework (e.g. changes in subsidy policies) hence possibly suggesting the need to redesign the experiment, we will present results on the comparison between MASCOT conventional and organic management in terms of energy efficiency and gross margins. Another approach to accommodate emerging research questions and societal needs is to build up a brand new LTE. In this respect, we will introduce the ambition and objectives of a new LTE on agroforestry and agrosylvopastoral systems that we have established in 2018 and that we will leave as heritage to future generations of researchers to enjoy.

Organic conservation tillage – evidence from more than 15 years of research

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In Europe, the plough is a common machine for soil tillage. Its history is dating back to the early days of agriculture and hence its use is deeply rooted in European culture. With ongoing heavier machines, larger fields and less landscape diversity, ploughing contributed to large-scale soil degradation. The bare soil surface is prone to erosion; the risk of soil fertility decrease is high. Long-term sustainability of current ploughing practices is therefore questioned. In organic farming, ploughing is seen as an important tool for weed control, ley termination and incorporation of organic material. Yet, also organic farming practices can still be improved. The aim was therefore to replace ploughing by less intensive tillage methods and to monitor changes in soil quality and yield performance. At FiBL, research started roughly in 2000 with both scientific and practice oriented trials and collaborations.

The long-term trial in Frick was established in autumn 2002 on a clayey soil with the aim to test continuous organic reduced tillage, in this case, the consequent use of non-inversion tillage to 10 cm and occasional deeper loosening to 15-20 cm with a chisel plough. For ley termination, a shallow plough ("Stoppelhobel") was used to turn the grass sward to ca. 5 cm. After three rotation periods, soil fertility improved substantially, namely humus content and microbial biomass and activity. Belowground biodiversity increased and shifted to more fungal based communities. Earthworms profit from reduced tillage with a higher reproduction. Yield performance was less stable with both higher and lower yields. Crop performance was more dependent on weather situations especially N supply in early spring that is provided by soil mineralisation. Weeds also increased. Problematic were perennial grasses and *Convolvulus* species at this site. Another long-term trial was started in 2010 in Aesch on a loess soil. Soil tillage is similar to Frick except that only chisel ploughs are used in the reduced tillage system to 10 cm. At this site, yields differed only slightly with a tendency to lower yields, also with the observation of slower soil mineralisation in spring in wet and colder years. Soil fertility did not change much within 9 years, presumably to the lower clay content. A compact zone below tillage depth and within the old plough layer in reduced tillage indicate the need of strategic aeration also in this soil. Weeds also increased, but are far less problematic than in Frick.

Both trials were already an important platform to test specific research questions in European collaborations. Two Core Organic projects, TILMAN-ORG (2011-2014) and FertilCrop (2015-2017) were compiling available data on organic conservation tillage in Europe and used the datasets of running trials to address questions like yield performance, weeds and soil fertility on a more global scale. In addition, socioeconomic questions, e.g. farmer's motivations and obstacles in adopting conservation tillage were assessed. A new collaboration within the SOCORT project is measuring soil organic carbon stocks with the same approach to find a more general indication if continuous organic reduced tillage can contribute to climate change mitigation by carbon sequestration.

A farmers network to test reduced tillage and also organic no-till on-farm was set-up at FiBL in 2009 and is still ongoing. Farmers test specific issues like reduced ley termination, green manures or different machinery to advance and gain experiences in organic conservation tillage.

At this stage, it can be concluded that continuous reduced tillage is possible in organic but that management is more difficult and needs to be combined with other strategies like green manures, strategic soil aeration and a more sophisticated weed control. At the conference, a compilation of results from the FiBL long-term and on-farm trials and European collaborations will be presented.

(What is) The best methodology to compare organic and conventional agricultural cropping systems

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Long term cropping system experiments (LTEs) are carried out for long times in several countries in various ways, ranging from randomised block design to system comparisons without repetitions and even different crop rotations between organic and conventional systems. Many of these experiments are criticized for their set up. This counts for experiments with scientifically sound setups as well as for single repetition experiments. General remarks on the scientifically sound experiments are that they do not represent actual farming practice, as system components are divided over separate fields all over the whole experiment and cannot have interactions with each other. Besides, interactions between system components of other adjacent systems are often likely but unwanted. Of course the remark on the single repetition experiment is that it can never be excluded that there are systematic differences between the systems independent of the treatments.

The purpose of this presentation is to examine if we can bridge the gap in critics or that clarification is needed on the objective of each experiment and the conclusions that can be drawn from the results. Based on the results we will (re)design new experiments in the Netherlands in the coming years.

In the presentation we will examine examples of LTEs from various countries and the Netherlands in particular. Important aspects are 1) the objective of the experiment, 2) whole system in one block or randomised within the experiment, 3) size of the experimental units and the possibility to use normal farm machinery, 4) presence of repetitions, 5) the length of the experiment, 6) fixed set up or focused on optimisation of the cropping system, 7) differences and similarities between systems compared in crop rotation, produced products, used inputs and applied tillage methods, 8) within experiment changes over years, 9) possibilities of certification of the cropping systems.

The objectives of an LTE determine largely the setup and size of your experiment. Experiments with a strong focus on fertilisation can be setup with small fields and randomized repetitions for example, since the expected interactions between adjacent fields are minimal. For tillage experiments larger fields are needed, just because of the practical size limitations of the machinery. For experiments where entomology is studied the landscape structure is also of influence, so experiments need to be very large to rule this out. In the Netherlands a large part of the LTEs is amongst others setup to inspire and teach farmers. Therefore fields are large and normal farm machinery is used. There are not always repetitions, for farmers this is not important. However, if we want to publish our results this is of importance. Is there a best way to set up a long term experiment? And if so, can we reach consensus on how this should look like?

The importance of long-term field experiments for modelling soil functions in agricultural systems

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Mechanistic simulation models are an essential tool for predicting the influence of changing external factors on ecosystem functions. For estimating the various functions in agricultural soil systems, knowledge about the long-term effects of different land management activities is mandatory.
In this talk, we will discuss the importance of long-term field experiments for the development of systemic soil models capable to simulate the dynamics of soil functions. This is demonstrated for the model which integrates biological, physical and chemical processes to predict the effect of management activities on soil functions. For validating the simulated outcomes, data of long-term field experiments are essential. We need such data also for increasing our mechanistic knowledge about the relationship of long-term management and different biological, physical and chemical soil properties.
Especially for the latter, we want to highlight how additional measures of soil properties in field experiments with a well-known land management history can contribute to the development of new systemic modelling approaches.

A comparison of four contrasting experimental rotations: reflections on an organically managed rotational LTE started in 1991

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This paper will present a selection of crop productivity and quality data, as well as soil data that has been collated since 1991 from an organically managed long term experiment (LTE) that was designed to compare rotations with different approaches to fertility. The experiment was originally established in 1991 in Aberdeen, Scotland, to compare two organic arable-ley rotations with contrasting levels of fertility building ley across a six course rotational period, with every crop grown every year. The design was based around the comparison of a rotation with a 50% ley phase and a 50% exploitative cropping phase with that of a rotation with a 67% ley phase and a 33% exploitative cropping phase. Both rotational treatments were stocked, and had grazing sheep on the grassland plots as well as manure return, based on stocking rate, at key points of the rotation linked to silage offtake of the leys, or key cropping phases, e.g. swedes. In 2006, after more than two full rotational cycles of the experiment, the data suggested that there was only minimal difference in a number of key performance areas between the two treatments that had been implemented at the start of the experiment. Both treatments appeared to be performing well, with little sign of deterioration of either crop productivity and its quality or soil fertility and its quality when whole rotations were taken into account. Both rotations appeared to be sustainable. This prompted a collective decision to modify the rotational treatments in order to try and elicit a greater contrast in productivity and soil factors. The 50% ley and 50% exploitative cropping rotation was retained from 2007, but the existing large plots were split so that half plots allowed the ley-oat rotation to continue as it had since 1991 in one half, but the other half of the plots were modified to a ley-barley rotation allowing comparison of the sustainability of different exploitative crops while maintaining the same approach to fertility. The rotation that had consisted of a 67% ley phase and a 33% exploitative cropping phase was modified, again by splitting the original large plots into two half sub-plots, to become a completely stockless system with no grazing or external imports of manures. The two rotations in this stockless system differ in that one has a sequence involving potatoes followed by spring wheat after the fertility cut-and-mulch grass-clover phase, while the other has spring wheat followed by potatoes after the grass-clover phase. All other crops in the rotational sequences are identical. The modified rotations have now completed two full cropping cycles and this paper will present some of the key findings in relation to the productivity and quality of the crops in the two systems and the two rotations within these. The paper will also present some key findings in terms of soil quality over time, particularly in relation to macronutrients and shifts in pH and organic matter.

Posters

Fertility losses in organic agriculture systems

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Maintaining the chemical fertility of the soil is a key issue in organic agriculture. While the insertion of legumes into rotations effectively contributes to injecting nitrogen (N) into organic cropping systems, the management of other elements such as phosphorus (P) or potassium (K) is more difficult. Indeed, exports of P or K by crops can only be compensated by the supply of exogenous fertilizers. However, in organic systems specialized in field crops, farmers have little access to livestock manure, which is the main mode of soil fertilization in P and K. In addition, some producers in AB do not compensate mineral element exports, arguing that their cropping system can be self-sufficient, or because of the high cost of commercial fertilizers allowed in organic agriculture. These fertilization impasses can cause, in the medium term, a decrease in soil P and K content and lead to deficiency situations and yield losses. The strong growth of organic agriculture could worsen this situation.

ARVALIS has been observed those soil fertility losses for many years through several devices. Since 1999, ARVALIS has been studying the P fertility matter in a system experiment located in the South-East of France. The aim of this trial is to evaluate the impact of the P fertility diminution on system production, and to explore the solutions to maintain system sustainability. Since 2005, one part of the experiment (P1) receives inputs of organic fertilizer rich in phosphor, with a P_2O_5 contents between 10 and 20%. The fertilization rate is fixed to compensate the P exportations. The other part (P0) of the trial is receiving rich nitrogen, but poor phosphor (less than 4%), fertilizers, to simulate P fertility decrease. After twelve campaigns, soil Olsen P_2O_5 contents are continually falling in the P0 system as expected (from 50ppm to 20ppm), because of the non-compensation of the exportations. In the P1 modalities, although the positive cumulative balance, contents are also decreasing but slower than in P0 (from 50ppm to 30ppm). This result can be explained because of the lower P solubility of organic fertilizers in calcareous environment. Some of the phosphorus provided by fertilizers probably remains blocked by the metallic cations of the ground and is not extracted during the analysis. A production decrease is also observed in P0, with lower and irregular yields. For rapeseed and alfalfa, the most demanding crops in P, yields tend to decrease over time, including in plots P1, but in a more moderate way than in the plots P0. K deficiencies seem also to appear and need to be studied.

In 1998, ARVALIS has also been set up a polyculture-livestock experiment in organic agriculture, in the centre of France, whose aims to reach the fodder and concentrate autonomy of a herd of beef cattle. In this trial, despite the inputs of organic fertilizers from the livestock, P and, in a lower extent, K deficiencies are observed, which lead to the difficult settle of legumes crops in meadows.

Following those observations, a fertility observatory consisting of a network of 50 plots conducted in organic agriculture was set up in South-West of France in 2017. The purposes are to monitor the evolution of different fertility criteria and yields in the medium to long term, and to identify farming practices that are beneficial and/or present risks for maintaining fertility. The first results have shown a decrease in P soil fertility, particularly in farms that have long been converted into organic agriculture.

Impacts of long-term input cessation and biomass management on soil nutrient dynamics in a New Zealand grassland

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A replicated field trial was established at Lincoln University in 1994 to investigate and quantify the combined impacts of nutrient input withdrawal and contrasting grassland management on soil carbon and nutrient dynamics. The trial area had been previously maintained under arable cropping and short-term grazed pasture with significant fertilizer inputs. A new grassland was established comprised of grasses, legumes and herbs, and plant biomass harvested 4-6 times per annum, with biomass either retained or removed. The trail has been running for 25 years, and is used for research and undergraduate teaching. This presentation will describe and discuss the major research findings that have emerged from the trial to date. This will focus on how contrasting biomass management has impacted key soil properties and processes related to the sequestration of organic carbon and the nature, dynamics and bioavailability of phosphorus.

Multi-performances of an organic cropping system led without external fertilizer, in the northern part of France, in arable crops: comparison with a conventional cropping system

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Agriculture has to succeed in producing food in quantity, in quality and in a sustainable way. This requires a shift towards new production systems, among which organic cropping systems may be promising. However, in some French areas, the absence of livestock deprives farmers of positive synergies between crops and animal husbandry.
The French technical institute on arable crops ARVALIS - Institut du végétal carried out since 2008 an organic cropping system (OS) led according to organic specifications and without any external fertilizer, in Boigneville, Parisian Basin, France. The objective of this system is to be economically profitable while producing quality grain, limiting nitrate leaching and preserving agronomic potential of the plots. Multi-performances of OS system were compared to those of a conventional one (CS), adjacent, led according to performant local conventional practices since 1990.
Crop management of these two cropping systems was realised in order to be as close to real arable farms as possible. Crop rotations differed for OS and CS, and were defined in order to meet economic, agronomic and environmental requirements. These two cropping systems were carried out in large plots of 0.5 to 3 hectares, following a set of decision rules. Each crop of each rotation was grown every year to be able to examine the climate impact on crop performance. Multi-criteria assessment was done after extrapolation at farm scale, with SYSTERRE®, software that calculates indicators at the plot or the system levels.
Overall, performances of OS are satisfactory. From 2009 to 2014, crop productivity was significantly lower for OS than for CS (e.g. wheat yield averaged 3.5 t/ha in OS, 7.7 t/ha in CS), but always met downstream quality requirements. With lower operational costs, higher and stable selling prices and specific public support, profitability of OS was not significantly different from CS (net margin with support: 569€/ha for OS, 444€/ha for CS) and economic robustness was significantly higher (OS coefficient of variation=16%, against 42% for CS).
Weed control was better in CS than in OS– but did not increase from 2009 to 2014 within plots of OS. Weed monitoring revealed high differences of the flora between the two systems: a majority of annual grasses in CS, a majority of dicotyledons and perennials in OS.
The main weak point of OS is about soil fertility. As there was no fertilizer inputs in OS since 2009, nutrient balances are negative (about -180 kgP_2O_5/ha and -430 kg K_2O/ha after a 6-year rotation). Alfalfa was first affected by nutrient deficiency (sulphur at first), leading to severe yield reduction. This threatened overall performance of OS, as alfalfa was key in nitrogen supply and weed control for other crops of the rotation.

Impact of long-term conventional and organic farming systems on barley

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Sustainable agriculture is the main aim in crop production. To identify the farming systems that would be sustainable for a longer period, a field experiment with seven different treatments (three organic and four conventional) was performed at Estonian University of Life Sciences during 2008–2018. The organic system was included three subtreatments: M0, MI with cover crops and MII with cover crops and composted cattle manure. Conventional system consisted of four subtreatments: $N_0P_0K_0$; $N_{40}P_{25}K_{95}$; $N_{80}P_{25}K_{95}$, and $N_{120}P_{25}K_{95}$. The aim of this study was to investigate how different farming systems influenced barley yields and quality (N, P, K) when it is a part of a five crop rotation experiment based on following order of the crop; red clover (*Trifoliumpratense L.*), winter wheat (*Triticum aestivum L.*), peas (*Pisum sativum L.*), potato (*Solanum tuberosum L.*) and barley (*Hordeumvulgare L.*). Results showed, On average 10 years crop rotation, the yield and nitrogen content were higher in conventional plots than organic ones. Interestingly there were a positive correlation between amount of nitrogen fertilizer and these traits so that highest yield and nitrogen content was related to the treatment receiving maximum mineral nitrogen. Potassium and phosphorous content increased significantly compared to their respective control but there was no difference between their own treatments. In terms of organic system, there was no significantly difference between treatments in all investigeted parameters. Nevertheless, impact of year on measeured features was considerable so that the highest amount of yield, nitrogen, potassium and phosphorous content was shown on 2013.

Seasonal climate conditions, pedogenic-topographic factors and management practices as main drivers of long-term carbon dynamics (1989-2016) in grassland soils of Bavaria

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Grassland soils store large amounts of soil organic carbon (SOC) and thus play an important role for climate change mitigation. However, the information about the long-term development of SOC stocks in temperate grasslands is limited. The Bavarian State Research Center for Agriculture (LfL) established 20 long-term grassland soil-monitoring sites in 1986 in the State of Bavaria, Germany. We analyzed SOC changes and identified the main controlling factors between 1986 and 2016. The results showed that the changes of SOC stocks were affected by i) seasonal changes of climate conditions (temperature, vegetation period), ii) pedogenic-topographic factors (slope, elevation, stagnic properties, clay content, pH), and iii) management practices (organic fertilizer application, cutting frequency, farming type). An analysis of controlling factors of SOC changes using the Random Gorest model showed that seasonal climate variables explained the highest variability of SOC stock changes, followed by organic fertilizer application. Based on this analysis we delineated scenarios that explained different SOC trends: i) scenarios leading to SOC stock increase or maintenance and ii) scenarios leading to SOC stock decrease.

Green manure crops for low fertility soils

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In this study, we present our preliminary results indicating that while white lupine () and buckwheat () are efficient green manure crops to grow on low fertility soil, garden sorrel () and oilseed radish () are more efficient to positively affect uptake of phosphorus (P) in subsequent crops, as indicated by the growth response of ryegrass.

Organic crop production is growing, but crop yields are still below potential. The purpose of our project "Nutrients for higher organic yields (NutHY)" is to increase yields and resource efficiency in organic crop production by optimizing nutrient supply. Growing green manure is an important tool to improve fertilization by biological nitrogen (N) fixation but also by mobilization and release of other nutrients such as P. However, development and performance of green manure are affected by low soil nutrient availability that is often reported as a problem in organic arable farms, especially with regard to phosphorus.

The purpose of this study was therefore to identify efficient green manure crops that are able to establish and grow fast in soils with low plant nutrient availability. We used fields and soil from the long-term nutrient depletion trial at the University of Copenhagen to study the effect of different soil fertility levels on growth and nutrient uptake of green manure and on their fertilizing effect on subsequent crops.

In a field experiment, six different species of green manure (white lupin, winter vetch (), crimson clover (), buckwheat, oilseed radish and winter rye ()) were sown after harvest of oilseed rape in plots with either low or moderate soil fertility due to different fertilization histories. Biomass sampling in autumn revealed that biomass production of winter vetch, crimson clover, oilseed radish and winter rye were significantly decreased when growing at low soil fertility whereas white lupin and buckwheat showed the same growth at both fertility levels.

In an incubation study, we studied the mobilization of P after soil amendment of aboveground biomass of white lupin, winter vetch, garden sorrel, crimson clover, buckwheat, oilseed radish and ryegrass () at low temperature (5°C). After 80 days of incubation, the treatments receiving sorrel and oil seed radish revealed the highest P mobilization, with an increase of water-extractable P corresponding to 50 and 31%, respectively, of the added P.

In a subsequent pot experiment with low fertility soil from the long-term field experiment, we investigated the P fertilizing value of 5 different species (buckwheat, oilseed radish, garden sorrel, white lupin and winter vetch), added at a rate of 50 mg P kg soil^{-1}. After 40 days of ryegrass growth, application of mineral P increased the biomass of ryegrass by 68% compared to the 0P control treatment. The application of green manure resulted in increase of ryegrass biomass varying from 1 to 44%. The highest increase was again achieved by addition of oilseed radish (43%) and sorrel (44%), confirming their value as green manure plants for crop P nutrition.

The *ServiceGrass* project: Effects of organic farming on ecosystem services and grassland multifunctionality

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Sustainable agriculture - and grassland based production in alpine regions such as in Switzerland - delivers not only private ecosystem services, i.e., market goods such as agricultural products, but also many public ecosystem services, i.e., non-market goods and services such as recreation and carbon storage. All these services are vitally needed for securing the supply of food, animal feed and other essentials for human well-being. Agricultural intensification, however, undermines the delivery of many public ecosystem services. Organic farming can decrease the environmental impact of intensive food production and might therefore be able to sustain the delivery of both private and public ecosystem services. However, this has never been comprehensively tested, especially not for organically managed grasslands. In the project , which starts in summer 2019, we will explore effects of organic grassland farming on 18 different ecosystem services and their simultaneous provisioning, referred to as multifunctionality. The principal aims are i) to compare the ability of organic and conventional grasslands to deliver ecosystem services, ii) to explain the impact of management (intensification) on single services and multifunctionality, and iii) to upscale plot-level results to entire farms, i.e. farm-level effects. Ecosystem services will be assessed in 92 plots within two study systems: the DOC trial containing organically and conventionally managed temporary grasslands, and on-farm plots in organic and conventional permanent grasslands. To assess the delivery of ecosystem service of grassland at farm-level, we will combine plot-level measurements with the Swiss Farm Accountancy Data Network, a database that contains detailed information on technical, structural and economic properties of more than 1000 Swiss grassland based farms. For overarching synthesis, we look for further available data on organically managed grasslands from previous projects. Findings of this project will underline strengths and weaknesses of organic and conventional farming systems in delivering private and public ecosystem services, helping to improve grassland farming for a more sustainable future.

Analysis of a long-term nitrogen fertilization experiment on fen grassland and presentation of the results

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A long-term field experiment with five nitrogen (N) fertilization treatments (annual N rates of 0, 60, 120, 240 and 480 kg N ha^{-1}) has been continuously conducted on drained fen grassland since 1961. The trial was established in a randomized complete block design with four replications. Since 1971 all plots were cut three times annually, and one third of the N fertilizer amount was applied to every cut. Dry matter (DM) yields of all cuts were measured during the entire experimental period.
The aim of the experiment was to study the impact of different N rates on the DM yield and to derive practical conclusions for drained fen grassland management. It could be expected that DM yields would depend not only on nitrogen but also on annually varying water conditions, and internally changing physical soil characteristics due to drainage. Therefore, the incorporation of further information about typical characteristics of the drained fen soil at plot scale is necessary. In 2015, peat layer thickness, dry bulk density, and elevation (describing the different distances between sward and ground water table beneath the trial area) were recorded for each plot separately.
As a first step, DM yield (per cut and total) was regressed on N rate (linear, quadratic), elevation, peat layer thickness and dry bulk density with models per each year using multiple linear regression (SAS 9.4 software, proc REG and MIXED) for the period from 1971 to 2016. We fitted the full model and all possible sub-models, and model fits were evaluated by Akaike Information Criterion and adjusted ^{2}. The N rate affected DM yield variously between the years as well as between the cuts. We could not find a similar pattern for all years (no as well as a linear or a non-linear N effect). The impact of the various soil characteristics on the DM yield differed too. Especially, elevation enhanced the model fit but peat layer thickness and dry bulk density were also often incorporated in the best model, either separately or in common.
As a second step, a joint regression function will be fitted for years with similar growing conditions. Therefore, the annual growth periods per cut were characterized by number of growing days, temperature sum, precipitation sum (daily weather data recorded since 1978), and average groundwater level (recorded since 2005).
In addition, the long-term trends of DM yields per cut and total DM yield for all nitrogen treatments are of interest. Due to the high annual variation of yields, an appropriate statistical model should incorporate characteristics of annual growth periods.
The results will be graphically presented and reasonable practical recommendations drawn for the agricultural practice where environmental conditions are similar to the experimental site.

Perennial leys for dairy cows: soil and plant attributes, yield and botanical composition with long-term low and high N input

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Soil chemical properties, plant nutrient concentrations, yields and botanical composition were studied in a high (mimicking conventional) and low nitrogen (N) input (mimicking self-sufficient organic) farming system over 7 years in a field experiment in Tingvoll, Norway. The two-factor experiment consisted of two organic fertilizer types (digested and undigested manure from organically managed dairy cows) and two fertilizer application rates, 110 and 220 kg total N ha^{-1} yr^{-1}. All, treatments and control, were cultivated with perennial grass-clover ley, re-established once during the study period. There was no significant difference between the average values of the above-mentioned characteristics evaluated for the digested and undigested manure, expect for K concentration in the ley (2018). Thus, results of treatments with high N input were combined to represent conventional farming systems, while low N input treatments represent organic farming systems. As expected, after 7 years, AL-extractable phosphorous (P) and potassium (K) concentrations in soil were significantly ($p=0.002$) higher in the conventional treatments than in the organic treatments. Despite the double amount of manure, cumulative ley yield (2011-18) was only 17% higher ($p<0.001$) in the conventional than in the organic treatments. In 2018, concentration of P in the aboveground plant material was significantly higher in all fertilised treatments than in the control ($p=0.041$), and significantly higher in the conventional than in the organic treatments ($p<0.001$). N use efficiency (NUE%) was calculated as NUE% = N removed (in ley yields) / N applied (manure) x 100. NUE(%)ranged from 102-163% for the organic treatments, suggesting that more N was removed by ley yields than it was applied with manure. This N may derive from soil or biological N fixation. Conventional treatments had a NUE between 59 and 96%. Low NUE% indicates excessive use of fertiliser that may cause environmental pollution. Botanical composition of the grass-clover ley (2015) was affected by N application rates, with significantly less clover ($p=0.008$) and more grass ($p=0.003$) in the high N input treatments. Overall, our findings indicate that in the long-term high N input farming systems do not necessary translate in significant gains of ley yield production when comparing to low N input systems. NUE and clover content of the ley will be reduced with higher N input.

The Gallecs trial, a mid-term experiment on reduced tillage, fertilisation and green manure in Mediterranean dryland arable cropping systems

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Conservation agriculture and organic farming are two alternative strategies aimed at improving soil fertility in arable cropping systems through reducing tillage intensity, maintaining year-round soil cover and increasing nutrient recycling, using farmyard and green manures. However, the reduction of tillage intensity can increase weed infestation and decrease nutrient availability. The mid-term "Gallecs" trial (Catalonia) was established in autumn 2011 at Gallecs, a periurban agricultural area near Barcelona. The effects of tillage (mouldboard versus chisel ploughing), fertilisation by farmyard manure (without versus with) and green manure (without versus with) on soil fertility indicators, weed abundance and grain crop yields were studied in a 4-years cereal-legume rotation for human consumption under organic farming conditions in the Mediterranean region (Catalonia, Spain).
Fertilisation was the most important factor, increasing the cereal yields, SOC, N, microbial biomass (C_{mic} and N_{mic}) content of the soil, and density and biomass of earthworms. However, fertilisation did not favour legume crops, probably owing to competition with weeds. Overall, there was a loss of SOC and a reduction of soil carbon stocks over the four years, irrespective of the ploughing intensity, while the nitrogen content increased. However, SOC losses were lower in plots fertilised with farmyard manure, even an increase in SOC occurred in the upper soil layer (0-10cm) of plots with chisel ploughing. The tillage system does not have a consistent negative effect on yields both in cereal and legume crops.
Summing up, fertilisation was the most effective way to build up soil organic matter reserve, through stimulation of microbial community functioning. Reduced tillage had also positive effects on microbial biomass and SOC contents, whereas the positive effect of green manures was very low. Improving soil management is necessary to increase SOC sequestration in the Mediterranean dryland arable fields, and thus mitigate climate change and sustain crop production.

Organic arable farming experiment Gladbacherhof - productivity and soil parameters of different farm types and various soil tillage systems

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The Organic Arable Farming Experiment Gladbacherhof (OAFEG) is a long-term field experiment that has been carried out since 1998 at the experimental station Gladbacherhof, University of Gießen. The OAFEG includes two factors: 3 different farm types and 4 soil tillage systems.

In the context of specialization and intensification processes taking place even in organic farming, an increase of organic stockless farming faces particular challenges with regard to nutrient supply as well as sustainable management of humus resources. A careful assessment of the economical and ecological performance of such systems is necessary in order to promote sustainable management.

Further, the reduction of tillage intensity has often been considered as desirable in organic farming. The reasons for this are manifold. Lately the issue has been given special attention in the context of climate change and carbon sequestration in agricultural soils. Still it has to be investigated whether reduced tillage systems in organic farming can cope with the requirements of nutrient availability and weed control.

After passing through the 3rd crop rotation (2010 – 2015) the trends of the 2nd rotation (2004 – 2009) could be verified. The mixed farming system showed a significant higher productivity in reference to the parameters “aboveground biomass”, “non-legume cash crop yield” and “sum of all harvested biomass” than both stockless farming types. Apart from that, soil organic carbon (SOC) and soil total nitrogen (STN) masses increased in the system with animal husbandry and decreased in both stockless systems.

All in all, the superiority of a management system with cattle over stockless organic farming is demonstrated. The mixed farm type led to higher yields and higher amounts of humus in the soil. Long-term reduction of humus in stockless farming is not acceptable. Therefore it is advisable that every crop rotation in organic farming should include a legume fodder crop element as a main crop.

Concerning the second factor of the OAFEG: The yield level with regard to the above mentioned parameters was significant lower in the soil tillage system without ploughing. On the other hand the differentiated intensity of soil tillage did not bring about any significant changes in the mass of SOC and STN in the topsoil.

As for the tillage systems it can be concluded that reduced tillage systems did not yield less than the regularly ploughed reference system if at least a shallow soil inversion was carried out. The reason for lower yields in the soil tillage system without ploughing seems to be the soil structure and the soil temperature and as a consequence of this a lower nutrient availability in special periods of vegetation.

Carbon sequestration and stabilization in a 40-year agronomic long-term experiment

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Soils contain more carbon (C) in the form of organic matter (soil organic matter = SOM) than the entire atmosphere and global vegetation put together. They are thus a central component of the global C cycle and its largest dynamic reservoir. On the one hand, intelligent agricultural practices are discussed as a way of mitigating climate change because they can increase the amount of SOM and thus actively remove C from the atmosphere. On the other hand, all intensively used soils lose C in the long term. Central questions in this context revolve around the extent and dynamics of storage, the stabilisation mechanisms involved and the impact of agricultural use on the C budget.

The DOK experiment is an agronomic long-term experiment near Basel (Switzerland), which has been comparing biodynamic, organic and conventional management systems for 40 years (six crop rotation cycles) and has an extensive soil sample archive covering the entire period. As part of the "DynaCarb" project, we are investigating how SOM behaves in different soil fractions during the 40-year test period in the systems. We compare an unfertilized control, a purely mineral one, a purely organic one and a combined fertilized, mineral-organic variant (four replicas each) in 1982, 1989, 1996, 2003, 2010 and 2017. Using physical fractionation (density and particle sizes) and CN analyses, SOM is separated into particulate and mineral-associated fractions and their development is quantitatively investigated during six crop rotation cycles. We use solid-state ^{13}C NMR spectroscopy, N_2 gas adsorption and radiocarbon dating to estimate the C sequestration potential of soils, their saturation and the dynamics of C storage.

"DynaCarb" investigates the medium- and long-term effects of different agricultural systems on SOM. These results are of great importance for the evaluation of the C-sequestration potentials of agricultural soils and for the identification of suitable utilization and fertilization strategies.

Organic cropping systems with winter cover crops in combination with composted manure significantly improve soil properties

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The influence of cropping systems on soil quality was investigated in three organic and two conventional cropping systems of the five-field crop rotation (barley with red clover undersown, red clover, winter wheat, pea, potato). Experiment is running since 2008 at the experimental station of the Estonian University of Life Sciences (58°22'N, 26°40'E). The system Org 0 just follows the rotation. In organic systems Org I and Org II winter cover crops are used as follows: mixture of winter turnip and winter rye after winter wheat ; winter turnip after pea and winter rye after barley. In Org II system composted cattle manure is applied 10 t ha^{-1} for cereals and 20 t ha^{-1} for potato. The conventional systems running without winter cover crops: Conv 0 is as control (no fertilizers) and Conv I - with mineral fertilizers (all crops received 25 kg ha^{-1} P and 95 kg ha^{-1} K; and N 150 kg ha^{-1} for winter wheat and potato, N120 kg ha^{-1} for barley undersown with red clover and N 20 kg ha^{-1} for pea. Both conventional systems are treated with insecticides, herbicides and fungicides.

Soil quality significantly improved in organic cropping systems where Corg was significantly higher ($p<0.05$) compared to conventional systems. In turn the use of winter cover crops in Org I and II systems increased Corg, pH, microbial activity and plant nutrient contents. The best soil quality was reached in Org II system, where cover crops were used in combination with manure. The highest organic carbon content was in Org II (1.58%) and lowest in Conv 0 (1.30%). Higher content of Corg is based by bigger input of organic matter from winter cover crops and manure. That was related by greater number of earthworms, collembolas and higher soil microbial hydrolytic activity. Soil life activation was correlated by better formation of plant nutritional elements. In the Conv 0 system ploughing layer contents of plant available P, K, Ca, Mg and total nitrogen was significantly lower, compared to Org 0 system. The content of P and K varied considerably between systems – accordingly from 95 in Conv 0 to 107 mg kg^{-1} P in Org II and from 114 to 139 mg kg^{-1} K respectively. Due to mineral fertilizers in Conv I system plant available P and K content were similar to the Org II system.

The highest content of N, Ca and Mg was reached in Org II system, where winter cover crops were used in combination with composted cattle manure. In conventional systems the lower content of nutrients is related by lower content of Corg and lower microbial activity but also higher acidity of these soil. Apparently the last together with pesticide residues in soil explains the reason of lower microbial activity. Soil pH KCl varied from 5.56 in Conv I system to 6.05 in system Org II and was significantly lower in both conventional systems compared to organic systems.

The highest soil bulk density, lower percentage of water permeability and lower air filled pores fraction was found in Conv 0 compared with the other systems.

Effect of long-term fertilizer management on spring and winter cereals on sandy soil in Northeast Germany

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Response to fertilizer on cereal yield is a function of several factors including weather, previous crop yield level, and the amount of fertilizer applied. This paper reports the effect of weather conditions and fertilizer application on grain yield of spring barley, winter rye, and winter wheat in a long-term experiment (LTFE). Data from a LTFE "V140", which established in 1963 in sandy soil at Müncheberg, located in Northeast Germany was used in this report. The experiment was designed in a randomized complete block with 21 treatments; five different rates of mineral N fertilization × four organic fertilizer regimes and a control treatment without fertilizer. Yield data were tested by the general linear model. Multiple regression models were used to estimate the impact of the weather variables, preceding crop yield and fertilizer on the mean yield for each treatment. Results of the study showed that the variability in spring barley yields were significantly affected by fertilization regimes and by meteorological variations. While variability in winter rye, winter wheat grain yield over the years do not well relate to weather condition. Other factors than weather variable may modify fertilizer response in winter rye and winter wheat, such as cultivars. These findings support the valuable information for future agricultural strategies in terms of crop productivity under climate change. The LTFE time series under different soil and climate conditions should be studied to investigate also in comparison to other LTFE sites and crops.

Long-term effects of different previous crops and NPK fertilization on soil parameters and biomass yields of subsequent crops in the LTE "BSG" Giessen

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The Long-Term Experiment (LTE) Biological Nitrogen Fixation, which is called as "BSG" (Biologische Stickstoff-Gewinnung) was established at the Justus Liebig University Giessen (Research Station Weilburger Grenze, Giessen) by the section of Agronomy in 1982. The general aim of this LTE is to investigate different cropping systems (varying previous crops and crop rotations) including fallow land in relation to its effects on relevant soil parameters, biomass yields and crops quality for a long time.

The site (186 m a. s. L.) is characterized by a mean precipitation of 650 mm and a mean air temperature of 9.2 °C (1948-2017). The soil of the LTE is a Fluvic Gleyic Cambisol characterized by 58% silt and 36% clay in the top soil (0-30 cm).

The BSG Giessen includes two factors (A: previous crops/crop rotation, B: NPK fertilization) consisting of 20 variants (5 x 4) which was established as a static LTE with randomized block design and four replications. The factors and variants can be characterized as follows: A (previous crops): bare fallow, green fallow (into the soil incorporated crimson clover), field bean, summer oats, grain maize, B (mineral NPK fertilization): without fertilization, PK fertilization, PK + 50% N fertilization, PK + 100% N fertilization. After the previous crops (see factor A) three subsequent crops (winter wheat, winter rye and summer barley) three years in a row are cultivated. Therefore, five cropping systems or crop rotations are established which are characterized by large varying impact of organic nitrogen (such as bare fallow compared to green fallow).

The presentation highlights selected results from the BSG Giessen over the last two crop rotations. In particular, the plant parameters like biomass yields, harvest indices and grain quality as well as the soil parameters like carbon (Ct, Corg) content, nitrogen (Nt, Norg, Nmin) content and soil respiration will be presented. The existing results express clear impact of the used previous crops or land use on the analysed soil parameters and biomass yields of the subsequent crops.

Soil carbon dynamics in croplands under conventional and organic management in Bavaria

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An intensification of agricultural management and ongoing climate change could lead to a decline of organic carbon stocks in agricultural soils in the long-term, with all known negative consequences for central soil functions. In order to gain insights into the long-term development of soil organic carbon (SOC), a soil monitoring program including 347 agricultural sites was initiated in Bavaria in 2001 in order to detect SOC changes. In this monitoring network both conventionally (266) and organically managed croplands (81) have been integrated. An evaluation of the results for the period 2001/2008 to 2011/2018 showed a mixed picture of SOC development. All regions of Bavaria experienced significant declines as well as increases in SOC. However, the majority of locations did not show any significant changes. Fundamental differences, however, arose between conventionally and organically managed locations. In addition to management aspects, the initial SOC levels at the time of the implementation of the monitoring program were identified as the most important causes of observed SOC changes.

Building a network of long-term experiments on agroecology and organic farming

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Sustainable development of agri-food systems is a key priority for the future. Organic farming, widely considered as an explicit form of sustainable farming system, is steadily increasing in Europe in terms of production and market.
The functioning of organic cropping systems is based on complex biological processes which are strongly inter-connected with the physical environment and the human management. This makes organic cropping systems models also for other cropping systems based on reduced use of external inputs and on agroecological practices.
To understand this complexity and to facilitate the transition of all agri-food systems to become more sustainable, organic long-term field experiments implementing the principles of agroecology are thus needed. They could be powerful research facilities to produce science-based knowledge essential to support prospective agricultural policies for the solution of societal challenges, e.g. climate-change mitigation and food security.
We thus propose to build the first international network of organic long-term field experiments designed and managed in accordance with agroecological principles and practices.
Launching such an international network of organic long-term field research experiences will therefore i) reduce knowledge gaps and harmonize methodological approaches, resulting in higher impact of their results; ii) promote the quality and quantity of research for the transition of the agri-food systems to become more sustainable; iii) expand the opportunity for collaborative, multi-actor research and co-innovation actions across the organic long-term experiments community; iv) to pave the road for further initiatives such as the European food system research infrastructure.

Establishing a long-term experiment to study the effect of organic cropping systems on GHG emissions, carbon and nitrogen cycles and environmental efficiency

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For the province of Quebec (Canada) in 2016, greenhouse gas (GHG) emissions from the agricultural sector accounted for almost 10% of total emissions or 7.6 Mt eq. CO_2. It is possible to increase carbon sequestration in Quebec agricultural soils and reduce emissions from the agriculture sector by further promoting organic agriculture. Increased field crop areas (mainly corn, soybean, and cereals) under organic management is an excellent way to achieve these objectives. In 2016, organic agriculture represented only 3.2% (29 600 ha) of the total area of these crops. A meta-analysis concluded that a significant mean sequestration gain of 0.45 t C ha^{-1} yr^{-1} was obtained in organic farming compared to conventional farming. According to the Rodale Institute, the organic farming sector emits around 35% less GHG compared to the conventional farming sector. The main objective of the project is to study GHG emissions and carbon and nitrogen dynamics in twelve organic cropping systems in a long-term experiment. Fertilization or not with animal or green manures and soil tillage practices will vary between selected agronomic sequences. This long-term field experiment will be set up in 2019 on the experimental farm of the National Institute of Organic Agriculture located in Victoriaville (Quebec, Canada). This project will monitor GHG (CO_2, N_2O, CH_4) fluxes and carbon and nitrogen cycles in soils. Soil microbiome shifts and soil health indicators (physicochemical, environmental) will be monitored. Agronomical parameters such as crop yields, biomass, diseases incidence, will be measured. The aim of this study is to identify organic farming practices in Quebec that improve GHG balance and soil health status while being economically viable.

The BonaRes Repository: overview of long-term field experiments and provision of research data

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BonaRes is short for 'Soil as a sustainable resource for the bioeconomy' (www.bonares.de). In this funding initiative of the German Federal Ministry for Education and Research (BMBF) the focus is on the sustainable use of soils as a limited resource. BonaRes is divided into the BonaRes Centre and 10 collaborative projects and has a planned duration of nine years (2015 – 2024). The research of most of the BonaRes projects is based on long-term field experiments (LTFE), which are here defined as agricultural experiments with a minimum duration of twenty years.

In the BonaRes Centre, one focus is on the acquisition, storage and provision of data from LTFE. For better findability and reusability of these data the BonaRes Repository was established. It aims at providing information about LTFE in Germany as well as LTFE's research data and metadata for free reuse. The data gained in BonaRes projects are also published in the BonaRes Repository.

An important information tool is the compilation of all existing LTFE in Germany with metainformation to each trial. This information is shown in a dynamic online overview map which is available in German and English (https://ltfe-map.bonares.de). The map offers information about more than 200 LTFE in Germany. The map content can be displayed according to different categories, e.g. the research theme of the LTFE. Therefore it offers valuable information for potential users for orientation and initiation of cooperation.

An assessment of the spatial distribution of LTFE according to different environmental conditions in Germany shall be part of the presentation. Furthermore details on LTFE in Germany, the use of LTFE in BonaRes projects and the progress of the common database shall be presented. As an example, the publication for free reuse of the dataset of the ZALF's LTFE V140 is described. The data can be downloaded in the BonaRes Repository via the BonaRes Data Portal (https://doi.org/10.20387/BonaRes-BSVY-R418).

Profiling soil microbial communities influenced by reduced summer precipitation and farming system history

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Soil bacteria and fungi are the basis of soil food webs and contribute to a wide range of essential soil functions in arable lands. Intense land use and climate change induced reductions in summer precipitation can have varying influences on abundance, composition, and activity of microbial communities with largely unknown consequences for soil functions and plant growth including crop yields. The impact of altered precipitation patterns on soil biodiversity and associated ecosystem functions is on top of the list of eight major research gaps identified by an expert group for the European Commission still, this relationship is rarely studied under field conditions. To explore the role of soil management and precipitation amounts on microbial communities and soil functions, we manipulated natural precipitation patterns in the long-term farming system comparison trial "DOK" (bio-Dynamic, bio-Organic, and "Konventionell") using fixed location rainout-shelters. Of the organic and conventional farming systems tested side by side in this trial, we chose the two most contrasting ones for the current study: The bio-dynamic (BIODYN) and the conventional (CONMIN) farming system, two systems which profoundly differ in fertilization and plant protection regimes. As model test plant, we grew winter wheat (L. cv. "Wiwa") in the experimental field plots. We assessed plant growth at four time points during the growing season and investigated activity, community structure and dynamics of bacterial and fungal communities with traditional soil ecological methods such as soil respiration, phospholipid fatty acid analysis, and the microbial biomass by chloroform fumigation extraction. We also performed amplicon based, high-throughput sequencing of the 16S rRNA and the ITS gene region for in-depth profiling of microbial communities and assessed abundances of bacteria and fungi with quantitative real-time PCR. We are analysing our data with structural equation modelling to study the direct and indirect effects of reduced summer precipitation and farming system history on characteristics of soil microbial communities and plant performance. Our data obtained so far shows that the two different farming systems harbor distinct microbial communities and that the specific farming system has profound impacts on soil respiration and total microbial biomass carbon.

Phenotyping – a link between field experiments and agricultural practice?

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Phenotyping of plants is understood as a key technology to foster sustainability of agricultural systems. Specifically, phenotyping is the use of sensor technology (often imaging or spectral sensors) combined with data processing and statistical interpretation methodology to infer plant or crop traits in spatial, spectral and timely manner to better understand the plant performance and its interaction with the environment. Prominent examples for phenotyping are genotype trials "phenotyped" by breeders to select for optimal trait combination and genetic background but also sensor based in-season variable rate application (VRA) of fertilizers. VRA is one of the most used methods in precision agriculture making use of in field plant or soil variability to optimize spatial distribution of inputs.

The presentation will show examples of field phenotyping from "phenocams" and "drones" being a static and mobile sensor application used in field phenotyping. Advantages and trade-offs of both sensor deployment methods are shown due to research examples from breeding and fertilization background being applied to field trials and farmers' fields. While stationary systems can resolve temporal changes in plant systems at hourly to daily rate, they are bound to a certain location and limited in space. Mobile systems can cover large(r) areas but need significant effort for temporal, radiometric and spatial alignment of data and more administrative and data processing efforts.

The conclusion will point out the high potential of digital methodology for field and particularly long term experiments but also the great value of such experiments for calibration and validation of new sensing systems, trait retrieval and data processing algorithms. To foster and improve digital sensing methods applicable in practice more calibration and validation studies are needed.

Combining long-term experiments to quantify the contribution of crop diversity to sustainability

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Crop diversity is widely recognised as key to agricultural sustainability, and is particularly critical to maintain yields in organic and low-input systems. However, to date there are no general 'rules of thumb' to guide the diversification of cropping systems around the world. How much diversity is enough diversity, in the long term? Is phylogenetic or functional diversity more important? Does crop diversity interact with other management factors, and are such effects stable or dynamic over time? Long-term experiments (LTEs) provide a valuable resource to investigate such questions, through their capacity to track the behaviour of different cropping systems over the generational timescales necessary to assess sustainability. Combining results from multiple LTEs offers even greater insights through identifying whether crop diversity has consistent effects across different environments and cropping systems. However, bringing together different LTEs designed for different purposes presents its own challenges. Here, we investigate the joint analysis of different LTEs from the United Kingdom and from sub-Saharan Africa, to quantify the contribution of crop diversity to sustainability. A careful selection of indices of diversity and measures of sustainability that are comparable between experiments is required, and statistical modelling and multivariate analysis approaches are necessary to identify key relationships amongst both variables and treatment combinations. We demonstrate and discuss the potential of such an approach, and present initial findings on the links between crop diversity and yield, yield stability, soil carbon, resource use efficiency, and the negative environmental impacts of agriculture.

What are the limits for recycling from society to organic agriculture?

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In 2008 Danish Organic farmers decided to ban import of manure and straw from conventional farms by 2021, based on the idea that the reliance on conventional agriculture for nutrient supply was not sustainable. Subsequently they had to moderate this decision, due to the lack of acceptable alternatives, in favor of a more gradual approach to replenishing soil fertility from alternative sources.

Due to development of environmental regulation and improved waste management strategies, waste streams in society have changed considerably over the past 40-50 years. We have assessed the implications of phasing out conventional nutrient supply in organic agriculture. A lesson emerging from this study is that it may be impossible to cover the need for P fertilization in non-dairy farms without resorting to reuse of sewage sludge, which is in line with the ideas of one of the forefathers of organic agriculture, Sir Albert Howard, who was a very strong proponent of the recycling of organic waste. This has led to a discussion within Danish organic agriculture about whether recycling from society can be a considered a breach of principles, a compromise or a fulfillment of the organic ideology of working with closed cycles. In 2013, the UK soil association recommended that amendments should be made to EU regulation No. 889/2008 to permit the use of sewage sludge on organic certified land subject to certain quality criteria and appropriate restrictions, including maximum concentrations of heavy metal and organic contaminants.

Over the past 20 years by we have assessed implications of recycling, drawing on the scientific literature and experiences from a unique Long-Term Ecological Research facility (CRUCIAL) at Copenhagen university. The overall conclusions are that the ecosystems capacity for processing large or even massive quantities of contemporary waste is remarkable. So far negative effects, apart from an undesirable loss of nutrients, have not been seen and while there are some knowledge gaps related to microplastics and the long-term effects on rhizobium and N_2 fixation efficiency, we opine that the resilience of the soil and ecosystem is generally underappreciated.

In the development of the long-term ecological research facility CRUCIAL experiment, at Copenhagen university treatments with accelerated amendments of contemporary waste corresponding to 100-250 years of legal application are available. We have documented that human urine, sewage sludge and composted household waste are beneficial and safe for soil fertility building with regard to physical soil quality, leaching and plant uptake of potentially toxic elements, soil microbial diversity, transmission of multiresistance and soil organic matter quality. In recent years we have initiated research on micro-plastics, establishing that microplastic is not a threat to epigenetic earthworms. Avoidance experiments showed that earthworms preferred to live in soils treated with large amounts of sewage sludge compared to cattle manure, and quantification of natural populations showed far higher earthworm numbers in the sewage treated soils.

In this presentation we propose that the limits for recycling from society to organic agriculture is predominantly determined by public perceptions and a ‘rational fear’ for consumer reactions, rather than clearly defined ecological hazards.

Estonian semi-natural grasslands in historical perspective

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Estonian agricultural landscapes are rich in semi-natural grasslands. The usage of these ecosystems has decreased considerably and in 2006 their area was estimated to cover only 130 000 ha and currently less than 30 000 ha are managed in traditional extensive way - without ploughing, sowing or fertilising. Fortunately, a valuable set of long-time data is available from the longest Estonian grassland experiment (established in 1962) in the Laelatu wooded meadow (Natura 2000 code 6530*), a semi-natural grassland with high value in plant species richness. During 1961-1981 in some parts of this wooded meadow a fertilisation experiment was carried out. Fertilisation impact on plant community is detectable for more than decade after nutrient application. From the second treatment year the ratio of other forbs and sedge/rushes biomasses on fertilised plots decreased and was replaced mainly by legumes and grasses. So far, the former ratio of legumes has not recovered. Likewise, the plant species richness has not reached the original level during next half of century. Previously fertilised plots still have 5% plant species fewer compared to the control plots. Without fertilisation the biomass production in the Laelatu wooded meadow increased steadily during 50 years. As in the European longest grassland experiment in Park Grass, UK the biomass production remained steady during the same period, we conclude that a plant community of semi-natural grassland is a homeostatic ecosystem for decades and no mineral fertilisers are required to replace the nutrient removal with hay. The yield growth in wooded meadow can be associated with shrubs and trees that support the herbaceous plants nutrient supply via hydraulic lift and/or leaf litter. A long-term experiment and comparison with other long-term study results is required, however, for better understanding of ecosystem functions.

The Global Long-term Experiments Network Metadata Portal

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The Global Long-term Experiments Network Metadata Portal is a new online resource for publishing and discovering information about long-term agricultural field experiments (LTEs). The portal aims to raise the online profile and visibility of LTEs and make them discoverable to a wider scientific audience, and connect researchers with LTE managers. We hope the portal will increase the impact of LTEs by creating new opportunities for collaborations and research through the re-use of valuable LTE datasets. The portal has been developed using existing metadata standards and metadata have been designed to be interoperable with similarly capable national and institutional repositories. This means the portal can automatically harvest metadata from other online repositories and redisplay experiment metadata. This further increases the profile of LTEs but without LTE managers having to enter the same information multiple times.

Long-term timescale for implementation 4per1000 initiative: comparison organic and mineral fertilization

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The "4 per 1000" initiatives encourages agricultural sector to apply practices aimed at **soil organic** carbon (SOC) management for greenhouse gases sequestration. Opponents of this concept argued that SOC accumulation grows only up to certain equilibrium value, in other words, the effect of SOC sequestration would have a short-term effect. In this regard, it is important to assess the potential for the SOC storage for different management practices in a long-term. Geographical Network of Field Experiments in Russia includes several long-term experiments (LTEs) with equivalent NPK rates of mineral, organic and organic-mineral fertilization systems. RothC dynamic model was used to monitor SOC changes in 7 such LTEs having been maintained for more than three decades with high quality monitoring of vegetation and soils and potential for access to data. These LTEs represent a diverse range of climatic factors and management practices in order to make an assessment of the potential of conventional management practices to store >4‰ per annum in European Russia. The experiments were launched in 1931-80 on Podzols, Retisols and Chernozems (Vladimir, Moscow, Tver, Perm, Rostov Regions). The initial SOC stock ranged from 16-26 $Mg \cdot ha^{-1}$ (0.5-0.8%) in the experiment in the Vladimir Region (Podzols) to 82-92 $Mg \cdot ha^{-1}$ (2.4-2.7%) in the LTE in the Rostov Region (Chernozems). Treatments with organic and organo-mineral fertilization provided practically the same average annual C input from plant residues as mineral fertilization treatments but additional 147% C input on Podzols, 28-60% on Retisols and 33-42% on Chernozems with farmyard manure (FYM). The gain of SOC in all the treatments with FYM application exceeded the desired value of 4‰ annual increase: among Retisols the lowest value 7.5‰ was obtained in Perm LTE and 2-2.5 times higher in Tver LTE and Vladimir LTE. In LTE at chernozem soil C average annual accumulation does not exceed 1.00‰, presumably as a result of high initial SOC level. At the same time, mineral fertilization in equivalent NPK rates was sufficient mainly for maintaining SOC stocks in a long-term, with small positive or negative values (± 0.7‰), except for Tver LTE demonstrating high interannual variability. In favourable climatic years SOC gain demonstrate twofold increase, the highest values are expected for treatments with the highest NPK rates. At the same time in the extreme years, with 25% decrease of average annual C input, the same treatments demonstrate losses of existing SOC stocks. Change of one-two favorable to extreme years in 25-year period is enough for tracing long-term changes of SOC stocks in the topsoil. The model outputs show preference of organic fertilization for obtaining the indicator value for SOC fixation in arable soil. The results also demonstrate that conventional land management practices with only mineral fertilization may hardly be recommended for C sequestration in arable soils. FYM application in a combined organic and mineral fertilizers application as well as possible change in management practices is required to reach the 4‰ limit for such areas.

Determination of greenhouse gas sources and sinks in Swiss arable soils under organic and non-organic management

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Agricultural practices contribute considerably to emissions of greenhouse gases (GHG). Knowledge on the impact of organic (ORG) compared to non-organic (NON-ORG) farming on soil-derived nitrous oxide (N2O) and methane (CH4) emissions is still limited. We conducted a literature search on measured soil GHG fluxes under ORG and NON-ORG from farming system comparisons and performed a meta-analysis. Based on 12 studies covering annual measurements, it appeared that area-scaled N2O emissions are with 14% significantly lower under ORG. However, yield-scaled N2O emissions are only 9% higher for ORG. Emissions from NON-ORG soils seemed to be influenced mainly by total N inputs, whereas for ORG other soil characteristics seemed to be more important because N2O from organic N fertilisers emits decoupled from the inputs. Furthermore, we observed a 12% higher CH4 uptake for arable soils under ORG.

The findings of the Meta-Analysis serving as hypotheses we investigated N2O and CH4 soil gas fluxes with manual chambers from 24 Aug 2012 to 18 Mar 2014 in a grass-clover– silage maize – green manure cropping sequence in the DOK. We compared the systems BIODYN and BIOORG with CONMIN and CONFYM together with NOFERT. We observed a 40.2% reduction of area scaled N2O emissions for ORG compared to NON-ORG (conventional). Despite the pronounced difference in maize yields, yield-scaled N2O emissions did not differ between ORG and NON-ORG. The 56% lower emissions for BIODYN compared to CONFYM can be related to the 52% lower input, but the resulting yield gap of only 27% for BIODYN indicates that this system's N efficiency is superior and thus contributes to GHG mitigation. We recorded on area scale under silage maize a modest CH4 uptake for BIODYN and CONMIN and high CH4 emissions for CONFYM likely due to the stacked manure applied. We found that, in addition to N input, soil quality properties significantly affected N2O emissions.

In order to discern pre-crop and farming system specific differences we monitored N2O and CH4 soil gas fluxes from October 2014 until July 2015 covering the cropping of winter wheat, either with rapeseed or soy as pre-crop, in BIOORG, CONMIN and CONFYM. We found no clear farming system differences but distinct pre-crop effects. The microbial mediated decomposition and mineralization of crop-residues influences considerably the N2O and CH4 fluxes with changing effects over time. The C/N ratio dependent decomposition trends towards a (steady state) low soil C/N ratio and pH neutrality and is heavily impacted by N-fertilisation. BIODYN was not included in this study.

BIODYN indicates a pathway towards ecological intensification of agriculture. Lower N-inputs applied as composted farmyard manure seem to cause the systems efficiency. This confirms the closing conclusion of the initial Meta-Analysis that closes as follows: "Improving resource efficiency through increased productivity is of key importance in this respect for the further development of organic farming systems."

Influence of long-term fertilization and crop rotation on the ^{13}C and ^{15}N natural abundance of soils from the Saria soil fertility experiment

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Old tropical soils are dominated by secondary and highly weathered clay minerals with a low cation exchange capacity. Those soils are depleted in rock derived elements and plant nutrition is driven by organic matter (OM) input. Carbon (C) and nitrogen (N), such as their stable isotopes ^{13}C and ^{15}N have proved to be very useful for analysis of soil OM and the impact of different agricultural managements. A long-term field experiment has been started in Saria, Burkina Faso in 1960 to study soil fertility and sorghum productivity under different fertilization treatments and crop rotations. We compared sorghum monoculture (SS) with the crop rotation sorghum-cowpea (SC) under control conditions without any fertilizer input (CON) and under low (MIN1) and high (MIN2) mineral fertilizer and low mineral fertilizer combined with a low amount of farmyard manure (MINFYM1) and a high amount mineral fertilizer combined with a high amount of farmyard manure (MINFYM2). We sampled for all plots topsoil in a layer of 0-10 cm and crop shoots and roots. Moreover, we sampled soils and below and above ground residues from dominating species of a near native vegetation. We analysed soil and plant material and farmyard manure for total C, total N and their isotopic signature. Preliminary data showed C concentrations in soils ranging from 1.9 g C kg^{-1} in CON plots to significantly higher C concentrations of 3.4 g C kg^{-1} and 9.5 g C kg^{-1} in soils, fertilized with MINFYM1 and MINFYM2, respectively. Similarly, the N concentration ranged between 0.19 g N kg^{-1} in control soils, and 0.94 g N kg^{-1} in the MINFYM2 treatment. Neither mineral fertilizer alone nor crop rotation did influence soil C and N concentrations and $\delta^{15}N$ values compared to CON, despite the N fixation of the legume. In contrary, $\delta^{13}C$ values of the soils showed an imprint of manure within the MINFYM2 treatment of -20.9 ‰ regarding -18.2 ‰ in the CON soils. Sorghum, a C4 plant, increased $\delta^{13}C$ values slightly within the monoculture SS, compared to SC. However, the $\delta^{13}C$ values were in the same range as those from C3 plants and soils and plant residues found under adjacent native vegetation. Organic input, such as farmyard manure was necessary to increase soil C and N concentrations. The lack of impact through the crop rotation on the isotopic signature might be on one hand due to the low amount of below ground root input and on the other hand due to the high mineralization rate of this fresh input and therefore the weak incorporation into soil OM. Old organic C from the ancient native vegetation might be very stable and protected, bound to clay particles and oxides.

Exploring agronomic performance of heterogeneous winter wheat populations under organic and conventional agricultural cropping systems in a long-term trial

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The challenging conditions found in organic agriculture in terms of nutrient availability, high weed and pathogen pressures, as well as the lack of suitable varieties available for such low-input cropping systems, have brought the concept of evolutionary breeding using adaptable heterogeneous populations into focus as an alternative breeding method.

Since 2005, 3 winter wheat composite cross populations (CCPs) have been grown at the University of Kassel, Germany, under both organic (O) and conventional (C) management (6 CCPs in total) in plots large enough to avoid genetic drift. The first population CCQ is based on the crossing of 12 varieties with good baking quality (Composite Cross Quality). The second population CCY is based on the crossing of 9 high yielding varieties (Yield). The third population CCYQ was created through the crossing of 20 parental varieties based on both good baking quality, as well as yielding ability (Yield x Quality). In 2006, these six populations were divided in half in order to create two parallel populations (I and II), resulting in a total of 12 populations (6 organic and 6 conventional), allowing for statistical comparison of the CCPs both within and between systems. In each experimental year, a number of popular pure line varieties at that time were grown alongside the CCPs as reference. Grain yield (t/ha), thousand kernel weight (TKW), foliar and foot rot disease assessments were carried out from 2005/06 until 2015/16, which depending on assessment, provided a dataset spanning 11 generations.

In both management systems, strong interaction effects between experimental year x CCP for a number of the agronomic parameters were found, indicating the high response plasticity of the CCPs under differential environmental conditions. However, no significant CCP x management system interactions were found suggesting that the differential genetic background of the CCPs did not prove advantageous in a particular management system within these 11 generations. The CCPs in both management systems showed moderate resistance to foliar pathogens, performing similarly to the pure line variety Capo, known for resistances to both stripe and brown rust (*Puccinia striiformis* and *Puccinia triticina*). Generally, the CCYQ populations achieved the highest yields in both management systems and the CCQ populations the lowest, reflecting the differential parental genetics and highlighting the importance of parental variety selection depending on management system and farmer requirements. Within the conventional system, the two parallel CCY populations yielded differentially over the selected experimental years, suggesting variation in adaptation to differing biotic and physical environmental pressures. These results could also be confirmed in a rooting system study. Under organic management, the majority of the CCPs yielded as well as the pure line varieties Achat and Capo; whilst under conventional management, the variety Capo was the highest yielding. As the breeding of heterogeneous populations has mainly been supported by organic breeders; parental variety selection has been based on varieties best suited to these organic and low-input systems and as such current CCPs may have a yield disadvantage in conventional systems and in comparison to pure line varieties bred for higher input environments.

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