Book of abstracts: XVII. Congress of the European Society for Agronomy

August 29 – September 02, 2022 – Potsdam, Germany

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Layout concept:
Leibniz Centre for Agricultural Landscape Research (ZALF)

This book of abstracts will be published only electronically: www.esa-congress-potsdam2022.de
Welcome to XVII. European Society for Agronomy Congress – Diversification & Digitalisation – Trends that Shape Future Agriculture

Dear Friends,

it has been two and a half years, since many of us have been participating in a scientific congress, as we have done so many years before, meeting other fellow scientists, old friends and the new kids on the block, and enjoying being in another place for a couple of days, with different habits, food and landscape. It has always broadened our minds, and we always learned new aspects of agronomy when visiting experiments and research facilities during the mid-congress excursions, as it was a well-appreciated custom during the Congresses of the European Society for Agronomy.

The Covid-19 pandemic has changed our lives, and also the modes of communication in science. Being forced to meet virtually in the aether, we experienced the first online Congress of the ESA in 2020. It worked, surprisingly well, and with the technology getting better and better, and the pandemic losing its evil face, we are now in the comfortable situation to choose whether we take on travels for a meeting, or quickly meet online, saving kerosene and time otherwise being lost at airports or in traffic jams.

Now we are back in 3D. The seventeenth congress of the European Society for Agronomy (ESA) will be held in Potsdam, Germany, from 29 August to 2 September 2022, and an overwhelming majority of you voted for having a “physical” congress, longing for all those side effects that we have been missing in the virtual world. And there is a lot of things we need to do: with yet another heat record this summer, climate change becomes undeniable for almost all of us. At the same time, more and more studies suggest a negative impact of chemical substances being used in agriculture on biodiversity, and the decline of insects and birds in European landscapes has alarmed policy-makers. The eutrophication problem also still is far from being solved. Mitigation of and adaptation to climate change, while reducing the use of agrochemicals and further increasing the efficiency of the resources used requires new ways of thinking. And it is our task, the agronomists and agricultural scientists, to develop this new thinking, with fresh ideas, new evidence and practical solutions. The digital world offers completely new approaches, and technological support we have never dreamt of. And on the other side, our ancestors have optimised their cropping and farming systems over millennia through diversification, and much of this knowledge is still very useful. But how to make best use of it? How to integrate the many ideas, so that all the multiple goals can be achieved in a well-balanced way?

The XVII Congress of the European Society for Agronomy is the place to exchange on all this. I hope that you all find an interested audience for your research, and learn many new things from your peers that inspire your future work. Have a safe journey to and fro, and ...

Enjoy your time in the beautiful town of Potsdam!

Yours

Claas Nendel
ESA President
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# Session 2: Towards Pesticide-Free Agriculture

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**With weeds against insect decline? Promoting in-field weed diversity increases absolute arthropod density and biomass in cereal cultures**
Nico Beier; Veronika Beier; Sarah Braun; Ben Nagy; Johannes Möser; Tsvetelina Krachunova; Frederik Lemke; Maria Bauditz; Dr. Matthias Nuß; Arne Cierjacks

*Influence of biodiversity of the segetal flora on yield of spring barley (Hordeum vulgare L.), spring oats (Avena sativa L.) and forage maize (Zea mays L.) in organic agroecosystems of Germany*
Veronika Beier; Nico Beier; Sarah Braun; Ben Philipp Nagy; Johannes Möser; Tsvetelina Krachunova; Frederik Lemke; Maria Bauditz; Knut Schmidtke; Arne Cierjacks

**Comparison of sequential herbicides applications in sugar beet in Belgium based on active substances analysis**
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**The effect of different weed communities on growth and yield of tender wheat**
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**Are no-till herbicide-free systems possible? A simulation study**
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**How hedgerow characteristics alter pseudocercospora fijiensis dispersal?**
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**Multicriteria assessment of alternative solutions for potato protection**
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**Reducing pesticide use through crop diversification**
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**Is phytochemical defence transferred between plant species?**
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Landrace cereal cultivation, weed management and other services – experiences of Swedish farmers
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Congress Keynotes
Climate change and food production

Prof. Dr. Senthold Asseng
Technical University of Munich, Germany

Food production systems are challenged to ensure food security for a continuously increasing global population. At the same time as countries try to supply more food, they struggle to achieve additional food-related goals such as environmental sustainability, biodiversity, economic development and rural poverty alleviation. These challenges have become increasingly global in scale with the development in international food trade. In addition, there is an increasing concern about the impact of global climate change on food production and its associated environmental, economic, social and political impacts. More recently, the COVID-19 crisis and the Russian-Ukrainian war further highlight the risks of massive disruptions in the globalized food supply chains, unveiling an underlying vulnerability of agricultural systems.

A combination of recent advances in knowledge, technology, changes in consumer preference and low cost of manufacturing is accelerating the next technology revolution in food production systems. This technology revolution will have major implications for how, where and by whom food will be produced in the future. This next technology revolution could benefit the producer through substantial improvements in resource use and profitability, but also the environment through reduced externalities. The consumer could ultimately benefit through more nutritious, safe and affordable food diversity. The next technology revolution in food production systems will create new opportunities in achieving progress towards many of the Sustainable Development Goals, but it will require early recognition of trends and impact, public research and policy guidance to avoid negative trade-offs. Potential food production system ‘game-changers’ include (1) Artificial intelligence linked with Big Data, sensors and food systems knowledge to increase productivity, optimize resource use with minimizing externalities, (2) Autonomous acting technologies including field robots and drones, (3) Tailored genes for specific food production, nutritional and environmental outcomes, (4) Vertical farming with controlled-environment production of food. Pros and cons of these potential ‘game-changers’ will be discussed.

Short Biography

Senthold Asseng is a professor of Digital Agriculture and the Director of the World Agricultural Systems Center at the Technical University of Munich. An agronomist specialised in wheat he has held positions at Humboldt University of Berlin and at CSIRO in City Beach, Australia, and has been appointed professor at the University of Florida. He is a Member of the Scientific Committee of the Agricultural Model Intercomparison and Improvement Project – AgMIP, co-leader of AgMIP-Wheat and chair of the Expert Working Group for Plant and Crop Modeling of International Wheat Initiative.
Crop responses and adaptation to climate change: the key role of response nonlinearity and interactions

Ing. Karel Klem PH.D.

Global Change Research Institute CAS, Brno, Czech Republic

Climate change represents, on the one hand, obvious long-term trends such as rising atmospheric CO₂ concentration, an increase in average temperatures, and in some areas a decrease in precipitation. However, on the other hand, it is also accompanied by a significant increase in the weather variability with an increasing frequency, intensity, and duration of weather extremes, such as heat waves, drought episodes, torrential rainfall, or periods with high intensity of UV radiation. Due to the increasing variability and extremity of the weather, with many combinations of weather factors, the few emission scenarios and the following RCPs are thus branching into hundreds of potential weather scenarios that agriculture will experience in the near future.

The situation in estimating the climate change impacts on crop production is further complicated by the fact that the plant responses to environmental factors are generally not linear, but usually have a sigmoidal or peak character, so the response can gradually change with intensity before reaching an asymptote or peak. For example, an increase in the photosynthetic performance with a slight increase in temperature is followed by a rapid drop in high temperatures. It is also quite common that low intensities of an environmental factor otherwise widely considered to be negative, have a stimulatory effect on growth and yield (for example UV radiation) mainly due to the effect on the induction of protective mechanisms in plants, such as the production of antioxidants or osmolytes, or by stimulating the development of root system. This effect, which is referred to as hormesis, can also be considered an important element of plant acclimation to adverse conditions accompanying climate change. Thus, its study is crucial not only for understanding the potential mechanisms of adaptation that can be used in crop breeding but also for the development of crop management practices stimulating such defense mechanisms in crops.

In addition to the response nonlinearity, the complex interactions between two environmental factors are another factor complicating the understanding of the crop responses to the ongoing climate change, modeling future impacts on the production and its quality, and finally also in designing possible adaptation pathways. It is common that not only additive interactions (the simple sum of the effect of two factors), but also synergistic (higher than additive) or antagonistic (lower than additive) interactions are reported as a result of the action of two or more environmental factors. This wide range of interactions is basically the result of the nonlinearity of the responses to the combined environmental factors but also originates from the internal molecular mechanisms in the plant, which can either alleviate or amplify the negative effects of another factor. In the vast majority of cases, however, the intensity of a particular factor is crucial, while the mitigating effect of its low intensities usually turns into an aggravating one at the higher intensities.
Experiments in which the possible interactions of the effect of two or more factors associated with climate change are evaluated, and primarily the regression type of experiments in which the response is evaluated at a range of intensities are absolutely essential for understanding the impacts of the future climate on agriculture. However, the question of intensity is further related to its duration, which, thanks to the increasing variability of the weather, will be a key modifier of the final impact of climate change. For the evaluation of the responses and interactions, indicators integrating the impact over time should be used, such as the proposed indices Heat Degree Hours, Drought Days Index, or Daily UV Integral.

A very important aspect of interactions can be documented, for example, in the effect of elevated CO$_2$ concentration. Although a number of studies report the positive effect of elevated CO$_2$ concentration on water use efficiency, this effect is positive only in the case of moderate or short-term water limitation. Our partial experiments show that elevated CO$_2$ concentration can also lead to the opposite effect, thus greater sensitivity to drought due to higher leaf area and therefore higher total water consumption per ground unit area. A number of examples where significant interactions and the nonlinearity of response to climate change affect the impacts on crop productivity and quality, and also the potential adaptation strategies will be discussed.

**Short Biography**

Karel Klem is senior agronomist at the Global Change Research Institute in Brno, CZ, with degrees from Mendel University in Brno (Agr. Engr.) and the Czech Life Science University in Prague (PhD). Having worked on weed ecology, plant nutrition, and crop physiology at the Agricultural Research Institute Kromeriz before, he focuses now on the impacts of climate change on agricultural and forest ecosystems, ecophysiology, and crop management aimed at adaptation and mitigation of climate change at the GCRI and teaches related topics at Mendel University since 2008.
Agriculture needs to change to provide enough food and enable healthy diets around the globe: the role European agriculture

Prof. Dr. Marta W. Vasconcelos

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Unprecedented declines in biodiversity, poor land management and climate change are affecting ecosystem functioning and negatively impacting people’s quality of life. An important driver of global decline of biodiversity is the unsustainable use of nature, based on a narrow set of values (e.g., prioritizing nature’s values as traded in markets (IPBES 2022). Ultimately this has human health impacts, including increased risks of diseases caused by human pests, less nutritious foods, lack of clean water and air. The recent FAO Food security report shows that 1 in 10 people are chronically undernourished, and that 2.3 billion are moderately or severely food insecure and, everywhere, women more food insecure than men (FAO, 2022). European diets continue being reliant on very few varieties of the same species, with an excessive consumption of protein (in general), and animal protein (in particular). As consequence, dietary recommendations are to move towards a more flexitarian diet, which in turn has created new market opportunities for plant-based foods, in particular plant-based protein. Also, consumer interest in diets that benefit environmental- and personal-health is rising, not only with millennials, but with over 65s. But can this dietary change be fed by plant foods that are locally grown, also given that ~75% of our plant protein is imported?

Europe is living unprecedent times with regards to climate change, pandemic situations, and more recently, the global conflict between Ukraine and Russia. This has brought several challenges to our food production systems, that have disrupted value chains at multiple levels. However, even if the conflict in Ukraine ended tomorrow, there would still be a global food crisis. As prices and the costs of inputs rise, farmers are often prevented from diversifying food production and shifting food production practices — ‘locking-in’ the current fragile system (IPBES 2022).

Given the high dependency of Europe for imported grain and it’s often overuse of nitrogen fertilizer and other chemical inputs, this has raised questions regarding the nexus between food production, food security and human nutrition, where safeguarding biodiversity and nature preservation are at risk. Thought must be given on how to balance between a ‘Yield’ driven farming systems to a ‘Sustainable’ driven farming systems and a ‘Nutrition’ driven farming system

Together, these challenges create ample opportunities for Europe to distinguish itself by investing in more sustainable agricultural practices that are mindful of biodiversity and that promote local production and more nutritious and diversified food products. This can be accomplished by implementing measures that are delineated by considering all value chain actors’ perspectives (Balázs et al, 2021).
Here I will present a conceptual model that highlights the concerted attraction and empowerment approaches that are needed to transform modern agri-food systems into a new sustainable state. The model recognizes that three interlinked approaches of “push”, “pull” and “capacitate” are needed for change and must entail a theory of change approach where all actors of the value chain are part of the creation of the most meaningful solutions (Vasconcelos et al 2020). Examples of results and tools developed by recent EU projects and that address these three interlinked approaches will be presented.

Reference:

Balázs et al. (2021) Agroecol Sust Food Syst 45 (6): 931-953
FAO (2022) State of Food Insecurity report.


Short Biography:

Marta Vasconcelos holds a degree in Biology (Universidade de Lisboa) and a PhD in Biotechnology (Universidade Nova de Lisboa, International Rice Research Institute). She was an Associate Researcher at the Children’s Nutrition Research Center (Baylor College of Medicine, USA) for 5 years and is now the Deputy Director of the Center for Biotechnology and Fine Chemistry (CBQF) at Universidade Católica Portuguesa (UCP), Assistant Professor at UCP and a Visiting Researcher at Universidade do Porto. She has a long track record in crop diversification, value chains, plant nutrition, and genetic resources. Currently, she coordinates the H2020 project RADIANT (Realizing Dynamic Value Chains for Underutilized Crops, 2021-2025).
Session 1

Orals

Increasing the Resilience and Resource Efficiency of Cropping Systems
Exploring soil-plant interactions to improve resilience and resource use efficiency in agroecosystems

Prof. Gerlinde B. De Deyn

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Future proof sustainable agroecosystems require productive systems with efficient use of resources and without negative environmental impacts under current and changing climate. Soil-plant interactions are fundamental to achieve this ambition given that soils provide stocks and flows of nutrients, water, air and rooting space and can thereby act as a buffer to changing conditions. Furthermore, negative environmental impacts such as nitrogen leaching and N2O emissions that are currently associated with intensive agriculture are due to imbalances in the availability and use of nitrogen in mobile forms. Better understanding of soil biological processes that underpin nitrogen cycling and plant N-uptake and how these respond to management and periods of drought or water excess will support the development of future proof sustainable agroecosystems.

In this talk I will present results from several experiments in which we tested 1) how conventional and ecological management affect the resilience (comprising resistance and recovery) of soil microbial communities when subjected to drought or flooding using intact field cores from grasslands in different cropping systems in Switzerland, France and Portugal; 2) how resilient different grass and legume species are to flooding and how this affects N2O emissions; and 3) how resource use efficiency can be increased in arable fields using plant diversity in space and time. We show that soil management significantly affected the resistance and recovery of the microbial communities to altered rain regimes. Microbes in soils under conventional management showed higher resistance in biomass and extracellular enzyme activities. In contrast, microbes in soils under ecological management showed better recovery capacity in biomass and enzyme activities after the release of the stress from altered rain regimes. This study illustrates potential management trade-offs in microbial functioning between stabilizing nutrient cycling during water stress at the expense of very low recovery capacity, versus promoting the microbial capacity to recover its functional potential after the stress. Management based on ecologically sound principles may thereby be the best option to sustain long-term soil functioning under climate change.

Different plant species can differ markedly in their resistance and recovery to stress imposed by water excess, thereby plant species choice can help in developing more resilient systems. In our experiment grass species resisted flooding better than legume species, whereas legumes recovered better after the flood. Across the grasses resource conservative species resisted flood better than resource acquisitive grasses, however acquisitive species recovered faster after the flood. Flooding triggered emissions of N2O, yet soils planted with resilient grass and legume species showed lower N2O emissions. These results show that variation in plant resource acquisition strategies is associated with variation in resilience to flooding, and that
combinations of gras and legume species with different resource acquisition strategies may promote flood resilience of aboveground productivity and decrease N2O emissions. To promote resource use efficiency in cropping systems plant diversity and growing cover crops can be important instruments to counteract nutrient losses and to provide organic matter to the soil food web to support their functions. At the same time, the build-up of pests and diseases should be avoided as these would impair plant performance and resource use efficiency. In a field experiment we tested how cover crop monocultures and species mixtures affect the productivity and quality of main crops through soil legacy effects. Main crop performance was better or worse than expected based on the legacies of the cover crop monocultures, demonstrating that the mixture composition was of main importance to support productivity and promote resource use efficiency.

The underlying mechanism comprised a combination of cover crop quantity (biomass) and quality (nitrogen concentration) and changes in the soil microbial activity.

Overall these empirical studies show that soil management and plant (mixture) choice have implications for resistance and recovery of ecological processes in soil and thereby for plant productivity and resource use efficiency. A main challenge is to capture the in situ dynamics, especially of the soil processes, at high enough spatio-temporal resolution in a non-destructive way; an aspect in which remote sensing and modelling can substantially contribute next to improved representation of soil ecological interactions.

Short Biography

Gerlinde De Deyn is Professor in Soil Ecology at Wageningen University. She obtained her MSc in Bio-engineering at Gent University and her PhD degree in Ecology at Utrecht University, followed by postdoctoral work in Canada and the UK. The focus of her research is on plant-soil interactions and feedbacks in which she links soil and plant ecology and remote sensing, with the aim to achieve higher nutrient use efficiency and produce more nutritious crops, reduce greenhouse gas emissions from soil and suppress the build-up of pests and diseases. She has a special interest in how plant diversification can help to promote resource use efficiency and resilience of grasslands and arable cropping systems.
Development of an assessment method for vulnerability to climate change of maize farming systems: a creative process involving participatory methods

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Keywords: Climate change, Sustainability, Farming

Maize irrigated farming systems are on the front line in the face of climate change. Farmers need to adapt to multiple impacts accentuated by climate change such as erosion and compaction of soils, as well as increasing water scarcity in summer, which can make them vulnerable. In this context, vulnerability assessment is essential, in order to enhance adaptation and design resilient farming systems. Vulnerability is defined by the Intergovernmental Panel on Climate Change as the resultant of exposure (i.e., external pressures from climate change exerted on the farming system), sensitivity (i.e., susceptibility of the system to be harmed by pressures) and adaptive capacity (i.e., ability of the farmers to implement adaptation strategies). Although the concept of vulnerability has been widely discussed in the literature, few studies focus on its operationalisation by translating the concept into assessment methods. However, many assessment methods exist based on the concept of sustainability. These assessment methods are widely diverse, in terms of choices such as selection of indicators, identification of interactions among indicators, objectives and end-users. Moreover, adoption of these methods by end-users are heterogeneous. The objective of our study is to develop an integrated framework for assessing vulnerability to climate change of maize farming systems. We choose to create a method (i) based on indicators, (ii) at farm scale, (iii) using a predefined properties approach. We offer a vulnerability assessment method that will be adopted by farmers and useful for them to build resilient farming systems, and that will include determinants of adaptive capacity of farmers in the set of indicators. To answer these issues, our method will be centred on farmers’ viewpoint. We will first conduct a survey with maize growers in order to elicit indicators they use for vulnerability assessment. Then we will confront the set of indicators to literature and scientists’ perceptions. Finally, we will use an iterative process between farmers, scientists and advisors, in order to design an assessment tool intended for advisors. Expected results are (a) a set of indicators for vulnerability assessment, (b) a proposal of a generic framework for use of the set of indicators, (c) a comparison of stakeholders perceptions regarding vulnerability assessment of maize farming systems, (d) a discussion on needs for designing a tool that both enables diagnosis of vulnerability and tests of adaptations strategies.
Projected wheat and maize yields in Germany in 2050 – a meta-analysis

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Climate change constitutes a major threat to the future of our planet. With the global population and respective demand for agricultural products expected to further increase until mid-century and climate change excerpting increasingly negative impacts on agricultural productivity the question of food security becomes of vital importance. To be able to adapt to climate change and develop climate resilient cropping systems it is crucial to first assess climate change impact on crop production. With more and more studies published over the past two decades, increasing evidence is available regarding the potential impact of climate-related changes on agricultural productivity. However, there is a lack of an integrated assessment of the current state of knowledge regarding climate change impact on crop yields in 2050 in Germany. Therefore, this study aims to summarize and analyse all relevant literature that project yields of winter wheat and silage maize in Germany in the mid-21st century conducting a meta-analysis.

20 peer-reviewed papers and reports published since 2005 were selected following a systematic literature review. Available data were extracted from all studies covering change in yield, temperature, precipitation and CO2-level, as well as information on the study location, modelling approach and considered climate scenario. In total 328 and 478 data points on yield change available for maize and wheat, respectively. Descriptive analysis was used to display relative yield changes according to crop, region, modelling approach and whether or not CO2-effects were included. Furthermore, a local linear quantile regression was conducted to describe the relationship between relative yield changes and changes in mean temperature, mean precipitation, and CO2-concentration. Finally, a core dataset was prepared (201 and 65 data points for wheat and maize, respectively), which entailed the yield change information together with all of the three climate variables. A linear mixed-effects model was fitted to determine and quantify the effect of the three climate variables on yield change.

The descriptive analysis shows that the vast majority of projected changes in average yields in 2050 vary from -10% to +10% for both crops, while wheat yields tend to increase and maize yields tend to slightly decrease. Moreover, maize is projected to experience mostly negative mean yield changes in eastern and southern Germany. Also statistical models project merely negative yield developments for maize. On the other side, yield increases are projected all-over Germany for wheat. Quantile regression revealed more distinct relations of CO2-, temperature- and precipitation-change on future yields in wheat compared to maize. The linear mixed-effects model confirmed these results with regard to precipitation showing a strong positive relation with wheat yields but a rather indistinct effect on maize yields.
Accordingly, no effect was found for temperature change on maize yields, but an exponentially negative effect on wheat yields, i.e., slight temperature increase acted positive, while an increase >2° C acted negative on future yields. An increase in CO2 concentration excerpts positive effects on yields for both crops, with the increase more prominent for wheat than for maize.

One needs to be aware that the depicted climate variables, describe mean seasonal changes in temperature and precipitation. However, future yields are likely to be influenced also by intra-seasonal shifts, e.g., wetter winters and drier springs. Furthermore, the results of the considered studies are influenced by the investigated trial sites, climate models and time slices, as well as the used models, which all entail their uncertainties. Moreover, the applied approaches differ regarding their extent and type of additional information, e.g., farming practices, pest and diseases, adaptation and others, which also influence yields.
Comparison of observed and simulated values for soil organic carbon in HERMES2Go and MONICA models


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Carbon sequestration from the atmosphere to soil is one of the possible mitigation measures against climate change and thus has grown in importance as a research topic in the past three decades. However, carbon can be lost from the soil due to wrong management. Correct determination of soil carbon content dynamic across various sites is critical also in order to determine potential changes in the carbon dynamics in the future. It should be remembered that soil contains 2-4 times more carbon than the atmosphere and 4 times more than the vegetation (Hussain et al., 2021). This is the main reason for keeping and possibly increasing the amount of organic matter in the soil. Soil carbon is influenced by used management. Accurate modeling of the carbon content in the soil can help to manage the soil properly and reduce the negative impact of the greenhouse effect in the next decades.

In this study, the soil carbon content was estimated by the model HERMES2Go and MONICA. Modeled values for soil organic carbon were compared with all available observed data from the long-term field experiments in the Czech Republic - Ruzyně (1961-2018), Hněvčoves (1979-2017), and Trutnov (1965-2010). In each experiment, there were 4 different methods of fertilization - controls, manure, mineral, and manure + mineral fertilization. These systems across locality alternate different crops but contain most years with necessary soil carbon data for each fertilization management. The first locality Ruzyně is situated near Prague at an altitude of 345 m above sea level with an average temperature of 7.9°C and annual average precipitation of 472 mm. The next locality Hněvčoves has an altitude of 265 m above sea level with an average annual air temperature of 8.1°C and the average precipitation per year is 597 mm. The last locality Trutnov is situated at an altitude more than 400 m above sea level. The annual average is about 8,7 °C and annual precipitation are approximately 580 mm.

The model calibration and validation based on the experimental data is an essential perquisite for further adjustments of the parameter’s settings for both models. The models differ also in the algorithms used to describe seasonal and long-term carbon dynamics. The contribution is an objective comparison of simulation accuracy. The results show that while models are able to explain a maximum of 0,15 % variance in the annual variation of carbon content, they are correctly estimating differences between different treatments and also long-term trends.

Impact of projected climate on processing tomato production

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Most climate change impact studies using crop growth models have mainly concentrated on wheat, maize, rice, and soybean, while fruits and vegetable have not received enough attention. Tomato is among the most important vegetables and ranks second only to potatoes by acreage, production, yield, commercial use, and consumption. There are two types of cultivated tomato, the one for fresh consumption and the one used for industrial transformation (processing) which is cultivated under field conditions. Processing tomatoes are used for tomato paste, tomato sauce, ketchup and other tomato-based products. Their production is concentrated in ten major “tomato baskets” around world and three of those (USA, Italy and China) account for 65% of the global production.

A current scientific gap is the lack of an up-to-date biophysical assessment of the potential impact of climate change in these three countries using the latest climate projections (CMIP6) and a protocol that makes the results comparable with the results from other global efforts (e.g. AgMIP, MACSUR).

The crop model used to simulate field-grown processing tomato is Cropping System Model (CSM)-CROPGRO-Tomato available in the DSSAT, V4.7. The model has been calibrated for tomato genotypes in different environments using published scientific literature and validated at regional level using the data from the World Processing Tomato Industry for the period 2005-2019.

For the gridded simulations the model was setup with the Global High-Resolution Soil Profile Dataset, and five bias-adjusted global climate models produced at 0.5° x 0.5° daily resolution by the Inter-Sectoral Model Intercomparison Project (ISIMIP) based on the CMIP5 were used. In addition, the crop model was run with three Shared Socioeconomic Pathway and Representative Concentration Pathway (SSP-RCP) scenarios: low (SSP1-2.6), high (SSP3-7.0), and very high (SSP5-8.5) greenhouse emissions and related socio-economic conditions and atmospheric carbon dioxide concentrations. And, with 5 Global Climate Models (GCMs)

Simulation results showed that processing tomato production in the three main producing countries decrease by 2050 under the ensemble of projected climate scenarios (the uncertainty range is due to the 5 GCMs projections), with minor changes for SSP1-2.6 (+0.2 to -9.9%) and more severe losses under SSP3-7.0 (+8.6 to -8.6%) and SSP5-8.5 (+6.5 to -15.2%). The amount of water required for irrigation increased by 5 to 50%, depending on the region. In China the projected water requirements is projected to be lower compared to California and Italy, suggesting that China has a potential to become one of the important
regions for processing tomato production by 2050 to become one of the main processing tomato production hubs.

This is because projected temperature increase tends to minimize the beneficial effect of higher carbon dioxide concentrations. In fact, the increase in air temperature causes an increase in irrigation required to meet the crop’s water demand, lowering the efficiency of irrigation. Projected water demand for irrigation might strain future water resources, which is critical in locations such as southern California and Italy. This suggests that these locations might not be able to sustain the current levels of processing tomato production. On the other hand, cooler producing regions, such as China and northern parts of California, could improve their competitive advantage being less affected by projected temperature patterns.

Future work includes additional political and socio-economic information to be integrated in similar studies to assess changes in the whole system to evaluate shifts in the value chain including processing plants and transportation lines that may be anticipated.
Increased biomass yield and soil carbon and nitrogen content with perennial crops: Insights from soil microbiology

Dr. Ji Chen PhD; Yue Li; Mingming Zong; Yuanliu Hu; Dr. Kiril Manevski; Prof. Uffe Jørgensen

Sustainable refining of biomass requires increased biomass yield while protecting soil carbon (C) stock. Here, we compared 14 different cropping systems grown on a sandy loam soil in central Denmark, including (1) two continuous monocultures of annual crops, (2) one conventional crop rotation, (3) four optimized crop rotations, (3) five intensively fertilized perennial grasses, and (4) two grass-legume mixtures without nitrogen (N) fertilization. Our results showed that biomass yield and yield stability differed highly across the cropping systems, highlighting crop-specific characteristics. Of all the cropping systems, tall fescue significantly increased soil C and N content by 7% for both, while sustaining high biomass yield and yield stability compared to the other annual crops. Increases in soil C stock were positively and significantly correlated with biomass yield ($R^2 = 0.175$, $p = 0.007$), suggesting a win-win strategy for climate mitigation and food security by promoting land conversion from annual to perennial crops. We also compared soil extracellular enzyme activity (EEA) between annual and perennial crops. These results showed significantly reduced oxidative carbon-degrading EEAs by 79% for tall fescue, concomitant with the increased soil C content for this perennial grass, compared to triticale. Moreover, tall fescue significantly increased EEAs targeting soil N and phosphorus cycling by 28-29% compared to triticale, supporting the emerging findings that perennial crops can be more resource efficient. Altogether, our results provide novel perspectives from soil EEAs to advance the understanding of climate-smart and resource-efficient perennial agroecosystems targeting refining of biomass.
Climate change and the most extreme wheat yield decline in the recent history of France

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France, a leading wheat-exporting country suffered the most extreme national wheat yield decline in its history in 2016. This 27% yield decline was caused by a combination of seasonal weather events, consistent with climate change trends in this region with warmer, wetter winters, when winter wheat is usually dormant and increased heavy rainfall in spring, during anthesis. Using statistical and crop models we analyzed detailed wheat data from more than 3000 field trials across the main French breadbasket with 221 cultivars from six cropping seasons (2014-2019). Low solar radiation and frequent heavy rainfall events around anthesis explain 93% of the up to 50% regional drop in grain numbers per unit area in 2016. Disease spread of foliar fungal and ear blight, enabled by a warm and wet winter and spring period, together with anoxia during grain filling explain 83% of the up to 40% regional average grain size decline. When ranked by the size of negative impact, the 2016 yield decline was caused by reduced solar radiation around anthesis (31%), anoxia during grain filling (26%), flower abortion from physical damage during heavy rainfall events at anthesis (19%), fungal foliar diseases (11%) and ear blight during grain filling (10%), with 3% unexplained. With continuing climate change, such compounding yield reducing events will threaten the stability of future grain production in France and elsewhere in the world.
Comparison of two acclimatization strategies in rapeseed and in camelina to heat waves: thermo-priming vs microbial-priming

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The increased frequency and intensity of spring heat waves negatively impact yield and grain quality of oilseed crops such as rapeseed and camelina. In this context, breeders are urged to develop rapid acclimatization solutions that would break with conventional genetic approaches and agronomic practices. Among these solutions, priming - which relies on the ability of the plants to be prepared to subsequent stresses by imposing a prior stress whether it is of similar or different nature – has been investigated in both species challenged with intense heat stress at the onset of grain filling. Two priming protocols were tested. One relied on a prior gradual increase in temperature while the other, on the prior inoculation of Plant Growth Promoting Rhizobium (PGPR). Both cues were shown to trigger stress specific or generic responses that could alleviate the negative impacts of later heat stresses on plant performances in terms of yield, seed quality. The PGPR-based protocol was also designed to observe the feedback loops between the plant, the PGPR and the soil microbial community through root morphology and exudation under heat stress. Our two-fold approach will provide insights in the priming strategies to be developed in contrasting oil crops (cultivated vs. rustic species) and in how the plants can modulate exudation to create efficient soil microbial connexions that will further help them acclimate to heat stress.
Performance of the soil-crop model STICS for a wide variety of agronomic and environmental outputs under Belgian pedoclimatic conditions

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Keywords: Crop model; STICS; Carbon balance; Multi-criteria evaluation

The 2030 Agenda for Sustainable Development recognizes that food and agriculture lie at the very heart of the Sustainable Development Goals and that it is key to examine food systems in a global way when looking for the end of poverty and hunger altogether with responding to climate change. Such a research for food security and agricultural sustainability requires that, when analyzing and comparing farming systems or crop rotations, multidimensional indicators should be used, assessing both their productivity (quantitatively and qualitatively) and environmental impact (N leaching, GHG emissions, etc.).

In the present study, we evaluate the ability of the soil-crop model STICS (Brisson, 2003) to predict indicators related to agronomic (LAI, dry matter, yield, N in the plant and in the grain, evapotranspiration) and environmental aspects (SOC, soil nitrogen and water content, CO2 emissions, GPP and NEE). STICS is a process-based soil-crop model that simulates crop growth as well as soil water, C and N balances. It takes as inputs weather, soil data and crop and management practices, and gives as outputs both agronomic and environmental variables. The 16-year (2004-2019) iCOS-LTO data (Lonzee Terrestrial Observatory, Belgium) were used. Crops have been cultivated following a 4-year sequence: sugar beet (SB), winter wheat (WW), potato (SP) and WW again. Mustard (MT) was planted as over crop prior to sprouting crops. The iCOS-LTO dataset is characterized by an important amount of available agronomic measurements and a daily acquisition of CO2 exchange.

In this study, no parameter optimization process was applied. The standard plant files provided in STICS v9.2 were used for MT and SB. WW and SP had been calibrated in other works (Dumont et al., 2014; Launay, 2022). Hydraulic properties of the soil file were derived using pedotransfer functions of the R package euptf2 (Szabó et al., 2021) while the bulk density was computed using Bernoux (1998) pedotransfer equation.

Since STICS only simulates heterotrophic respiration and has, to our knowledge, never been used to assess complete carbon balance, rules were derived to compute GPP and NEE. Above-ground maintenance autotrophic respiration was computed from biomass and plant N content, following Sun et al. (2007). From there, a coefficient of 1.5 was applied to consider the below-ground maintenance autotrophic respiration (MR). Net photosynthesis (GPP) was derived from biomass. Finally, GPP and MR were used to compute Total Ecosystem Respiration following equations of Vuichard et al. (2016).
Results specific to the different indicators are contrasted. Total biomass, yields, evapotranspiration, GPP and NEE predictions range from very good \((rRMSE < 0.5)\) to satisfactory \((rRMSE < 0.7)\). It has to be noted that it remains not so easy to obtain satisfactory RMSE on large datasets. Other simulated indicators (SOC, SWC, LAI and N in the plant) were not satisfactory in terms of RMSE and would benefit from calibration.

This study is the first evaluation of STICS soil-crop model considering altogether such a large panel of indicators, including C balance and CO2 emissions. It shows that STICS is adequate to evaluate multi-criteria performance of cropping systems. The innovative methodology proposed to simulate carbon balance yielded very good results.

The accuracy of STICS in predicting all indicators at once, concerning both agronomic and environmental performances, was demonstrated. More globally, it emphasizes the potential to use crop models to support the design of innovative cropping systems, allowing for a broader and finer comparison of crop rotations and management practices and accounting for their ability to mitigate and adapt to climate change.
Effects of ley and N-application rates in rotations on soil organic carbon and crop yields

Fatima El Khosht¹; Johan Nilsson; Johannes Forkman; Prof. Göran Bergkvist; Pernilla Tidåker; Prof Christine Watson; Prof. Dr. Ingrid Oborn PhD

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There is a need to transform agriculture to more sustainable production systems regarding environmental impacts such as greenhouse gas (GHG) emissions and eutrophication potential. Increased soil carbon sequestration and reduced nutrient inputs can contribute to mitigating GHGs. Increasing nutrient use efficiency would also decrease the eutrophication potential from agricultural practices. At the same time, high productivity and sufficient yields are needed for farming to be economically sustainable and to meet the demand of healthy diets for an increasing population.

The aim of the study was to evaluate the effects of including ley in crop rotations on soil carbon sequestration and annual crop yields compared to rotations with only annual crops under different nitrogen (N) application rates. Specific objectives were to assess the effect of ley in crop rotations on soil carbon sequestration, quantify how leys in crop rotations with different N-rates (up to 135 kg N/ha) effect annual crop yields, and evaluate the effect of ley in crop rotations using LCA methodology including energy use and environmental impact. The study was based on 50-years long-term field experimental data (1970-2020) from three locations in Sweden. The experiments included three six-year rotations where two of the rotations included two years of ley, one rotation with a grass ley and one with a grass/clover ley. The third rotation included five years of annual crops and one year of bare fallow. The results show that including ley in the rotation significantly increased the mean soil carbon concentration (0-20 cm) over 50 years compared to the annual crop rotation. However, the soil carbon concentration decreased in all three rotations indicating an early effect of the inclusion of leys. Moreover, the N-fertiliser application rate had a significant effect on the soil carbon change where a higher N-addition resulted in a smaller reduction in carbon over time. In the subsoil, the C-concentration did not differ between the rotations and it did not change over the 50-year period.

Over the 50-year period, higher mean oat and winter wheat grain yields were recorded in the two-ley based rotations compared to the annual crop rotation. With no nitrogen addition (N0), the grass/clover ley delivered the highest mean oat yield, and the yield differences between the rotations decreased with higher N-application rates. At the two lower N application rates (N0, N1), the mean winter wheat grain yields were highest in the grass/clover ley rotation as compared to the other two rotations. To be noted, the winter wheat mean grain yield obtained from the grass/clover ley at the two highest N-level (N2, N3) was not significantly different from the mean yields obtained from N3 in the other rotations.

Analysing the changes over time, the oat grain yield changed depending on rotation and N-
rate. There was a slight yield increase for all N-rates in the grass/clover rotation (N0-N3) but only for the two higher N-rates in the grass ley and annual crop rotations. Winter wheat grain yields showed a similar result. The yield change was dependent on N-level, rotation and their interaction, Also, regarding yield trends the difference between rotations decreased with higher N-levels.

To conclude, adding ley in the crop rotation may provide a higher top soil organic carbon concentration as compared to sole annual crop rotations, hence mitigating GHG emissions from agriculture. Additionally, including a two-year grass/clover ley in the crop rotation provides less need for N-additions to winter wheat grown in the rotation decreasing the potential nutrient leaching which in turn can lead to reduced eutrophication and GHG emissions.
Cropping systems in the Middle East: Production is primarily controlled by harvested area, not yield

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To meet the growing demand for food, an increasing number of people and severe shortages of water are placing boosting pressure on crop production systems in the Middle East (Constantinidou et al., 2016; Zampieri et al., 2020). Nevertheless, minimal information is available on the distinct contribution of harvested area and yield on long-term trends and variability of crop production in the Middle East (Song et al., 2022). In particular, it is imperative to quantify the looming effects of the water shortage and temperature rise on crop production in the region. Here in this study, we aimed to (1) quantify the importance of harvested area and yield on trends and variability of crop production for main crops in Iran (12 crops under irrigated and rainfed conditions, separately – 2001 to 2016) and Turkey (16 crops – 2004 to 2020) and (2) assess relationships with dynamics of drought and temperature. We use remote sensing-based land cover and evapotranspiration time series derived from the 500 m Moderate Resolution Imaging Spectroradiometer (MODIS) to quantify the extent of cropland and drought severity and test the credibility of statistics. Remote sensing products were used to estimate the monthly ratio between actual and potential evapotranspiration to evaluate the intensity of drought stress. Our results showed that the variability of the harvested area is strongly correlated with estimated cropland area using remote sensing data showing the integrity of reported statistics. Analysis of the response variance indicated trends in harvested crop areas explain a majority of crop production trends. (7 out of 9 rainfed crops in Iran and 13 out of 16 crops in Turkey). On the other hand, in the production of heavily subsidized crops including wheat and barley, variability in yield was a major contributor to the variability in production in both countries. Variability in the harvested area was primarily explained by drought, not temperature in particular for the more arid regions in the south and central parts of Iran and Turkey, respectively. We also found out the difference between planting and harvested areas is highly correlated with precipitation sum in Turkey for wheat and barley. It confirms that the farmers do not harvest the planted lands under extreme dry years because of crop failure. These results indicate a need for better and more adaptive drought surveillance for adequate food production in the Middle East.

Reference:


Resource efficiencies in wheat management to enhance grain production and longer bread shelf-life

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NUTRIENT BALANCE, GRAIN PRODUCTION, RESOURCE EFFICIENCY.

Bread is one of the most dominant foods for the human diet. Due to its nature, it is easily wasted and loses quality during preservation, resulting in changes in physiological, biochemical, microbial, and sensorial properties. For that reason, bread industry is not only focused on quantity production, but also on long-lasting product. The shelf-life of bread is influenced by wheat flour components, such as starch and storage proteins (1). Starch is present as granules and is the most important carbohydrate in wheat flour due to its water-absorbing capacity, composed principally by amylose and amyllopectin molecules. However, the grain production is affected by important agronomic factors, such as nitrogen (N) and phosphorus (P) fertilization, especially in central Italy where soils are often deficient of the macronutrients. The right nutrient balance is important both to enhance quantity and quality production and ensure a store to maintain soil fertility (2). However, different wheat genotypes require specific macronutrients amounts and vary optimum combinations. Old wheat varieties have been rediscovered in the last years for the excellent nutritional values and the high sustainability that characterizes the production (3). A field experiment was carried out during 2019-2020 and 2020-2021 crop seasons in Val D’Orcia area, central Tuscany. The aim was to test the effect of different balances of N and P fertilizers on the grain wheat yield and composition. In addition, the shelf-life of bread was evaluated, based on the grain composition. Different varieties were tested, three modern (Bologna, Bolero and Pandas) and one old variety (Verna). The treatments consisted of factorial combinations of three rates of N (45, 90, 135 kg N ha⁻¹) and two P (46 and 92 kg P ha⁻¹) laid down in a randomized complete block design with three replications. The effects of year showed significant (p < 0.01) differences for hectoliter weight, 1000-grain weight, protein, starch and amylose, but not for grain yield. Instead, the effect of variety was significant (p < 0.01) for all the parameters, but only for the old variety Verna. Hectoliter weight and 1000-seed weight did not differ significantly due to application of P and N fertilization. Yield, protein and starch increased adding P and N, while amylose was increased by N and decreased by P addition. Conversely, the effects of year by N interaction were significant (p < 0.01) for protein, starch and amylose. Effects of year by P interaction were significant for the same and also for grain yield. The year for variety interaction were highly significant for grain, 1000-grain weight and protein. As for the bread produced, significant differences were found (p < 0.05) not only in the rate of water loss and in the hardening of the breads, but above all on the shelf-life (appearance of the first molds) which is double in the flours obtained in the grains with lower balances of N/P (45/46, 90/92, 90/46). This result represents an opportunity to maintain high
resource use efficiencies, reducing fertilizer applications and producing high value product with extended shelf-life.


Describing Nitrogen dilution curve and physiological behavior of Thinopyrum intermedium

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Nitrogen dilution curve; Kernza; Nitrogen requirements; Perennial crop.

The perennial grain crop, Thinopyrum intermedium ((Host) Barkworth & D.R. Dewey) can provide various ecosystem services. Among them we can mention preservation services such as the reduction of nitrate leaching, the improving of soil food webs or the carbon pools and sequestration as well as a dual production of grains and forage. Currently, Th. intermedium is characterized by a recent selection history and its resource allocation to grains is low and variable. At the same time, its perenniality leads to large resource allocation to the belowground organs composed of short rhizomes and a deep root system to ensure crop continuity. Consequently, the development of intermediate wheatgrass in cropping system is still impeded by grain yielding capacity and stability, and knowledge gaps about best management practices in fields. To improve yields and crop management, a good description of its physiological behavior and a better understanding of its growing habits are yet required.

Through the determination of its critical nitrogen dilution curve, we aimed to characterize its nitrogen (N) requirements and to establish diagnoses of the N status of the crop in different climatic and agronomic conditions which will allow further to inform fertilization practices to optimize crop growth and yields in fields. A field experiment was conducted in Gembloux AgroBio-Tech, Belgium, for three growing seasons with nitrogen fertilization schemes differing in the timing of application and amount of N applied. Globally, results showed that N fertilization had a positive impact on the dry matter of leaves, stems and ears. The maximum aboveground biomass and N uptake were obtained with a fertilization comprised between 100 and 150kg N/ha over the entire growing year. Additionally, fertilization applied at fall were integrated into the evaluated N management strategy of Th. intermedium crop. Splitting a full rate of nitrogen usually applied at spring into a fall N application (50%) combined with an early spring application (50%) resulted in relatively similar aboveground production levels. At maturity, the total aboveground biomass ranged from 7,0 to 16,4T DM/ha for a 100kg N/ha fertilization, depending on the growing season. The N content tended to decrease with the evolution of growing stages. The resulting critical nitrogen dilution curve was linked to several life traits of the crop. Actually, a strong decrease in the leaves/stems ratio after the beginning of the growing season was observed. In addition, the study of Sprunger et al. (2018) reported that, considering the N uptake of the whole plant regarding the N applied, the nitrogen use efficiency of Th. intermedium is very high: the plant tended to assimilate large quantities of nitrogen and even more than what has been applied. Its deep and dense root system allows an extensive exploration of the soil profile which can further increase the nitrogen use efficiency and reduce nitrate leaching. Combined with the observed decrease of the N amount of the aboveground biomass in the second phase of growth, this is more likely associated to

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the long-term survival strategy of the crop which results in substantial investments in perennial belowground structures coupled with reduced resource allocations to seeds. Indeed, storage in rhizomes and roots can be part of a resource-conservative strategy of Th. intermedium that could store a part of the N absorbed in its belowground organs, which reduces the amount of N within the aboveground biomass. Sakiroglu et al. (2020) found out that the plant is effectively storing non-structural carbohydrates and proteins in its roots and rhizomes.
Potential yield and water use efficiency of oilseed rape in Egypt - a modelling study using the CROPGRO canola model

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Production of oilseed rape (Brassica napus L.) might help to break the wheat-dominated crop rotations of Egypt and overcome the critical edible oil supply gap of the country. Despite first promising experimental results of oilseed rape cultivation, there is still no commercial oilseed rape production in the most populous country of North Africa. Building on an extensive primary experimental data set of 20 year*location*sowing date combinations, covering three production regions of Egypt, we conducted a cultivar specific calibration of the CROPGRO canola model. Yield simulations for the local cultivar SERW4 were satisfactory with an RMSE of 0.39 t/ha of simulated vs. observed yield levels. We then used the calibrated model to run virtual experiments for our three production regions over thirty years during 1991 to 2020 using site-specific soil and daily weather data. We tested eight different sowing dates between September and December investigating attainable yields and water use efficiency. While in the northern delta 30-year-average yields reached up to 2.7 t ha⁻¹, yields in newly reclaimed land in the west, as well as in the south of Egypt only reached about 1.9 and 2.0 t/ha, respectively. Optimal sowing was later in the north (mid Oct - mid Nov) than in the west and south (beginning - end Oct). Moreover, evapotranspirative water use efficiency was highest in the north (7-8 kg/m³), followed by the west (5-7.5 kg/m³) and the south (4-7 kg/m³), with earlier sowing dates always related to higher water use efficiency. This study demonstrates the application potential of crop models to investigate the performance of an exotic crop in a new environment. Further investigations should include the testing of modern hybrid varieties in local field trials and the cultivar specific calibrated crop model.
Biofortified and climate-resilient food and fodder production on marginal soils

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In the EU and world-wide, agriculture is in transition. Future land use must embrace efficient production and utilization of biomass for improved economic, environmental, and social outcomes, as subsumed under the EU Green Deal, including also sites that have so far been considered as marginal and excluded from production. Another frontier is to supply high-quality food and feed to increase the nutrient density (including micronutrients such as Se, I, etc.) of staple crops.

To combat the decreasing productivity of arable soils and progressive climate changes, the BioFoodOnMars project develops new opportunities to increase the amount and quality of food and feed crops in Europe using new strategies for sustainable growth of plant production and increasing climate change resilience of agroecosystems. This project aims at mapping potential crop yields and the valorization opportunities on marginal soils under various regional conditions in Europe and trying to optimize the biomass production and valorization with biofertilizers, soil additives, foliar fertilization (Si, Se), and management changes supported by remote sensing and digitalization.

Field experiments with spring barley cv. Fantex have been carried out in Estonia, Lithuania, Poland and Germany in 2020 and 2021. The treatments included different nutrient regimes (control, mineral and organic fertilization) and various foliar treatments (control, Si, Se, combined). Same barley variety was grown in an ecootron in Belgium, where the future climate conditions were simulated. Winter barley and also two grasslands established at contaminated sites in France were treated with silicon and selenium (foliar spray). In all cases, the above ground biomass, resistance to abiotic and biotic stresses and yield were determined. Further to that we have analysed the impact on soil microbiota and studied underlying mechanisms in plant using RNASeq methods. The results will provide valuable information for farmers and also stakeholders of contaminated sites on how to increase the stress resistance of crops and produce biofortified crops on marginal soils.
References:


Microorganisms and plants in the bioremediation of arsenic contamination. Environmental Science and Pollution Research 3, 28-30. doi: 10.36346/sarjbab.2021.v03i02.003
Temporal change of Soil organic carbon stock in Mallorca agricultural soil over the last 10 years

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INIA-CSIC (Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria)

The agricultural sector is heading towards the implementation of more sustainable agronomic practices to promote environmentally friendly crop production. Environmental sustainability in agriculture can be promoted through efficient resource management and crop rotation. In this regard, the objective of this study was to provide on-field data of the effect of applying two types of organic fertilizers on a crop rotation system of Camelina sativa (L.) Crantz to evaluate the agronomic performance and soil properties. Field experiments were carried out during three growing seasons, from 2015 to 2018. The experimental design consisted of the crop rotation camelina–barley–camelina and three fertilization treatments (composted sludge fertilization, dewatered sludge fertilization, and control treatment without fertilization). Camelina and barley were cultivated in a non-irrigated block design with three replications of each treatment including the control.

The findings from this investigation revealed that camelina’s yield in the first and third seasons was limited by relatively high temperatures and low rainfall, which delayed the crop’s growth and did not show any differences between the fertilized treatments and the control. Regarding camelina’s yield components, composted sludge presented a significant difference with respect to the control and the dewatered sludge in the number of silicles plant−1. In relation to the number of seeds plant−1, the dewatered sludge fertilization presented the highest values, being 17% higher than the control. Results also showed a significant increase in the thousand seed weight in both organic fertilizations with respect to the control, but this difference obtained between the organic fertilizers was not significant. The application of organic fertilizers did not significantly increase camelina’s height compared to the control. This effect could be due to the limiting water availability during the experiment period. Nevertheless, the findings of the thousand-seed weight and plant height were in agreement with studies applying mineral fertilization, being the average values of thousand-seed weight and height 1.3 g and 114.4 cm, respectively. Furthermore, it was seen that nitrogen fertilization applying organic fertilizers enhanced protein synthesis obtaining high protein content in camelina’s seed. Therefore, potential use for camelina crop could be animal feed.

With respect to soil fertility, the combination of crop rotations and appropriate fertilization leads to the maintenance of nitrogen and organic carbon at adequate levels. In this study, organic matter content in the soils was positively increased with organic fertilization. After the crop rotation, no significant change was observed in the content of nutrients, meaning this crop rotation system had not depleted the soil’s nutrient content. Although an increasing tendency in heavy metals concentration was observed after the three-year investigation, the levels remained below the critical values established by the Spanish government for heavy metals in soils.
Despite the undesirable weather limitations, camelina’s yield components and seed quality showed, to some extent, a positive response to organic fertilization, while ensuring suitable soil characteristics. This study highlighted the potential use of the composted sludge and the dewatered sludge as organic fertilizers for the cultivation of camelina as an alternative to chemical fertilization to promote resource valorization.
System-based analysis of N cycling in a spatio-temporal diversified cropping system

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Agricultural landscapes in Germany are often defined with few crop species, narrow crop rotation and large field sizes as consequence of intensive crop production. Current crop production involves high levels of inputs, including pesticides and fertilizers causing detrimental environmental impacts and adversely affecting ecosystem service and economic benefits for farmers. There is a rising demand for crop diversification to increase sustainable intensification by replacing sole-cropped large fields with new cropping system approaches that increase the temporal, spatial and genetic dimension of diversity at the field and landscape level (Ditzler et al., 2021). Spot-farming, pixel cropping or patch cropping conceptually address diversified cropping systems with small-scale and site-specific diverse crop mosaics at different spatial scales with highly varying nutrient demands. Although site-specific management strategies by precision agriculture are established to exploit small-scale heterogeneities and to increase efficiency of N fertilization, they focus on sole-cropped fields. Best fitting land use, and therefore a selection of different suitable crops for the respective zones of the field (e.g. unproductive, low and high yield potential zones) differ in their nutrient requirements, especially Nitrogen (N). There is a lack of understanding how spatial and temporal diversification affect N dynamics and how sustainable cropping systems of the future call for a rethinking in above-belowground interactions regarding N cycling. We present a systems-based approach to evaluate N balance and N cycling in patchCROP, an experimental platform established in 2020 in Brandenburg, Germany were a 70 ha intensively managed field was re-designed into smaller field units of 0.5 ha (patches) following high and low yield potential zones with varying soil texture and topography and two site-specific five-year crop rotations. The high yield potential crop rotation includes: Rapeseed - Barley - cover crops - Soybean - cover crops - Maize - Wheat, while the low yield potential crop rotation is comprised by cover crops – Sunflower – Oats - cover crops – Maize - Lupin - Rye. For each individual crop rotation element, three patches were implemented. Surrounding sole cropped fields were used as reference areas. We will investigate if higher crop diversity at the field level caused a tightening of the soil N cycling by wider crop rotations, if there was a N scavenging effect by cover crops and if previous crops have created positive local soil legacies for the subsequent crop. For this purpose, mineral soil N (Nmin) was determined in spring, after harvest and in autumn for each crop in 2020 and 2021 in three different depths (0-30, 30-60, 60-90 cm). Biomass N was measured four times over the vegetation cycle and grain and straw N were determined after harvest. For the estimation of the inputs (deposition, soybean and lupin N fixation) and the outputs (gaseous and leaching losses) for each crop and patch, predictive and crop models are used. To compare both crop rotations of the high and low yield potential with simplified crop production, a system nitrogen use efficiency (NUE) will be applied using crop and soil-based balances and NUE indices (Martinez-Feria et al., 2018). The N balance was
calculated as changes in soil N storage during the course of the experiment and reveals N flows, N retention and N losses (Sainju, 2017). Preliminary results from the spring sampling 2021 suggest that Nmin levels were similar across depths for all crops in the high yield potential crop rotation. In addition, overall Nmin contents were lower after harvest in the second experimental year, which points towards a tighter N cycle and crop-specific N fertilization. The drop between the autumn and spring sampling indicates high risk of N losses, since the plants can hardly take up Nmin.
Climate change impacts on subterranean clover flowering and safe grazing period in New Zealand

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Keywords: Subterranean clover, climate change, flowering, safe grazing

Plants are highly sensitive to climate, particularly temperature and rainfall patterns and have demonstrated a trend of advance in phenophases due to climatic change (Ausseil et al., 2021). Temperature drives vegetative and particularly reproductive development because plant hormonal synthesis and balance are temperature dependent. These play a critical role in adaptation to changes in environmental stimuli, like increased temperature, to optimize reproductive development. Plant phenological events have shifted due to recent changes in climate, with earlier onset of budding and flowering in spring and longer growing season durations reported. Subterranean (sub) clover (Trifolium subterraneum L.) is a winter annual pasture legume commonly used in Europe, and summer dry environments in Oceania (Pecetti, et al., 2020). Its life cycle means it is the earliest to grow in spring but then buries its seed to survive dry summer months before its regeneration each autumn which provides feed for in situ grazing by livestock through the winter and early spring. Our research questions were (i) will sub clover flowering season, which affects seed yield, be earlier in some regions of New Zealand due to climate change? (ii) Would the grazing duration be affected by earlier flowering and reduced rainfall?

In this study, the phenophases of subterranean clover under future climate scenarios were simulated using a thermal time-based model (Guo et al., 2022). This used three different greenhouse gas and aerosol pathways over the 21st century know as Representative Concentration Pathways (RCPs) (IPCC, 2013). Sub clover flowering was estimated to occur around the same date or shift x to y days earlier date under the mitigation pathway (RCP2.6, which requires removal of some of the CO2 presently in the atmosphere) and under the stabilization pathway (RCP4.5, which requires CO2 emissions start declining by approximately 2045 to reach roughly half of the levels of 2050 by 2100) respectively. In contrast, a notable early shift is expected under the ‘worst-case’ pathway (RCP8.5, if emissions continue to rise throughout the 21st century), which in turn, decreased the safe grazing window. Our results show that the date of national flowering (50% of the plants had their first visible flower) of ‘early’ and ‘late’ cultivars shifted 19 (min=8 and max=33) and 23 (min=13 and max=36) days forward across 50 districts in New Zealand by the end of the century under RCP8.5. As a result of the early flowering, the safe grazing period shortened by 18 (min=9 and max=28) and 22 (min=14 and max=32) days for the two genotype groups. Understanding the sub clover phenological events change can assist agronomic management decisions on farm. These include the need to balance reseeding events with grazing requirements, the tactical
use of beef cattle and sheep mobs grazing in combination and to inform options breeders of cultivar requirements for adaptation for future climates.

Reference:


Pre-crop effect is often neglected in LCA of crops in cultivation sequences – simulations with selected approaches for allocation

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In field crop production, legumes offer the additional benefit of biological nitrogen (N) fixation. They need only minimal inputs of fertilizer N and leave N-rich residues that may reduce the need for fertilizer N input to the following crop.

Life cycle assessment (LCA) is a well-accepted method for the assessment of environmental impacts of products. While the LCA approach is fairly standardized, especially for climate change, development needs still arise. This is the case with the pre-crop effect, which is usually neglected in LCA (Costa et al. 2020). Blackbox assessment and functional units based on multiple products have been proposed as solutions for the LCA of crop rotations (Knudsen et al. 2014). When farm-level emissions are analyzed, approaches function well, but when the environmental information is communicated as a single-product carbon footprint, results for separate products are needed.

In this study, the objective was to assess the carbon footprint (CF) of selected crop sequences and to investigate the impact of allocation approaches of the pre-crop effect. The aim was to identify a reasonable method of allocating, for assessment of individual crops grown in sequences containing legumes.

The CF of crops were assessed with LCA following IPCC methods (IPCC 2006, 2013). The aim was to assess all crops in the sequence separately and to provide CF per crop with a functional unit (FU) of 1 kg of produced crop. Finnish crop cultivation characteristics were included as described elsewhere (Hietala et al. 2022). The crop sequences were 4 – 6 years long and designed to represent typical Finnish rotations for a livestock farm with one from the Leg4Life project’s field experiment. The typical rotations comprised continuous cereal (CC) and a single break of faba bean (SBB). The experimental rotation had a high bean content (HBC) with wheat and turnip rape. The amount of N left in the soil after faba bean was set at 35 kg ha⁻¹. It was assumed that the input fertilization level of the following crop would be reduced by the amount of the residual N. Three approaches were used: 1) without allocation, 2) with allocation to residual N and 3) blackbox assessment for pre-crop and benefiting crop, utilizing allocation to co-products. The allocation was conducted on the alternative bases of mass, economic value, N yield and fertilization rate (kg N/kg FU).

The assessment compared the situation without pre-crop effect related to N residue to one allocating it to N residue and another allocating it to co-products. With mass and economic allocations to N residue, emissions shifted slightly from the pre-crop to the following crop,
whereas allocation based on N yield resulted in higher emissions for wheat, in comparison to the situation without pre-crop effect. For turnip rape, the allocation based on N yield functioned better and remained below the reference value. When allocation to co-products was tested, only the one based on fertilization rate resulted in lowered emissions for the pre-crop, yet the approach resulted in higher emissions to turnip rape than in the reference, so the approach was found to be unreasonable.

In further analyses, more detailed data will be collected from crop sequence experiments and utilized to rerun the comparison of approaches. Clearly, the legumes in crop sequences benefit the following crops, and this should be considered in LCA.

Acknowledgments this study was conducted within Leg4Life project (2019-2025) funded by the Strategic Research Council at the Academy of Finland (grant numbers 327700 and 327698).

Reference:

Biological nitrification inhibition with ribwort (Plantago lanceolata L.) and alfalfa (Medicago sativa L.) for groundwater protection in organic farming

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Nitrate leaching in stable ecosystems is extremely low. Not only due to the constant vegetation covering the soil but also due to the nitrification inhibiting root substances different plant species can exude. Ribwort roots are able to exude the secondary plant substance Aucubin, which is known for its strong effect in inhibiting the oxidation of ammonium to nitrate in the soil. The inhibition of nitrate leaching during the autumn and winter period, after alfalfa growth, is a major problem for organic farmers in groundwater protection areas. The following project examined the impacts of nitrate leaching of growing alfalfa, ribwort and meadow fescue, as a fore crop, then ploughing them up in the autumn period. For this purpose, alfalfa, ribwort and meadow fescue were sown in the early spring, in pure stands and in mixtures, containing respectively, 33 %, 50 % and 67 % of ribwort or meadow fescue with alfalfa. The plants were cut every two months until the ploughing date in the autumn. In order to enhance the nitrogen exploitation two winter cereal crops were grown after the alfalfa and ribwort plough up, winter wheat followed by winter barley. The results of the first three years clearly showed that the soil samples from the variants with alfalfa and ribwort as a fore crop contained a higher concentration of ammonium and a lower nitrate concentration, in a difference of the soil samples after pure stands of alfalfa and the mixture of alfalfa and meadow fescue in the autumn and winter period. The nitrification inhibiting effect became clear during the growing of winter wheat in early spring, when the combination of alfalfa with the lowest, and ribwort with highest sow density, amounted to the highest concentration of ammonium. The effects of nitrification inhibition remained measurable until next autumn period in all ribwort variants. With the beginning of the winter barley growth in early spring, the nitrate content in the ribwort variants started rising, while the mixtures with alfalfa and meadow fescue showed lower nitrate rates. The yields of winter wheat, after the presence of ribwort, suffered a slight decline, due to an inhibition of nitrogen uptake. The effect faded with the cultivation of winter barley. The pure stand of alfalfa, as well as the mixture variants with alfalfa and ribwort registered the highest dry matter of winter barley corn and the highest crude protein yields. The results of the project show how the cultivation of ribwort is a practical and important contribution to the protection of groundwater after an alfalfa autumn plough, which also at the same time diversifies the crop rotation in organic farming.
Are cover crops climate friendly?

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Cover crops are well known for their beneficial effects in terms of reduced nitrate leaching and erosion control, whereas precise knowledge about direct greenhouse gas (GHG) emissions and changes in nitrogen (N) fertiliser demand of subsequent crops is lacking. Within the joint research project “THG ZwiFru” field trials with cropping sequences of winter cover crops – spring cash crop – winter cash crops were established in two consecutive years on four sites representing a soil and climate gradient across Germany. The cover crops included species from different functional groups. After preceding crops with high potential for N leaching losses (oilseed rape, field pea) four unfertilised cover crops (oilseed radish, saia oat, spring vetch, winter rye) in comparison to a bare fallow as control were cultivated followed by typical site-specific spring crops (silage maize, sugar beet) and winter wheat in the second season. Both subsequent crops were installed as trials with increasing N-fertilisation in 4 to 5 levels between 0 and 365 kg/ha.

An intensive monitoring included regular crop ratings, intermediate and final yield and quality parameters, weekly closed-chamber measurements of direct GHG emissions and frequent soil mineral nitrogen analyses (0-90 cm) as well as spectral reflectance recordings. Additionally, soil incubation experiments and 15N labelling studies on micro-plots were conducted on selected sites. Potential nitrate leaching losses were derived from a site-specific parameterised dynamic plant-soil-water model.

Results after 4 years revealed higher direct N2O emissions (0.4 to 1.6 kg/ha N2O-N) from cover crops and the following spring crop compared to plots after bare fallow for all field-site-years. Soil mineral nitrogen contents during the winter seasons were lower under cover crops (21 to 140 kg/ha N) compared to bare fallow plots, reflecting N incorporation in cover crop biomass during the winter months and preventing nitrate leaching losses as well as indirect N2O emissions from leaching. However, those beneficial effects were less pronounced in terms of economic optimal nitrogen rates for the following cash crops. Whereas oilseed radish and spring vetch showed a slight tendency of lower N need compared to fallow, after saia oat and winter rye optimal N rates were higher in some field-site-years. This pattern of different responses between the tested cover crops was the same for the first and second subsequent crop. Overall, a large variation of optimal N rates across treatments, sites, and years was observed and N mineralisation from cover crop biomass after incorporation and transfer into the subsequent crops was lower than expected. For a final evaluation of the net GHG-emissions from cropping systems with winter cover crops, ongoing evaluations on (long-term) soil carbon effects will be included.
Growing energy cover crops in double cropping: which ecosystem services or environmental impacts associated?

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Key-words: anaerobic digestion, nutrient recycling, carbon storage, modeling

Energy cover crops are currently being developed in France and Europe to provide biogas through anaerobic digestion and thus contribute to renewable energy production. These crops have the double advantage of (1) not competing with food crops, as they do not occupy the soil at the same time, and (2) providing the ecosystem services expected from a cover crop (e.g. reduction of nitrate leaching, reduction of erosion, carbon storage).

However, if agronomic issues related to their management and methanogenic potential have been addressed (Molinuevo-Salces et al. 2013*; Wannasek et al. 2019**), issues related to their environmental impact have been very little explored, particularly coupled with digestate return to the field. We focused on ecosystem services related to nitrogen recycling (reduction of nitrate leaching, reduction of nitrous oxide and ammonia emissions) and soil carbon storage. We also studied whether energy cover crops could compete with food production by inducing nitrogen or water stress on the following main crops, which could lead to yield loss.

We conducted a two-year field experiment in southwestern France. Two main crop sequences were implemented: wheat [Triticum turgidum subsp. Durum (Desf.) Husn.] - Winter barley [Hordeum vulgare L.] - winter peas [Pisum sativum L.] and wheat [Triticum turgidum subsp. Durum (Desf.) Husn.] – Sunflower [Helianthus annuus L.] – grain sorghum [Sorghum bicolor (L.)]. Summer energy cover crops (sorghum [Sorghum bicolor (L.) Moench] – vetch [Vicia benghalensis L.] mixture) were grown on the short fallow period of the first rotation and winter energy cover crops (rye [Secale cereale L.] – fababean [Vicia faba L.] mixture) on the long fallow period of the second crop sequence. These energy cover crops were exported from the plot at harvest to produce biogas and fertilized with digestate produced during anaerobic digestion. They were compared to the same unfertilized and non-exported cover crop and to a soil left bare. For the long fallow period, the comparison was also made with a white mustard, growing over the autumn and plowed into the soil earlier. The biomass and yield of cover and main crops, ammonia volatilization and soil water and nitrogen content were regularly monitored. This experiment was then simulated with the STICS crop model in order to assess unmeasured variables (i.e. nitrate leached, nitrous oxide emissions carbon stored over 30 years, crop stress indices) and to extend the simulated period from 2020 to 2050.

About competition with food crops, our study shows that in 2021, energy cover crops did not decrease the yield of the main crops. Repeating the trial over several climatic years using the model will allow us to confirm whether this result is isolated or generic. Secondly, with regard
to ecosystem services, we observed a decrease in leaching during long cover crop period that was lower than with fast-growing mustard, and a decrease in nitrous oxide emissions compared to bare soil. Conversely, spreading digestate increased ammonia emissions, particularly when spread on the crop and not buried in the soil as done before sowing. According to biomass produced and incorporated to the soil (including digestate) in the different treatments, we expect a similar carbon storage that would be verified through simulation results. A greenhouse gas (GHG) balance will allow us to assess if the reduction of direct and indirect N2O emissions and increased in carbon storage compensate for higher ammonia emissions. Finally, the GHG balance of these energy cover crops, if negative, and the assessment of potential other environmental impacts would make possible to ensure that the gas produced is renewable.

* https://doi.org/10.1016/j.biombioe.2013.10.008
** https://doi.org/10.1016/j.eja.2019.125934
Variety testing innovation for new challenges and a more resilient agriculture: The example of oilseeds and protein crops in Switzerland

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The current market calls for the introduction and diffusion of varieties with a stable yield through the adaptation to climatic and sanitary conditions. New technologies for variety testing and recommendation are expected to enhance crop performance and help to adapt to climate change effects. Criteria and methods for plant variety testing must be innovative, global, and efficient to enable the adoption of new varieties that perform better than current ones. Variety testing is presently exclusively based on field experiments in multiple locations, which does not enable to cover all environmental conditions existing within the cultivation area used by farmers. To better characterize the behaviour of varieties in various environments – including abiotic and biotic stress – new criteria must be identified and readily available. Crop modelling could reinforce the evaluation of the suitability of varieties to an extended set of environments that represent better the cultivation area. This study will focus on advances in variety testing using oilseed rape and protein crops as case studies.

Making variety testing efficient and practical requires the involvement of farmers and extensionists. A survey was distributed among farmers to collect information on their expectations. In summary, the survey indicated expectations for the adaptation of the variety to the evolution of cropping systems. There is a need for varieties that are adapted to lower input management and organic farming, for which new criteria for variety evaluation is crucial. Rapeseed growers face an increasing number of insecticide withdrawals, and therefore variety evaluation is expected to increase efforts in assessing tolerance of varieties to insects. Early vigour, ground cover, collar diameter and growth resumption in the spring are under study and could be, in a near future, included as official criteria. In soybean, reducing herbicide use is targeted through the identification of cultivars with high weed competitiveness. Artificial weeds are included in soybean variety trials and image analysis aims at evaluating their performance in sub-optimal conditions. To meet the needs of organic farming systems and systems based on agroecological principles, variety testing should also consider mixed cropping. In Pea, cultivars are characterized for their mixed-cropping potential with barley or lentil. The specific objectives are to compare the productivity, lodging resistance, disease resistance and the competitive relationships of pea cultivars in mixed-cropping.

For a long time, variety testing has relied on visual observations. However, over the last few years, automatisation, robotisation and the use of non-destructive approaches for measurements have made their way into this domain. Digital tools are available for phenotyping as well as for understanding the response of the different varieties to the
environment. A current study aims at incorporating these technologies into the toolkit used for sunflower variety testing. It consists in evaluating the correlation between measured field data and UAV measurements, and thus assessing the potential use of UAVs to determine crop density, crop height, canopy cover, crop phenology and crop water status. Additionally, the use of crop modelling would supplement the information from variety trials by accounting for environmental and agronomic conditions unencountered in trials.

A short overview of the challenges and new practices that are still under development or that have recently become available reveals promising prospects for variety testing: i) integrating sustainability criteria into performance testing, ii) developing digital tools suitable for variety testing, and iii) implementing decision support tools in variety testing.
Fine tuning N fertilization to target wheat yield components: toward a spatially and temporally explicit approach

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Nitrogen use Efficiency; Winter Wheat; Yield Components; Precision Agriculture; Nitrogen Fertilization

Nitrogen is a central element in European crop productions. Price volatility and environmental concerns are some of the reasons to seek to maximize Nitrogen Use Efficiency (NUE). Great efforts have been made to understand nutrient dynamics and mechanisms of winter wheat yield elaboration. These researches have allowed to target specific phenological stages to ensure optimal N allocation and the maximization of yield. However, homogeneous conditions met in experiments are seldom observed on the field. Precision agriculture aims to help farmers diagnose and manage spatial heterogeneity at the field scale. An interesting method was developed by Blackmore (2000) to analyze spatial and temporal trends of yields and delineate management zones. Yield is considered as the integrative response of crop to soil and climate interactions and their combined limiting effects. Management zones are characterized by the level and stability of yield observed over years. Thus, three zones are generated: (i) the unstable, (ii) the low and stable and (iii) the high and stable. Basso et al. (2011) suggested to manage N within each zone combining strategic and tactical approaches to optimize N supply. Strategic approach aims to define N supply response to pedoclimatic tendencies whereas tactical approach considers real-time conditions to adjust N applications. Strategy and tactics complete each other temporally by the factors considered in decision. Including the impact of N supply on yield components within these approaches could lead to manage precisely N fertilization spatially and temporally.

Trials analyzing the influence of N management on wheat yield, yield components and N losses were conducted between 2010 and 2019 on a loamy soil in Wallonia (Be). N was supplied in three applications: at tillering stage, stem extension and flag leaf. Total N supply ranged from 0 to 360 kgN.ha⁻¹. Final yield, thousand-kernel-weight and ear density have been measured as well as residual N in the soil. From measured yield components, grain density and number of kernels per ears were calculated.

Strong correlations were observed between yield, ear density and grain density. These findings highlight the importance, in this agronomical context, to supply crop at tillering stage and at the beginning of stem elongation to ensure ear emergence and spike growth. N supplied at the end of stem elongation is less correlated to yield but is still necessary to maintain wheat flower fertility and grain number. First N application is the highest, from 60 to 100 kgN.ha⁻¹. Second application could be weaker, but sum of the two first applications should reach 120
kgN.ha\(^{-1}\). The total supply ranges between 160 and 180 kgN.ha\(^{-1}\). 180 kgN.ha\(^{-1}\) is a common N supply in the region whereas environmental part of the analysis reveals that total N supply should not exceed 140 kgN.ha\(^{-1}\).

These experimental results will now be used in the frame of a crop model. Once calibrated on their yield components part, simulations will be conducted to analyze the impact of N fertilization schemes on wheat yield elaboration and N losses in each management zone. This multicriteria analysis, combined with strategic and tactical approaches will lead to define decision rules to adapt N fertilization practices spatially and temporally and improve NUE.


Evaluating the impact of cover crops on carbon sequestration and water productivity of olive orchards under present and future climate scenarios

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Olive orchards represent one of the most emblematic agricultural systems in Spain, and especially in Andalusia, its southernmost region. The use of cover crops in the orchard alleys has long been proposed as an alternative soil management for ameliorating erosion rates while providing additional ecosystem services. However, quantitative reports accounting for some of those ecosystem services are still scarce in the scientific literature. In this work, we used an improved version of OliveCan (López-Bernal et al., 2018), a complete process-based simulation model of olive orchards, to estimate how carbon sequestration and ecosystem water productivity are affected by the use of cover crops. The model originally solved the water balance independently for two soil compartments representing the fractions of the soil i) wetted by irrigation emitters and ii) only receiving water by rainfall. For the simulation of the cover crop we added a third independent soil compartment representing the soil strip occupied by the cover crop and where the water balance considers water uptake by the roots of the cover crop. Such uptake rate depends on the leaf area index of the cover crop and is constrained under soil water deficit. A simple thermal time approach is used to simulate the development of the cover crop, which modulates its growth along with soil water availability. Biomass production is calculated through a simple radiation use efficiency approach taking into account the atmospheric CO2 concentration and, at the end of the cycle, the residues of the cover crop are considered inputs for the labile soil organic carbon pool. Simulation experiments were performed for rainfed olive orchards in southern Spain considering different widths for the strip occupied by the cover crop. Results indicate that the management of the cover crop has practical implications in terms of carbon sequestration and water productivity at the orchard scale and illustrate the potential of crop simulation models for identifying best management practices to meet environmental objectives. Further simulations performed for future climate scenarios are also presented, providing clues on the sustainability of alternative cover crop management strategies in the context of climate change.

Keywords: cover crops, crop modelling, Olea europaea L.

Reference:

To what extent can ecoclimatic indicators assist crop performance predictions in oilseed rape upon repeated heat waves?

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Keywords: oilseed rape, heat stress, stress memory, crop modelling

Modelling is an obligate approach to predict crop yield under a wide range of environmental conditions. Simulations under different climatic scenarios can provide useful information to adapt management practices (i.e. earlier sowings, new cultivars, innovative fertilization strategies) in order to maintain, or even improve, crop performances under changing environments. Based on the last Intergovernmental Panel on Climate Change (IPCC) report, heat waves are expected to become more frequent, to last longer and to increase in intensity during the plant’s reproductive phase, thus impacting the yield and quality of economically important crops such as oilseed rape (Magno et al., 2021). In our work, we aim to improve crop predictions by considering the effects of repeated heat waves into ecoclimatic indicators that can be used in statistical models. Our underlying hypothesis was that the plant’s response to a stressing event might be modified if the plants were previously exposed to similar stresses.

Based on large datasets in oilseed rape (Corlouer et al., 2019), we developed statistical models to look for correlations between ecoclimatic indicators related to high temperature and the plant final performance variables (i.e. yield, oil and protein content). For this purpose, (i) we divided the plant cycle into four intervals after flowering, according to the physiological stages of development in oilseed rape; (ii) we scored the number of warm days (i.e. above 25°C and 30°C) in each interval for 26 combinations of location x year in France; (iii) we proposed several models that differed from the combination of ecoclimatic indicators; and (iv) we selected the best fit predictive models of the final performance-related variables by using an automatic stepwise approach using the stepAIC function, as performed in Akmouche et al. (2019). With this approach, we first observed that contrasting final performances were tightly related to the timing, frequency and intensity of high temperature events after flowering. In addition, specific combinations of these ecoclimatic indicators seems to be much more predictive of the final crop performances than a single cumulative indicator which reflects the sum of all stresses in the same period. These results support our prior assumption that the outcome of several successive stressful events is not equal to the sum of each individual effect. Our approach is a proof of concept of the need to consider stress memory (i.e. the capacity of plants to store and process information acquired during an initial exposure to stress) in
predictive crop modelling approaches, so as to better estimate the effects of repeated stresses and their consequences on crop yield and quality of harvested products.


Yield prediction of cereal-legume intercrops: from data gathering to modeling

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Intercropping; Modeling; Data

In crop science, mixing two species in the same field (intercropping) has gained a lot of interest. Cereal-legume intercrops are a particularly promising mixture type and field experiments involving these intercrops have increased in the last decades. Gathering the results of these multiple experiments to gain knowledge on intercropping is a promising, yet uncommon, approach. Indeed, observing crop species responses to various soil and climate conditions is necessary to generalize the results obtained in single locations and to enable the development of predictive approaches of crop performance. However, experimental results produced for different goals are heterogeneous and combining them is challenging, because of diverse experimental designs, samplings, measured features, and data format (Pappagallo et al., 2021).

In this study, we describe the workflow that we have conducted to face the challenges arising from the gathering of heterogeneous experiments to the building of predictive models of intercrop yield.

We gathered results from 35 factorial experiments in diverse environmental conditions (5 locations x 15 years, 8777 observations). Main crop features (yield, height, shoot biomass) were collected in intercropping and sole cropping conditions. We first developed an R package to combine experimental data, used a single data format and versioning to track modifications caused by data curation. To face the heterogeneous sampling across the experiments, we used smoothing splines to fit the growth dynamic of height and shoot biomass, from which we derived key features of plant growth dynamic (i.e. maximum growth rate, lag phase).

Our goal is to predict intercrop yield as a function of plant-plant interactions, environmental variables and agronomic practices. For plant-related features, we focused on a set of predictors rather than using all available data, mobilizing concepts from community ecology. For instance, differences between crop features within the intercrop (cereal-legume) can be a proxy for plant-plant interactions (competition / complementarity). Plant-environment interactions were estimated through the computation of nitrogen nutrition index, adapted for intercrops (Louarn et al., 2021). For environmental variables, we seek to compare different approaches (classification of similar environments based on the sole crop reference, computation of rough climatic indicators, functional data analysis, etc.). This former step will allow us to reduce the dimensionality of climate and soil variables and to obtain a set of environment-related predictors.

We seek to use these two sets of predictors to build machine learning models. Until now, we have built models based on 3 algorithms (boosting, random forest, LASSO regression).
including plant-plant interactions predictors and some agronomic practices. Our preliminary results, based on these models, are encouraging, on both training and evaluation data sets. These results tend to indicate that the difference of maximal height was often a good proxy for the legume’s yield in many mixtures. Differences between maximal growth rates seem also to strongly influence the outcome of intercrops. The predictive ability of our models is affected by the combination of species and by the output variable predicted (yield of the legume seems to be harder to predict). Next steps of our work include i) the use of environmental variables as new predictors, ii) fitting other model types (support vector regression, mixed models, etc.) and iii) evaluation of robustness of our models via stratified cross validation techniques.

Louarn et al., 2021: Plant nitrogen nutrition status in intercrops– a review of concepts and methods
https://doi.org/10.1016/j.eja.2021.126229

Pappagallo et al., 2021: Coordinating data collection in intercropping: A feasible example
Comparative analysis of plant-environment-management interactions along longevity axis: Novel insights into the nitrogen balance

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Agronomic and ecological analyses of plant life history regarding longevity and resource use along an axis from annual to perennial species provides a framework to evaluate trade-offs in plant-environment-management interactions in agroecosystems necessary for a future bio-based society. This field study on a sandy loam soil in Denmark compared annual crops grown in either (1) monocultures of maize and triticale, (2) conventional rotation of barley and wheat or (3) rotation optimized for large biomass yields including maize, beet, hemp, triticale and winter rye, with perennials from Poaceae and Fabaceae families as (4) intensively fertilized festulolium, (5) low-fertilized miscanthus and (6) grass-legume mixture without nitrogen (N) fertiliser. The agro-environmental analysis comprised statistical comparison of 5-years (2013-2017) observed data on N in biomass and leached out of the root zone of the different agroecosystems.

The results showed that biomass N differed highly across the agroecosystems due to an integrative effect of plant-specific characteristics and management actions. Of the seven agroecosystems and on mean annual basis, the lowest leaching of about 20 kg N ha⁻¹ was observed for grass-clover mixture with 217 kg N ha⁻¹ in biomass at no N-fertilizer cost, highlighting plausible option to extensity agroecosystems with perennial legumes. Leaching below the highly-fertilized festulolium was highly variable, but on average 53 kg N ha⁻¹ and similar to 48 kg N ha⁻¹ for the conventional rotation, yet, at significantly larger harvest of 480 versus 140 kg N ha⁻¹. The high productivity of the perennial grass observed under intensification was ascribed to high canopy radiation interception (800-1200 MJ m⁻²) with large synchronized soil N uptake (150 kg N ha⁻¹ cut-1 of biomass at three-cut frequency fertilised125-175 kg N ha⁻¹ post-cut), though the latter appears to diminish with the age of this agroecosystem. Renewal of the festulolium showed large peak in nitrate concentrations in the end of the root zone the following year, followed by rapid stabilization thereafter, prompting for agronomic intervention such as grass re-sowing together with a fast-growing single-season cover crop and N-fertilizer adjustments. The renewal dynamics of the soil nitrate for grass-clover mixture was slightly extended, but at a much lesser intensity compared to festulolium. Leaching from the optimized crop rotation was either comparable or lower to that from the conventional systems, alongside equally or higher biomass N and associated agroecosystem diversification benefits.

Altogether with positive effects of perennial crops on the soil N and carbon stocks observed by concomitant studies at the site, these results provide novel insights to advance the understanding of resource use efficiency of both perennial and annual crops in agroecosystems targeting provision of biomass for the bio-based society.
Effects of irrigation and sowing pattern on growth and yield of five spring barley genotypes

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Keywords. Spring barley, drought stress, sowing pattern, climate change

Climatic change shows a spiraling trend of scarce rainfall mirrored with a fall of majorly produced cereals such as barley. Germany, the largest producer of spring barley in Europe, has experienced a series of severe drought spells at the end of the last decade. The increase in frequency and intensity of drought events represents a threat to yield stability and grain quality, endangering productivity and the economic viability of barley production in Germany. Thus, finding solutions through crop management and cultivar selection has become crucial to minimize crop losses and stabilize the dropping trends. In this study, we test the effects of irrigation and sowing patterns on five genotypes. We conducted the experiment in 2021 at the experimental fields of Julius Kuehn Institute Berlin. We applied three irrigation treatments: Rainfed, supplementary irrigation (irrigation is applied when plant available water capacity (PAWC) < 30% and refilled to 70%), and non-limiting irrigation (irrigation is applied when PAWC < 50% and refilled to 100%). We tested four genotypes, which are promising to feature high drought stress tolerance, i.e., Morex, Golden Promise, BCC1589, HOR7985, and we used RGT Planet as a reference. We further tested two sowing patterns with a sowing density of 290 seeds/m², i.e., equidistant sowing in a triangular pattern with 6 cm distance between single plants vs. conventional row drilling at 11 cm row distance. The main traits we assessed during the growing season are plant spacing (at emergence BBCH 11), above-ground biomass (at BBCH 30, BBCH 59, and BBCH 87), and weekly, we assessed crop phenology, canopy height, leaf area index (LAI), as well as multi-spectral indices such as normalized differential vegetation index (NDVI), soil adjusted vegetative index (SAVI), crop water stress index (CWSI), etc. using the MicaSense-Altum camera, mounted on a copter. At harvest, we assessed yield and yield components. The effects of the sowing pattern were evident, especially during the early vegetative growth (39 days after sowing (DAS)). The uniform sowing pattern showed substantially stronger canopy coverage and significantly higher NDVI than conventional drill seeding for all five genotypes. Later in the season, i.e., from 61 DAS to 91 DAS, we experienced a drought period that coincided with the flowering and beginning of the grain filling stage, resulting in a significant difference between irrigated and rainfed treatments. We observed the highest values of LAI under the irrigated treatments for the genotypes Golden Promise, BCC1589, and RGT planet. For the same genotypes, biomass at yellow ripe was negatively affected by water deficit. Under all irrigated treatments, we recorded a significantly higher grain yield for all genotypes, except for Morex. We observe a
significant effect of sowing pattern on yield of the reference cultivar RGT Planet under rainfed and supplementary irrigation. The genotype Morex expresses drought tolerance traits, as it does not underperform under water stress; however, it generates significantly lower yields compared to the reference cultivar. Although we aim to identify drought tolerance traits, it is important that these traits do not relate negatively with yield and quality traits but that drought-tolerant genotypes are also capable of producing competitive yields under non-stressed growth conditions.
Future area expansion will likely outweigh increasing drought risk for soybean in Europe

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Introduction
The EU strives to increase the production of protein crops to (i) to further diversify the current cropping systems to enhance ecosystem services and (ii) reduce the dependency on imports from foreign countries, including the control the quality of the produce that enters the EU market. Soybean exhibits the greatest potential for its large content of proteins and high economic potential. Currently, this potential is underutilised in Europe, while it is a dominating agricultural produce in e.g. US and Brazil and one of the ten most important crops at the global scale. Under expected climate warming, agronomists assume that the potential to successfully grow soybean in Europe to achieve competitive yield levels will increase significantly. Here we show the current soybean suitability across European site conditions, predict the potential productivity under current climate and explore the potential productivity under future climate based on multi-model simulations.

Materials and Methods
We use an ensemble of well-tested soybean growth models to simulate soybean yields across Europe. We used experimental soybean growth data from Müncheberg (Germany), Toulouse (France), Kraków (Poland) and several sites Serbia to calibrate three crop models MONICA (Nendel et al. 2011, Battisti et al. 2017), HERMES (Kersebaum 2007), APSIM (Mohanty et al. 2012) and STICS (Jégo et al. 2010) for early to very early maturity groups in Europe. Soybean data represented maturity groups ranging from 0000 to II. The data was split to calibrate and test the models. We simulated a 30 year time period and calculated the 75% percentile for each grid cell and maturity group and analysed the phenology and the response to average temperature, cold spells, rainfall at harvest and drought. Based on this distribution we produced a yield map across Europe that exerts the yield produced by the most likely maturity group per grid cell.

Results and Discussion
Results demonstrate the northward shift of soybean production across the European continent and how the overall yield potential increases with the higher potential to grow high-yielding maturity groups in central Europe, where water scarcity is still not limiting the
production. We also demonstrate that the potential area for rainfed production of soybean is expected to decrease in Southern Europe, with less water being potentially available in the soils.

Conclusions
We conclude that the overall potential to grow soybean across Europe will increase significantly under climate change, based on the new areas becoming available in central Europe outweighing the areas that will be lost to drought in the South. This will increase Europe’s potential to become less dependent on soybean imported from overseas.

Acknowledgements
The authors acknowledge financial support from the Federal Ministry of Education and Research of Germany (BMBF) through the InnoSoy network (01DR17011A).

Reference:


Linking seasonal ensemble weather forecasts and dynamic crop modelling for improving in-season N-management

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Keywords: crop modelling, seasonal weather forecasting, N-management, winter wheat

Crop forecasts have been promoted as a promising means to facilitate a more targeted investment of agronomic resources. Traditionally, such crop forecasts were based on statistical or mechanistic crop models that use climatological records to generate projections of future crop growth and development. Increasing evidence that -due to climate change and increased climate variability - future growing conditions will significantly deviate from historic averages, and the advent and continuous improvement of seasonal weather forecasting methods, give reason to move from climatology-driven crop forecasts to crop forecasts that use long-term weather forecasts instead. This approach has already been shown to be skilful for predicting different crop and soil variables of agronomic interest (Vogel et al., 2021). The aim of our study was to develop and evaluate an integrated crop forecasting approach that provides operational decision support for in-season nitrogen (N-) management at field level by using state-of-the-art seasonal ensemble weather forecasts (Johnson et al., 2019) linked with the dynamic, process-based crop model SSM-iCrop (Manschadi et al., 2022). We used winter wheat production in Eastern Austria as a case study.

This integrated crop forecasting approach needs to provide not only end-of-season yield estimates, but also accurate predictions of other in-season variables relevant for N-management. Therefore, we first investigated how well important crop phenological stages (tillering, stem elongation, booting, and flowering), plant available soil water and soil Nmin, and plant N-uptake, gain N-uptake and grain yield are predicted by crop forecasts of different forecast lengths and lead times. These variables are key for decisions related to N-management at field scale. We created forecasts of different lengths by linking ensemble weather forecasts of 0-7 months with climatological records until the end of season. Different lead times describe how far in advance certain events (for example anthesis or harvest) are forecasted. This crucially depends on the quality of the ensemble weather forecasts. If the quality of the ensemble weather forecasts declines with lead time, crop forecasts quality will consequently also decline with forecast length.

Preliminary results indicate that using a combination of ensemble weather forecasts of one month in length together with climatological records until the end of season provides the most accurate crop forecasts, and that the quality of pre-anthesis crop forecasts across different forecast lengths are independent of lead time and only increase post-anthesis. For example, total grain yield is forecasted with RMSE of 57.28 g/m² (+/-3.03) for lead times of six to three
months, with RMSE of 45.62 g/m² for two months lead time (i.e. forecasts issued at the beginning of anthesis month), and RMSE dropping to 4.51 g/m² for one month lead time (i.e. forecasts issued at the beginning of harvesting month).

To evaluate the operational potential of this integrated N-management approach, we conducted three different on-farm experiments (two locations in growing seasons 2020/21 and 2021/22), where we divided experimental fields into a "Farm strip" where N-fertilizer was applied according to common farm practice, and a "Model strip" that was fertilized according to the integrated ensemble weather forecasting-crop model approach such that the forecasted mean grain yield and quality are equally high as within the "Farm strip". We based calculations for fertilization amounts for the “Model strips” upon field-specific monthly SSM-iCrop runs, reflecting local soil characteristics, previous management measures, crop cultivar parameters, and weather conditions as forecasted by the ensemble. Results from the first season of comparative on-farm experiments (2020/21) showed that a total reduction of 60 kg N/ha in supplied N-fertilisers resulted in no reduction of either yield quality (14.40% grain protein content) or quantity (5.57 t/ha) within the “Model strip”.
Identification of the trade-off between soil health and crop production with the LANDSUPPORT best practices tool

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The web-based “Best Practices tool” runs on the fly (https://dev.landsupport.eu/template.html) to identify optimized solutions for enhancing crop production and soil fertility while reducing nitrate leaching. The tool was developed in the framework of the LANDSUPPORT project (H2020-RUR-2017-2/No. 774234) and applies a what-if scenario approach at regional scale (average area of approximately 2500 km²) in three case studies (Marchfeld – Austria, Campania Region – Italy, Zala County – Hungary). The tool is dynamically linked to the ARMOSA process-based model (Perego et al., 2013), which simulates at daily time step many combinations of farming systems (conservation, organic, conventional), crops, nitrogen fertilization rates, tillage solutions, crop residues management. Out of the wide set of daily ARMOSA outputs, the tool returns the mean annual value of (1) the crop yield, (2) the nitrate leaching at the bottom of the soil profile, and (3) the change of the soil organic carbon stock in the upper soil layer (0-0.4 m). The tool also gives the value of the synthetic “best practices index” (IBP) that is computed as a linear combination of the three variables and the weights that the user dynamically assigns to each of the variables according to the specific goal (e.g., increase in soil organic carbon). The user then sorts the IBP values in descending order to identify the most suitable combinations of practices. The mean value of IBP is plotted in charts for each of the simulated combinations.

The tool has been developed to be applied by public authorities, such as regional environmental agencies, to find the best solutions according to a goal (e.g., increase in soil organic carbon stock, reduction of nitrate leaching) in a region of interest (ROI) which can be freely drawn by the user. The ROI is associated with soil properties described for each horizontal layer (data available from the pedological database or LUCAS European database). A ROI can be described by 1 to n number of soil profiles and there is no limit to the area of the ROI to simulate. The user sets up the combination of agronomic practices via web interface. The high number of combinations (up to 2520 combinations) derives from: 5 climate scenarios specific for each ROI (20-year period of current, near and far future under RCP 4.5 and 8.5 IPCC scenarios), 7 crops, 2 systems (conventional, organic), 3 fertilization rates (optimal amount, 15% and 30% reduction), 2 residues management (removal, retention), 3 tillage practices (ploughing, minimum tillage, sod seeding), and 2 uses of cover crops (yes, no). The user-friendly interface hides the high complexity of the soil and crop processes which are simulated on the fly by ARMOSA, which has many crop and soil parameters already calibrated using the dataset available in the project and in previous studies (Valkama et al., 2020). As the close link with ARMOSA, the tool allows the close representation of actual and optimized cropping systems with the possibility of further applications at a larger scale (e.g., European), in other regional case studies, and in tailored scenarios in which the user enters her/his data of soil properties and climate.
Root growth of spring barley in Worm or Root characterized Biopore Sheath

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Keywords: barley, biopore sheath, biopore types, root length density, root diameter

Periods of increased drought as well as the trend towards extensive farming systems requires more details about root growth and nutrient acquisition in heterogeneous structures in the subsoil. Of particular interest are large-sized biopores (diameter >5 mm), which are vertical, continuous voids with favorable properties, such as low penetration resistance, enriched organic residues, and increased microbial activity. Consequently, crop roots have been reported to preferentially follow these pores especially in compacted soils. Thus, they may enable access and nutrient uptake in deeper soil layers. However, it has not been sufficiently investigated whether the biopore sheath is an environment for root growth and facilitates further exploration of the bulk soil.

The characterization of these biopores by a taproot or an earthworm effects pore properties differently. This can potentially have beneficial (roots may create lateral pores) or inhibitory (worm linings may close lateral pores) effects on root growth into the biopore sheath (Pagenkemper et al. 2015). Therefore, a pot experiment was performed with biopores either formed by an earthworm (Lumbricus terrestris L.) or a taproot (Cichorium intybus L.) to test effects on root growth of spring barley (Hordeum vulgare L.) in the biopore sheaths. For this purpose, root length density (RLD) and root diameter were measured in the biopore, the biopore sheath at 0-2, 2-4, 4-8 mm, and the bulk soil at 20-36 mm lateral distance from biopore surface.

Significantly higher RLD within the biopore compared to biopore sheaths and bulk soil were found in both biopore types. In the worm type, RLD of 3.68±0.82 cm cm⁻³ (LS-Mean±SEM) were found in the pore, laterally decreasing from 0.51bc±0.13 to 0.15c±0.07 in the biopore sheath, and 0.49bc±0.11 cm cm⁻³ in the bulk soil. In the root type, the RLD was 4.30±0.93 cm cm⁻³ in the pore, laterally decreasing from 0.26b±0.14 to 0.15b±0.07 in the biopore sheath, and 0.33b±0.11 cm cm⁻³ in the bulk soil.

In the worm type, the percentage of fine roots (root diameter 0-0.2 mm) in the pore (44.52±3.51%) was significantly lower than in the biopore sheath up to 4 mm distance (0-2 mm: 69.02±3.89, 2-4 mm: 73.11±4.16%) and bulk soil (68.35±3.57%). There was no difference in the root type between the pore 64.18±4.09%, the biopore sheath (from 72.37±4.71 to 79.69±4.66%), and the bulk soil 71.04±4.33%. The root type showed a significantly higher proportion of fine roots in the pore and at 4-8 mm lateral distance compared to the worm type.

Root diameter provides evidence for root aging and differentiation or axial (thicker) or radial
(thinner roots) mechanical resistance (Kolb et al. 2017). The comparatively low percentage of fine roots in the pore of the worm type could indicate either older roots, or roots encountered axial resistance at the pore wall. Based on the RLD, it appeared that neither the worm type inhibited nor the root type encouraged root growth in the biopore sheaths. The decreasing RLD with increasing distance from the pore towards the bulk soil reveals a low potential for roots to access the bulk soil through the biopore sheaths. The roots grow mainly vertically along the biopore, however creating contact laterally in the biopore sheaths, which can serve for anchorage and nutrient acquisition.

Reference:


Cover crops introduction in a maize cropping system: biomass yield and N dynamics

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Cover crops (CCs) can provide several benefits related to the agrosystem (Fageria et al. 2005) and their potential multifunctionality in determining agricultural and environmental services has been widely demonstrated. However, from an agronomic point of view, important metrics for evaluating cropping systems are the crops yield and short-term profitability (Schipanski et al. 2014). These latter are becoming even more significant nowadays when agricultural systems should ensure food security for the growing global population in a scenario of climate change. In this context, CCs are considered a valid agronomic practice, only if they don’t interfere with the cash crop yield. The right species selection and the proper management of CCs might determine the cash crops’ yield in the short-term (Bourgeois et al. 2022) while maintaining multiple others ecosystem services. Among the management systems, the periodic rotation of CCs species is strongly suggested to avoid the negative impacts due to the monosuccession.

This study aimed to investigate the impact of 2 winter CCs managements on waxy maize crop yield and nitrogen (N) cycle, through a comprehensive evaluation of crop-nutrient interactions and mineral-immobilization turnover of N. The CCs systems included a fixed treatment with a graminaceous species (triticale), a 2 years graminaceous-leguminous succession (rye, clover) and a control with NO CCs. The 2 years research study (2019-2021) was conducted on a 6.5 ha field in North-east Italy (45°20′53″ N, 11°57′11″ E).

Obtained results showed that the use of different winter CCs species significantly affected the N mineral-immobilization turnover and the crop-nutrient interaction. The inclusion of leguminous species in a CC succession, rather than using a fixed graminaceous species, led to a better maize response both in its early development stages and at harvest time. Both SPAD and height (m) values (at 7-11th leaf stage) were indeed found to be higher in the succession (34.6; 1.7 m) compared to the fixed treatment (27.3; 1.6 m). Similarly, higher maize biomass yield was measured in the succession, and the No CCs treatments (+7.1%), compared to the fixed one (16.2 Mg ha-1). The triticale behaved as a “catch crop”, while the leguminous crop, was able to fix additional N (23.6 kg Nfixed ha-1), acting as green manure. The lower N uptake (30.7 kg ha-1) and higher C:N ratio (26.1), measured in the triticale biomass, led to a lower soil mineral N availability (28.1 kg ha-1) before maize sowing, compared to the succession management (44.3 kg ha-1). This latter showed the same cumulative CCs biomass production (2.1 Mg ha-1) with a higher N uptake (43.1 kg ha-1) and a lower C:N ratio (19.9) than triticale. Our findings showed that in the short-term period the use of a CC species succession can support maize biomass yield production while the use of single graminaceous species can reliably act as a catch crop for N leaching reduction. In conclusion, both the CCs species and
the type of management can affect the cash crop yield, confirming that periodic rotation of CCs species (with the inclusion of leguminous) might favour the agronomic short-term profitability.

Reference:


Dutch case study shows that large variability in farmers’ input use and efficiency provides scope to maintain potato productivity levels while using less inputs.

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Yield gap; resource use efficiency

High intensive agricultural systems use large amounts of nutrients and pesticides, often accompanied with high yields. In the Netherlands, ware potato production is an example of such a system, with an actual ware potato yield at ca. 70% of the potential yield. However, the input use also comes at a cost of larger nutrient and pesticide residue losses to the environment. An often used argument to keep using large amount of inputs, is the uncertainty that ware potato productivity may decline when inputs are reduced. However, reducing input use and thereby increasing efficiency is essential to move towards a more circular and sustainable agriculture. In this study, based on farm data, we quantified nutrient use efficiencies and surpluses, calculated the environmental impact of pesticide use and analysed potential trade-offs between yield and input use for Dutch potato fields.

In 2020 and 2021, we collected data from 96 different ware potato fields throughout the Netherlands equally divided over sandy soils (cv. Fontane) and clay soils (cv. Innovator). Each field was visited biweekly for taking measurements. Nitrogen use efficiency (NUEtot) was calculated as nitrogen output divided by total nitrogen input from spring and fall applications. Effective nitrogen use efficiency (NUEeff) was calculated similarly to NUEtot but considering nitrogen fertilizer replacement values used by the Dutch government. Nitrogen (N), phosphorus (P) and potassium (K) surpluses were calculated as the difference between nutrient input and nutrient output. The Environmental yardstick for Pesticides was used as a tool to calculate the environmental impact of pesticide use (EIP) in each field. Drought stress was used as a covariate in the regression models and estimated using the model SWAP-WOFOST.

Average gross Fontane yield was 64 t/ha in 2020 and 69 t/ha in 2021. Average gross Innovator yield was 66 t/ha in 2020 and 56 t/ha in 2021. Across the two years, Fontane yields ranged from 41 to 89 t/ha. Innovator yields ranged from 36 to 80 t/ha indicating large variability among ware potato fields. Median NUEeff was 0.83 kg N/kg N on sandy soils, which was significantly higher than 0.54 kg N/kg N on clay soils. Considering the EUNEP framework - EU Nitrogen Expert Panel - and effective nitrogen application, 65% of the ware potato fields were within the desired NUE range and 52% of the fields were below the N surplus threshold of 80 kg N/ha. However, considering NUEtot only 59% of the ware potato fields were within the desired efficiency range and only 16% of the ware potato fields were below the N surplus threshold. P and K output was in balance with P and K input on sandy soils with a median P
surplus of 1.2 kg/ha and a median K surplus of 1.63 kg/ha. On clay soils median P and K balances were positive with a median P surplus of 27.3 kg/ha and median K surplus of 58.9 kg/ha. There was a large and significant difference in the median EIPs of pesticide use between the two varieties with 2708 EIPs for Fontane and 1868 EIPs for Innovator. No correlation was observed between N inputs and yields, indicating an oversupply of N on part of the fields. This was confirmed by the significant negative correlation between yield and nutrient surplus. Moreover NUE showed a negative correlation with nitrogen input and drought stress. These results suggest that there is scope to reduce average resource use without declining yields in high input systems, such as ware potato production in the Netherlands. In addition, improving management, for instance through irrigation, can lead to a more efficient use of applied inputs, especially nitrogen.
Effect of timing, duration and intensity of heat and drought on on-farm wheat yields in Germany in 1995-2019

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Key words: weather index; heat stress, drought stress; winter wheat

Climate change-induced adverse weather conditions have successively increased in frequency and intensity since the mid-20th century until today, leading to globally increasing yield losses. These yield losses pose increasing income risks for European and German agriculture. However, there are large regional differences in the sensitivity and severity of extreme weather-based yield variations in Germany. Hence, it is vital to improve the understanding of the spatio-temporal development of weather extremes and the corresponding plant-climate relationships. Weather indices (WIs) are used to determine region-specific influences of weather extremes on crop yields. Therefore, WIs must accurately represent actual weather conditions, spatially and temporally, to determine yield effects for a particular region. In that regard, the aim of this study was to analyze the impact of timing (i.e., effect of different observation periods), duration (i.e. number of days above threshold within a period) and intensity (i.e., different threshold values of a weather variable) of heat and drought to explain crop yields.

We used the FADN yield data set, which contained farm yield data of 10,983 farms in 5,446 major crop producing municipalities between 1995 and 2019. Furthermore, we analyzed interpolated (1 × 1 grid level) weather data from the German Weather Service (DWD) and interpolated (1 × 1 grid level) observational phenology data from the model PHASE. We aggregated these data sets at municipality level and derived various heat and drought WIs that differ in timing, duration and intensity. We used mixed models to derive the explanatory power and region specific effect strength of each WI individually. We use the explanatory power as an indicator to identify WIs that best explain yield losses. Furthermore, we multiplied the region specific effect strength with the duration of a WI, to derive average yield losses per municipality in agronomic and economic terms.

Our results highlighted that timing strongly affects the explanatory power of a WI. In that regard, we found the highest explanatory power for drought WIs during the late vegetative phase (BBCH 31-51). Furthermore, heat and drought WIs exposed twice the explanatory power during the reproductive phase (BBCH 51-75) compared to the extended generative phase (BBCH 51-87). Looking at the region specific effect strength, heat and drought effects were largest in the north and east of Germany, whereas drought WIs revealed no significant negative yield losses in the south of Germany. Moreover, wheat depicted a higher sensitivity to drought during the late vegetative phase than during the reproductive phase. In that regard, soil moisture levels of 50% plant available water capacity (PAWC) already led to major...
negative yield effects during the late vegetative phase, where the strongest yield effects occurred at 30% and 10% PAWC during the reproductive phase. Heat WIs indicated moderate negative yield effects at daily maximum temperatures above 27°C and the strongest negative yield effects at daily maximum temperatures above 31°C during the reproductive phase.

The computations of average yield losses showed that WIs with higher frequency caused stronger yield losses despite lower effect strength. In that regard, 50% PAWC caused on average 2-5 dt/ha higher losses than 30% PAWC during the late vegetative phase. Also during the reproductive phase, the yield losses are 2-5 dt/ha higher for 30% PAWC compared to 10% PAWC. Moreover, during reproductive phase heat days with daily maximum temperatures above 27°C revealed 3-8 dt ha⁻¹ higher yield losses than maximum temperatures above 31°C. Overall, yield losses ranged between 0.1-8 dt/ha and the spatial pattern was very similar for all heat and drought WIs, with highest yield losses occurring in northern Brandenburg and southern Mecklenburg-Vorpommern as in northern Bavaria.
Grain yield responses to pre-flowering heat waves in wheat and barley: inter and intraspecific genotypic variations

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Given the current trend of rising temperatures, the probability of heat stress will increase, thus compromising food security due to the negative effects on the performance of most crops. In this context recognizing differences in sensitivity between crops that are grown alternatively on the same fields, like wheat and barley, may be relevant. Barley is frequently considered to be better adapted to stressful environments than wheat. This difference is mostly assumed regarding water stress (although hard evidences not always agree with this assumption). However, to the best of our knowledge, there have been no studies comparing sensitivity of wheat and barley to heat waves. Besides, the fact that there must be intraspecific genotypic variation in that sensitivity is certain for both cereals. In this presentation, we will report the results of a field experiment aimed to (i) determine for the first-time interspecific differences between wheat and barley in responses to heat waves at pre-flowering stage, (ii) quantify the intraspecific variation among current cultivars, and (iii) ascertain physiological traits, avoiding the confounding effects of changes in phenology, that are often responsible for the plasticity in response to heat. Uncovering true differences in tolerance to heat across well-adapted and high-yielding cultivars, within the same phenological pattern, is relevant for having sound decisions on the preference of growing one crop or the other. The experiment comprised three current cultivars of each wheat and barley in factorial combination with two levels of heat: an unheated control and plots heated for a brief period using portable chambers with transparent polyethylene films placed over the plots, immediately before flowering. We analysed the dynamics of floret initiation and survival, the resulting changes in spike fertility and possible trade-offs with the average grain weight.
Analysis of N, P and K interactions in long-term experiments

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Nitrogen and phosphorus use efficiency in intensified systems is low due to excess applications of artificial and organic inputs. Better balancing supply with demand is key to improve nutrient use efficiency but requires detailed understanding of short- and long-term responses to organic and synthetic fertilizer applications. At present, there are no models available that can give reliable predictions of soil P and K supply and crop uptake, especially for situations where P and K are suboptimal or deficient. A better understanding of short- and long term responses to fertilizer applications can help to optimize fertilizations of crops in a rotation.

Here, we present a new model that includes labile and stable pools for P and K and a K pool to account for fixation, losses and interactions between supplied N, P and K. This model was used to analyse crop nutrient uptakes in long-term experiments from Siaya, Kenya and Hanninghof, Germany. The on-farm trial in Siaya was a standard nutrient omission trial with replicates on 23 farms that ran for 11 seasons, starting at the long rainy season in 2013 up to and including the long rainy season in 2018. It had two phases and five plots per field. Treatments in phase one included a control, PK, NK, NP and NPK. In phase two, 16 farms remained. On 4 farms, plots were subdivided and PK, NP, NK and NPK were superimposed on phase one treatments, on the other farms NPK was applied to all plots. This experiment allowed to study depletion and build-up phases of soil nutrient pools.

The Hanninghof experiment started in 1958 and included 14 treatments, including the same treatments as in Siaya with an additional N and NPKMg treatment, a pig manure only treatment and combinations of all treatments with pig manure. We used only data from 1961-2009, when the rotation included potatoes, winter rye and oats. Pig manure was applied to potatoes only. Linear regression models were used to differentiate the effects of fertilizer supply and treatment from annual variability on nutrient uptakes.

The model was initialized using uptakes from NK and NP treatments. N supply from soil and deposition was estimated using yields in the control or PK treatments. Actual uptakes were computed using concepts from the QUEFTS model. Relative transfer rates between pools and crop-specific uptake coefficients for placed and broadcast P and K were calibrated. Predicted uptakes were compared to measured uptakes and root mean squared error (RMSE) values determined. The results showed that the model could describe measured uptakes well with RMSE of 1.5-3.1 kg ha⁻¹ for P and 15-25 kg ha⁻¹ for K. Relative transfer rates for the stable K pool differed between the two sites, reflecting large differences in soil K retention characteristics. When placed, a fraction of applied P was directly taken up and bypassed the labile pool. Initial soil P and K pools strongly differed between farms and explained the observed differences in yield responses to applied fertilizer. Estimated uptake coefficients differed strongly between crops.
and between treatments with and without pig manure. We conclude that this relatively simple model provided valuable insights in (1) differences in crop responses to fertilizer applications due to soil fertility; (2) differences between crops types and (3) the influence of organic manures on the response to applied mineral fertilizer in crop rotations.
Simulating wheat under German growth conditions – a comparison of different calibration strategies for the DSSAT NWheat model

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Crop models are important tools in today's agricultural research. They allow us to investigate crop development, growth, and yield formation in virtual experiments by integrating genotype, environment, and management data in a dynamic process-based approach. The DSSAT-Nwheat crop model is a freely available and widely used crop model. Because Nwheat was rarely applied for studies in Germany, prior to simulating the performance of specific regional cultivars under German growth conditions, model calibration and evaluation are required. While model calibration is frequently conducted in an unstandardized and non-reproducible manner, with the individual crop modeler’s expertise and effort exerting a significant influence on final coefficient setting, we propose, implement, and compare six alternative calibration strategies. We were kindly supplied with the Federal Plant Variety Office’s cultivar-specific value for cultivation and use (VCU) data, which we supplement with additional wheat field trial data from published sources, to establish a cultivar-specific database for a total of 100 site-years per cultivar. For model calibration, we use the time-series estimator tool (TSE), which allows for the calibration of multiple cultivar coefficients in a coordinated manner. We test the effect of differences in the considered observation data in combination with different calibration strategies. With regard to the observation data, we ignore data on yield components, i.e., number of ears per m² and single seed weight (thousand kernel mass) in the first calibration run, while we consider it in the second. With regard to the calibration strategy, we compare three different approaches. In calibration strategy one (S1), we calibrate phenology first, then growth, and finally yield, whereas in strategy two (S2), we calibrate all coefficients together at once. Strategy three (S3) combines S1 and S2 by considering grain yield during each calibration step by assigning a specific weight to it in the calibration algorithm. We find significant differences between strategies in terms of coefficient setting and model performance, with S3 leading to the best performance based on various statistical indices, i.e., RMSE, NSE, MAE, d-statistics. We also discovered that including yield component data for calibration, such as single seed weight, number of ears per m², and grain number per m², improves model performance. We show how different calibration strategies can affect model performance and propose a standardized and repeatable model calibration approach.
Agronomic resilience of various maize varieties affected by rhizosphere traits under drought stress

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Due to climate change, extreme weather events are expected to occur more frequently. One of these events with severe impacts on agriculture is drought. The lack of water could lead to a decrease in crop production and hence food security. Belowground processes are of particular importance for drought studies since soil water storage and plant water acquisition are intricately linked to crop performance. The rhizosphere is especially interesting as it is the soil volume directly affected by root activity, in which plant-soil-microbe interactions happen. This study aims to uncover rhizosphere traits (e.g. root length density, soil aggregation and hydraulic properties, microbial activity) influencing agronomic resilience under drought stress. The study consists of two main parts: a pot experiment and a field trial. In the pot experiment, we screened 38 maize varieties, including hybrid varieties, open-pollinated varieties, and landraces, with a high-throughput phenotyping facility in a greenhouse. Half of the pots underwent drought stress at stem elongation stage. Images of both aboveground and belowground parts were taken regularly for each pot. Shoot area over time was measured from images and used as the expression of plant growth. Biomass samples were collected and weighed at the end of the experiment.

Twelve varieties were further studied in the field trial to test the agronomic performances and rhizosphere traits under field condition. The varieties were selected based on biomass loss and water-use efficiency of plants under drought stress in the pot experiment. Rainout shelters were set up to impose drought from stem elongation stage to harvest. The shelters were composed of multiple v-shape plexiglass gutters with gaps in between to reduce precipitation to 40%. Rhizosphere and biomass samples were taken at milk stage to determine rhizosphere traits. The whole plants and grains were harvested when the majority of the field reached physiological maturity to determine yield and yield components. Growth inhibition under drought stress was found to be distinct between varieties by comparing their growth curves. The response of plants to drought also varied between varieties in terms of root-to-shoot ratio. For example, Benedictio KWS increased root-to-shoot ratio steadily with decreasing soil water content, while Gelber Badischer Landmais increased root-to-shoot ratio drastically when soil water content dropped to a critical value. More image and data analyses are under way to further study the impacts of drought stress on agronomic performance and their relation with rhizosphere traits.
The productive performance of intercropping

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Sustainable intensification of agriculture is needed to meet the worldwide growing demand for nutritious food while mitigating the environmental costs of high input agriculture. Intercropping is the planned combination of two or more crop species in one field. Intercropping often saves land compared to sole crops. It remains unclear, however, whether intercropping produces a higher yield than the most productive single crop per unit area, i.e. whether intercrops achieve transgressive overyielding. Here we quantified the efficiency of intercropping for the production of grain, calories and protein in a global meta-analysis of several production indices. The results elucidate an apparent paradox; while intercrops show better efficiency than the constituent species grown as sole crops, they usually do not outperform the most productive sole crop in terms of the production of grain, calories, or protein. Thus, while intercrops outperform sole crops when the objective is to achieve a diversity of crop products on a land area, they are in many instances less efficient than sole crops for producing raw products (grain, calories, protein), with one exception: maize/legume intercrops for protein production with nitrogen (N) input below 283 kg ha⁻¹. Furthermore, intercrops produce more grain (and calories) per unit of N fertilizer than the most N-efficient component sole crops. Overall, the results show that, on average, intercrops are efficient when diversity of crop species and efficient use of nutrient resources are at stake but intercrops are less often optimal for bulk production.
Ingredients for successful crop diversification

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European arable cropping systems are often characterised by a low crop diversity, leading to agronomic and environmental issues that contribute to climate change and biodiversity loss. In this context, the use of diversification practices, (i.e., intercropping, multiple cropping including cover cropping, and rotation extension), could help enhance agrobiodiversity and support ecological functions that would contribute to the challenges of food and feed production and environmental preservation. In this context, DiverIMPACTS is a Horizon 2020 project, gathering 34 partners across Europe, to achieve the full potential of diversification of cropping systems.

We used a network of 10 field experiments across Europe providing data from about 100 crop sequences to study the ability of crop diversification to address different challenges: provision of high yields, low use of inputs and, therefore, reduction of negative environmental impacts. Based on these observations, we conclude that crop diversification does not always lead to positive impacts on all the sustainability dimensions. However, the results show that regardless of the starting point (i.e., level of diversification and production mode, conventional or organic), it is possible to design innovative systems which combine higher energy yields, higher gross margins, reduced fertilizer and pesticide use and reduction of greenhouse gas emissions. Through this network, we identified 5 key ingredients to obtain these desired outcomes and avoid trade-offs:

Ingredient 1: Keep a significant proportion of major crops in the diversified sequences to maintain high production and profitability levels and adapt the crop management of these dominant species to the other changes made in the cropping system;

Ingredient 2: Add minor crops to increase both the taxonomic and functional diversity of the crop sequences, thus providing an overall increase of ecosystem service provision;

Ingredient 3: Use compensatory agronomic practices (e.g., multiple cropping or intercropping) to increase and secure yields while increasing ecosystem services provision;

Ingredient 4: Integrate the above-mentioned components in a systemic manner, to address the local agronomic and pedo-climatic factors that affect crop production;

Ingredient 5: Adapt continuously the diversification process, i.e., crops and practices, to face evolving pedo-climate and socio-economic (e.g. infrastructure, markets, regulations, available knowledge) factors and increase performance.
Our results support a gradual introduction of diversification/minor crops and diversification practices rather than a breakthrough from current systems. This calls for moving from crop-specific and practice-oriented measures to a dynamic pathway driven by continuous monitoring of diversification performances. The use of the sustainability assessment tools is crucial to increase the awareness of stakeholders and of society at large about trade-offs and limits of prescriptive solutions. More broadly, crop diversification requires coordination between all actors in the agri-food system to effectively engage in the research and development that minor crops require to increase their relative performance towards major crops and thus further increase the performance of diversified cropping systems and associated value-chains.
Fine tuning of N fertilisation rates in cereals based on N status and modelling

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Developing more efficient and sustainable cropping systems is a global aim, and one of the main challenges is the efficiency of nitrogen (N) fertilisation and the losses of N through leaching. Despite recommendations on crop and site-specific N fertilisation rates, there is a risk that excess N is applied. Reasons for this include unrealistic yield expectations with overestimated crop N requirements, unfavorable weather conditions (i.e. drought stress) and diseases. These shortcomings generally occur after the first N fertiliser application, but split application with an adjusted amount of the fertilizer in the later application(s) could potentially ensure optimum N fertilization amounts according to the given conditions.

Winter wheat (Triticum aestivum L.) is a widely grown cereal crop in Denmark and most of northern and western Europe due to its high yield potential. Common N fertilization rates in Denmark are about 200 kg N/ha, applied in two splits with about one third at growth start in early March and the remaining in BBCH growth stage 30. A potential option for reducing N losses is fine-tuned estimates of N requirements, both spatially and temporally, based on crop N status during the early development stages. In this respect, the use of a crop model in conjunction with sensor technology has potential as a fast, site-specific, and cost-effective approach for guiding N fertilization.

However, this requires that crop models adequately simulate the development, biomass and N accumulation during the early growing stages. In this study we firstly tested and parameterized the Agricultural Production System Simulator (APSIM) based on data of phenology, biomass accumulation, yield and N uptake at five locations across Denmark and for 4 different years. The model was then used to evaluate the effect of targeted spatial N fertilization based on the plant N status at Stage 30 on yield and N leaching. Model results suggest that in a soil with high plant available water content, redistributing N fertilisers from areas with high N crop status to areas with lower N status increased the overall yield, with little affect on N leaching. In contrast, on a soil with low plant available water, such practice would drastically increase N leaching.
Warmer Environment Effects on the Homeostatic Temperature Range of Yield Differ Between Diurnal and Nocturnal Periods for Spring Wheat

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Keywords: binned temperature exposure yield models

Climate uncertainty will impact the earth’s major cereal grain production regions. Globally, semi-arid desert regions experience the widest range in ambient temperature (-2 to 44°C). Our objective is to elucidate the possible changes in the homeostatic temperature range for field-grown hard red spring wheat (Triticum aestivum L. cv. Yecora Rojo) in a semi-arid desert region of the southwest USA. Two heat exposure projects were conducted under ample water supply at Maricopa, AZ USA [Hot Serial Cereal (HSC) and Thermal Regime Agronomic Cereal Experiment (TRACE)]. Sowing dates were staggered from the normal cropping season in Dec. to Apr.-Jun. Use of a day-neutral cultivar negated any vernalization requirement or photoperiod effect. Our objective was to characterize and quantify cereal grain crop yield to a wide range of ambient air temperature using binned temperature exposure yield models [absolute (aEM); normalized (rEM)]. In contrast to the multi-year seasonal replications of the HSC experiment, the range of seasonal temperatures in the multi-year seasonal replications for TRACE is shifted towards higher temperatures. This makes it possible to estimate the upper limit of the homeostatic yield range against temperature increases more precisely. In general results for the nocturnal (12-hour phase), diel (24-hour phase) and diurnal (12-hour phase) yield responses to temperature changes are offset to the right in both projects, i.e., nocturnal temperatures in the same temperature class causes a different yield response than diurnal temperatures. The diel temperature response is therefore the mean of the responses to diurnal and nocturnal temperatures. Comparing function graphs of the rEM and aEM models for HSC and TRACE, both models indicate a rightward shift of the mean temperature optimum, which is more pronounced for rEM than aEM. Overall, the effect of the nocturnal temperatures is more influential on yield then the integrated effect over the diel phase. While the upper limits of the homeostatic temperature ranges for the diurnal phase of the rEM and aEM models are similar, those of the nocturnal phase of rEM remain below that for aEM. Consequently, this leads to a limitation of the homeostatic temperature range of the diel phase at 25°C. Given further confirmation these preliminary results contribute to the development of specific adaptation strategies to facilitate global food security.

Reference:

Long-term impact of pH management on crop productivity and soil health

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Managing soil pH is fundamental for maintaining crop production. Soil acidification is a major cause of soil degradation across the world. The chemical principles of soil acidification are well understood but changes in atmospheric deposition and climate are constant challenges. The impact of lime on soil respiration and CO2 emissions is also a cause for concern in terms of climate change. It is well known that pH strongly affects both carbon and nitrogen cycling, however, there is significantly less understanding of the effect of pH on soil biology in relation to soil function, particularly the relationships between soil biology, soil health and crop production.

There are several long-term experiments in Europe that include soil pH treatments but as far as we know the pH plots In Woodlands Field at SRUC Craibstone, Aberdeen, Scotland are unique in including both a pH gradient and a ley/arable crop rotation. The pH plots at Craibstone have provided land-users and biological/environmental scientists, both in Scotland and worldwide, with a uniquely powerful resource to understand this pivotal role of soil pH in regulating agricultural productivity and environmental pollution.

The experimental at Aberdeen was established in 1961 and investigates the impact of different pH levels (ranging from 4.5 to 7.5 in 0.5 increments) on soil properties and crop performance of an 8-course rotation comprising: 3-year grass/clover ley, winter wheat, potatoes, spring barley, swede and spring oats (undersown with grass/clover). Each crop in the rotation is present every year enabling a comparison of the response of all crop types within the same season. The soil is a sandy loam with a soil organic matter content of 9.3 ± 0.4% at pH 6 (loss on ignition). The long-term annual rainfall is 843 mm and average daily temperature 8°C (1961-2020).

The influence of soil pH on crop yield over 60 years illustrates the differences between crops in the tolerance of both acidity and alkalinity with maximum median yields at pH 5, 5.5 and 6 for spring oats, spring barley and winter wheat respectively. In terms of soil health, microbial biomass and respiration both peaked at 6.5 and earthworm numbers were adversely affected at low pH. We are also building a database of information on the impact of pH on nematodes and mesofauna and DNA profiling of the microbiomes are underway. The available dataset affords us the ability to zoom in to the soil microbiome and zoom out to the systems level impacts of manipulating pH at field and farm scale.

This research has been supported by the Scottish Government RESAS Strategic Research Programme and AHDB Soil Biology and Soil Health programme.
Evaluation and acceptance of heterogeneous wheat populations in organic value chains – Agronomic performance and baking quality results from the first experimental season 2020/2021

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Introduction
Increasing climate unpredictability highlights the need and importance of innovative agricultural strategies for increased crop diversification for increased agricultural system resilience. As the positive relationships between diversity, stability, and productivity are known, evolutionary breeding methods including heterogeneous populations, are gaining attention. This is particularly relevant for organic farming as the new EU organic regulation, which came into force on 01.01.2022, allows for the cultivation of organic heterogeneous material for all crop species. Heterogeneous wheat populations have indicated better yield stability, as well as comparable yields and leaf disease resistance compared to line varieties (Weedon and Finckh, 2019, 2021). Despite support from science and legislation, the acceptance of heterogeneous wheat populations along the value chain has been limited due to inexperience and low product volume. A major barrier to the establishment of wheat populations is the lack of experience in handling heterogeneous material along the process chain. The overall goal of the BAKWERT project is to further develop and disseminate this innovative agroecological breeding approach by establishing and exploring regional organic value chains for heterogeneous winter wheat populations in collaboration with farmers, millers and bakeries (www.bakwert.de).

Materials and Methods
Two heterogeneous winter wheat populations Brandex and EQuality were tested on-farm in comparison to the pure line variety Aristaro. For the first cropping season (2020/21), ten organic farmers sowed each wheat entry in strips (min. 0.4 ha/entry) within the same field. A number of field assessments were made including leaf disease assessment, soil Nmin at flowering, plant height, as well as biomass cuts for grain yield and yield components (TGW, harvest index, tillers per m², kernels per tiller). In addition, a number of baking quality parameters including protein content, sedimentation value, Hagberg Falling Number, wet gluten content and gluten index were analysed through near-infrared spectroscopy (NIRS) on 9 x 1kg samples per wheat entry and farm (270 samples in total). Additionally, chemical analyses of the abovementioned parameters, as well as baking tests with both whole wheat and refined flour (T550), were completed using 10kg samples per wheat entry and farm (30 samples in total).
Results and Discussion

The most common pathogens found across all sites were Drechslera tritici-repentis and Septoria sp. followed by yellow rust (Puccinia striiformis). In general, disease pressure was low across all sites, with the Brandex population (mean 8%) indicating significantly lower disease pressure compared to Aristaro (mean 11%) and EQuality (mean 12%) (F2=25.06, p-value= < 0.001). Grain yields ranged from 4.4t/ha in Aristaro to 4.6t/ha in EQuality, with no significant differences found between the three entries (F2=5.73, p-value=0.06). However, mean grain yield between the 10 farms was significant and ranged from 1.1t/ha to 6.2t/ha. The population EQuality achieved the highest yields in 7 of the 10 environments, followed by Aristaro (2 environments) and Brandex. Protein content values (%) ranged from between 10.4% in EQuality to 11.4% in Aristaro, and were generally considered poor. However, wet gluten content was found to be moderate to good and ranged from between 25% (EQuality) to 28% (Aristaro). Further baking quality, as well as yield and protein grain stability results will be presented at the conference.

Reference:


Session 2
Orals
Towards Pesticide-Free Agriculture
Ecological redesign for pesticide-free crop production

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Integrated Pest Management (IPM) is not being implemented as originally framed: With preventative crop protection provided by biodiversity and management of the landscape and the cropping ecosystem at its base, and with and chemical pesticides and other curative actions applied only as very last resort. Instead, the design and ecology of major global crop production systems leads to a heavy reliance on chemical pesticides to maintain yields and mitigate losses to weeds, pests and pathogens. There is, however, a decline in functioning pesticides available for use. Drastically reduced use of chemical pesticides is demanded by societies, such as aim for in the European Green Deal. Technological innovation will be needed to maintain yields without pesticides, but more efficient and precise technology cannot alone sufficiently reduce pre-harvest losses to pests. Maintaining crop yields will require redesigning our cropping systems. Taking pesticides out of the equation with maintained and improved crop protection, requires us to strengthen preventative biotic pest regulation services provided by enhanced wild beneficial biodiversity and diversified cropping, and to employ new cultivation practices. New technologies and genetic material will be needed in support of these cropping systems. A transition is likely to require transformations of the geography of agriculture and food infrastructure, processing and distribution well beyond the individual farm. There is scope to build more resource use efficient, resilient and multifunctional ecologies in pesticide-free cropping systems. I outline strategies and principles of redesign for strengthened crop health with examples. A broadening of the knowledge base will be required as we redesign and rethink how to grow our food and shape the agricultural landscape based on ecological principles.

Short Biography

Riccardo Bommarco is Professor of agricultural entomology at the Swedish University of Agricultural Sciences, Sweden. His research interests concern insect and plant ecology in Agricultural landscapes, and how it affects crop protection, pollination and yield of agricultural crops. Together with researchers, farmers and stakeholders, he co-designs sustainable Climate-resilient cropping systems that build on ecosystem services provided by wild and managed biodiversity. Find out more here about the research team he leads www.slu.se/bommarco-lab/
**Undersown clovers in oats promote pollinators and suppress arable weeds without reducing yields**

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Sustainable crop production requires agriculture to conserve biodiversity, facilitate ecosystem services and maintain productivity levels while reducing inputs harmful to ecosystem functioning. Increasing vegetation diversity within the field by intercropping with legumes seems promising to facilitate cropping system multi-functionality, but the effects on ecosystem services are so far not sufficiently understood. Using 26 semi-field plots in a paired design, we studied the effects of intercropping oats with a mixture of three annual undersown clovers on cropping system multi-functionality. Investigated responses covered both below- and above-ground factors and included soil nitrogen, arable weed control, pollinators, plant health, natural pest control and crop yield. We found lower arable weed cover and marginally lower arable weed biomass and higher flower cover and pollinator densities as well as decreased root feeding nematode densities in intercropped plots compared to the control. However, intercropping decreased spider activity densities and oat yield nitrogen content. Soil borne plant diseases, pest damages, natural pest control or crop yields were not affected by intercropping. The biomass of undersown clovers was positively correlated with flower cover, pollinator densities and an increase in soil mineral nitrogen and negatively correlated with arable weed cover. We demonstrate that undersowing annual clovers is a simple and comparably cheap method to suppress arable weeds and support pollinators without sacrificing cereal crop yields or taking land out of arable production. Intercropped plant mixtures should, however, be optimised to support a wider spectrum of pollinators and benefit natural pest control in order to support a higher level of overall cropping system multi-functionality.
Tracking ideal varieties and cropping techniques for agroecological weed management: a simulation-based study on pea

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Pea (Pisum sativum L.) is a key diversification crop but current varieties are not very competitive against weeds. The objective of this study was to identify, depending on the type of cropping system and weed flora, (1) the key pea parameters that drive crop production, weed control and weed contribution to biodiversity, (2) optimal combinations of pea-parameter values and crop-management techniques to maximise these goals. For this, virtual experiments were run, using FLORSYS, a mechanistic simulation model (Colbach et al., 2021, Field Crops Res 261:108006). This individual-based 3D model simulates daily crop-weed seed and plant dynamics over the years, from the cropping system and pedoclimate. Here, this model was parameterized for seven pea varieties (Cameor, China, DCG0449, Enduro, Isard, Kayanne, 886/1), from literature and experiments. The latter focused on potential plant morphology and shading response. Differences between varieties depended on the analysed parameter, e.g., varieties were very similar in terms of leaf biomass ratio (LBR, leaf biomass divided by above-ground plant biomass) whereas specific leaf area (SLA, ratio of total leaf area divided by total leaf biomass) at early stages was lower for the two tested spring varieties (Cameor and Kayanne) than for the five winter varieties (except Isard). Then, ten virtual varieties were created by randomly combining variety-parameter values according to a Latin Hypercube Sampling (LHS) plan, respecting parameter ranges and correlations observed in the actual varieties. A global sensitivity analysis was run, using another LHS plan to combine pea varieties, crop rotations and management techniques in nine contrasting situations (e.g., conventional vs organic, no-till, type of weed flora). Simulated data were analysed with classification and regression trees (CART). We highlighted (1) Parameters that drive potential (weed-free) yield and competitiveness against weeds, depending on variety type (spring vs. winter) and cropping system. These are pointers for breeding varieties to regulate weeds by biological interactions; (2) Rules to guide farmers to choose the best pea variety, depending on the production goal and the cropping system; (3) The trade-off between increasing yield potential and minimizing yield losses due to weeds when choosing pea variety and management, especially in winter peas. In short, any parameter values that delayed and/or reduced crop emergence decreased potential yield and increased yield loss due to weeds. Conversely, parameter values that increased crop canopy volume (e.g., large LBR during reproduction stages) and crop growth duration (e.g., delayed flowering onset) had the opposite effect. Shading response was crucial: the more pea varieties increased plant height and leaf biomass per unit biomass when shaded, the better they controlled weeds. These main rules describing pea ideotypes were the same for all performance goals, management strategies and analyses scales. But the key parameters depended on variety type and aims. For instance, parameters driving germination and pre-emergent growth were crucial for
reducing yield loss in winter pea but not in spring pea or for potential yield. Some variety features only fitted to particular systems, e.g., parameters delaying pea emergence were only beneficial in case of herbicide-spraying and disastrous in unsprayed systems.

The more the grown variety differed from the weed-controlling ideotype, the more management rules were needed to compensate. Conversely, if one of the two main weed-control levers, herbicide or tillage, was missing from the cropping system, the choice of the pea-variety and/or of other management levers became more important. We are now applying this methodology to identify ideal trait combinations for wheat-peaintercrops.

Funding
INRAE, ANR PeaMUST (ANR-11-BTBR-0002), EU Horizon 2020 (N 727217 ReMIX), French Ministry of Agriculture and Food (CADAR RAID).
Crop rotation diversity compensates for climate-induced yield losses across Europe and North America

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Keywords: Climate adaptation, crop rotations, crop diversification, long-term experiments

Climate change is globally jeopardizing crop production. We need to adapt cropping systems to increasingly warm conditions and uncertain precipitation patterns to provide sufficient and stable food production. Diversifying crop rotations has been proposed as a promoter of ecosystem services that increase yields and self-sufficiency of cropping systems, and that can provide resistance of crop yields to climate-induced disturbances. Yet, it is unclear how crop rotation diversity relates to crop yields, and how the relationship changes under varying climatic conditions. We need to understand how much diversity is needed to buffer negative effects of temperature and precipitation and maximize yield output. We collected data from 32 long-term (10 to 63 yrs) experiments across Europe and North America, including rotations of different diversity. We assessed how the yield related to crop rotation diversity as growing season climatic conditions deviated from the local long-term average, with maize and small grain cereals as indicator crops.

For all indicator crops, increasing crop rotation diversity benefitted yields through non-linear interactions, increasing from monocultures up to an intermediate diversity, and decreasing at even higher levels. The intermediate yield maximum diversity depended on indicator crops and temperature and precipitation anomalies, with four-crop four-year rotations providing the highest outcome in most cases. For spring-sown small grain cereals, five-crop five-years rotations maximized yields under warm anomalies in dry conditions, while about four-crops three-years rotations maximized winter-sown small grain cereal yields under such conditions. Therefore, crop rotations can be tailored to maximize small grain cereal yields, depending on climatic conditions and indicator crop.

The magnitude of yield increase from monoculture to yield maximum diversity was independent of temperature and precipitation anomalies for spring-sown small grain cereals and maize. For winter-sown small grain cereals, yields responded more positively to decreasing temperature anomaly at intermediate to high crop rotation diversity in dry and warm anomalies compared with monocultures. By adding crops in rotations to monocultures, farmers can thus compensate crop yield losses from adverse growing conditions under increasing temperatures and anomalous wet or dry conditions. Moreover, winter-sown small grain cereals can benefit more from cooling temperatures if included within a minimum diversity of four-crop four-years rotations. Our findings suggest that adjusting crop rotation diversity is a promising climate adaptation practice, capable of reducing yield losses of various cereals caused by warming and anomalous wet or dry conditions, and increasing yields in less detrimental conditions.
Performances of pesticide-free agroecological cropping systems: the CA-SYS platform

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Meeting the challenges of current agriculture requires the development of innovative cropping systems with high environmental, economic and social performances. Agroecology seeks to optimize the services provided by cultivated and wild biodiversity to reduce the reliance on external inputs while maintaining/increasing cropping system sustainability. Maximizing the delivery of ecosystem services from biodiversity requires an in-depth redesign of production systems considering in-field management as well as ecological infrastructures surrounding the fields. An agroecological system experiment aims to design and assess cropping systems, the spatio-temporal arrangements of these cropping systems and ecological infrastructures at the farm level (Petit et al., 2021).

Located on the INRAE Domaine d’Epoisses experimental farm (Bretenière, France), the CA-SYS platform is a collaborative research platform experimenting agroecology. Since 2018, an agroecological system experiment has been implemented on 125ha, and tests pesticide-free agroecological systems comprising four cropping systems and a high density of ecological infrastructures (Petit et al., 2021). The pesticide-free constraint is as well an objective to enhance the beneficial organisms involved in the biological regulation of pests and improve the environmental performance of the systems. The four cropping systems represent two main agricultural strategies that may foster biotic interactions: 1) two tillage-based systems (occasional ploughing, false seedbed, mechanical weeding); 2) two conservation tillage/agriculture systems (i.e. rotational/permanent no-till). These two options require mobilizing crop and cover crop diversity in time (at the scale of the crop succession) and space (e.g. mixture of crop species and/or varieties, companion crop). Legume crops play an important role in contributing to pest management (diversification of crop species and sowing dates) and in reducing N fertilizer. Other agroecological practices are combined in the cropping systems to have robust and competitive crops (e.g. choice of resistant cultivar, delayed sowing date, increased sowing density). The implementation of agroecological principles started in summer 2018 with the objective to reach similar profitability and productivity than in neighbouring conventional farmers at a 10-year horizon. Data are collected on a yearly basis to assess crop performances through agronomic diagnosis, systems performances through a multi-criteria assessment, and the ecological transition through a temporal analysis of ecological indicators.

After three years of experiment, the performances of the four cropping systems were assessed with the MASC 2.0 multi-criteria assessment method (Craheix et al., 2012). The cropping
systems have intermediate to high environmental performances (high air and water quality, biodiversity conservation, intermediate energy consumption, intermediate to low energetic efficiency) and intermediate social performances (high farmer’s working conditions but low supply in raw material). However, the cropping systems have low economic performances (low productivity and profitability). Yield losses due to difficulties to manage pest pressures (e.g. diseases on protein crops, insects on oilseed rape; slug and vole damages and weeds in no-till systems) partly explain the low economic profitability, despite the low input costs. Low profitability is also partly due to several crops, used to diversify crop rotations, but with low productivity and poorly valued in the current sectors.

The difficulties in the management of some of these innovative agroecological cropping systems and their unsatisfactory performances have prompted some adjustment of farming practices. Further multicriteria assessment, i.e. at the end of the crop succession, will be necessary to analyse the impact of these adjustments. In addition, we expect in the coming years that the ecological infrastructures implemented in 2018 will increase beneficial organisms to improve pest management in the pesticide-free context of the platform. Methodological developments are needed to assess the whole agroecological system, including the ecological infrastructures.

Reference:

https://doi.org/10.1007/s10661-020-08812-2
Craheix, et al. 2012. Innovations Agronomiques. 20, 35 - 48. hal-02265455
Environmental and economic risks of the mechanical, mechanical-chemical and chemical weeding in sugar beet

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The use of herbicides in agricultural plant production is widely criticized because of its high aquatic and terrestrial toxicological risks. To reduce the herbicide application in future, EU is going to promote the use of mechanical weed control techniques. However, the environmental impacts of mechanical weeding have not been studied yet. Therefore, the objectives of EvaHerb project were to evaluate the environmental and economic risks of mechanical, chemical and mechanical-chemical weed control in sugar beet. The environmental risks under study included runoff and erosion risks, risk for losses of earthworms and epigeic arthropods (Carabidae, Staphylinidae, Araneae) and the risk of increased greenhouse gas emissions. Further the weed control efficiency, yield and quality as well as costs, man-hours and resources consumption were assessed.

Field trials were carried out at 5 sugar beet fields in 2019-2021 in Southern Lower Saxony near Göttingen for all studied risks and additionally 2 fields in Braunschweig 2020-2021 only for epigaeic arthropod assessment. At each study site, three weed control methods were tested in 4 replicates using a completely randomized block design. The weed control treatments were (1) machine hoeing with duckfoot shares between rows and in-row hoeing by hand (hoeing); (2) machine hoeing with duckfoot shares between rows and in-row herbicide band spraying (hoeing-spraying); (3) broadcast herbicide application (spraying). Rainfall simulations were carried out on small 2mx1m subplots to determine the amount of cumulative runoff and cumulative soil loss for a given storm event under hoeing and spraying weed control. Earthworm abundance was determined in October on 4 small 50cm x 50cm subplots using a formalin method. Epigaeic Arthropod populations were assessed with photoeclectors, pitfall traps and insect suction sampler. Additionally predation performance was assessed with caterpillar dummies and aphid cards. The man-hours, costs and resource consumption for each method were assessed using the Web-tool of Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL), whereas CO2 eq. emissions were calculated from consumption of diesel and herbicides using Biograce (Version 4d).

Hoeing of a crusted soil reduced significantly the runoff volume and soil loss due to an increase in infiltration. Hoeing in a non-crusted soil did not affect runoff or erosion. The earthworm abundance was in most study sites not affected by weeding strategy. The abundance of epigaeic arthropods and the predation performance did not differ at most sites in most years. The energy consumption and greenhouse gas emission of mechanical weed control depended greatly on its intensity, thus 3x machine-hoe + 2x hand-hoe produced 44 % more and 1x Harrow+2x machine-hoe+1x hand-hoe produced 1.5 % less CO2 compared to 3x spraying.

The combined hoeing-spraying treatment with 3x (band + machine-hoe) has the highest energy consumption, producing 3% more CO2 as compared to the 3x machine-hoe + 2x hand-
hoe. The mechanical weeding (3x machine-hoe + 2x hand-hoe) is 6 time as expensive and 170 time as time-consuming as the conventional chemical weeding (3x spraying). The combined hoeing-spraying weeding has the lowest cost but an intermediate time efficiency between mechanical and chemical weeding.
NatApp 2.0- a digital tool to improve biodiversity in agricultural landscapes

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The negative effects of intensified and one-sided production, associated with the reduction of agricultural landscapes, are putting agricultural environments under high pressure. To not only protect the significantly decreasing biodiversity but also ensure the long-term usability and efficiency of agricultural production systems, nature conservation measures are the main instruments to retain and improve the ecological and productive status of agricultural used landscapes (Lestan et al. 2016; Meyer et al. 2013). They are implemented in the first and second pillar of the European Common Agricultural Policy (CAP). Especially, the region-specific and small-scale, field-integrated designed agri-environmental climate measures (AECM), implemented in the second pillar, have demonstrated high efficiency of biodiversity protection (Redwitz et al. 2019). In addition, they only have marginal effects on the productivity and yield of the respective fields or grasslands (Science for Environment Policy 2017). But currently, several considerable obstacles against the implementation of these nature protection measures in agriculture still exist. These are fear of sanctions and economic losses on the farmers’ side and personnel-demanding and time-consuming procedures on the part of the responsible administration (Long et al. 2016; Sattler und Nagel 2010). The pivotal challenge is to facilitate and better organise the implementation of AECM.

Digital tools can offer a valuable assistance to mitigate these barriers and limitations. Nowadays, they play a crucial role in establishing more progressive and elaborate structures for farmers and simplify the management of farms. Furthermore, they enable a much easier data transfer between different actors (Walter et al. 2017). Ideally, the technical options and advantages of digital tools can be used to facilitate a shift to a broader implementation of AECM and simplify as well as enhance the transparency of the underlying processes (Bacco et al. 2019).

The aim of this study is to consider, to which extent a specifically designed app, like the NatApp, can help to facilitate the current structures and even increase the participation in AECM. Which features are necessary for such an app and in which way must these features differ from the present state of the art?

To get an overview of the already provided digital tools an extensive literature review on published concepts regarding digital solutions in the range of nature conservation, sustainable and environmentally friendly agriculture is conducted. On this basis, the attributes and scientific status of the NatApp can be discussed and compared. This includes its advantages and disadvantages, its constraints and applied character. The comparison helps to evaluate to which extent the today’s NatApp can assist farmers with their current barriers and simplify
implementing AECM. Which role can the NatApp play in the contribution to a more sustainable agriculture? How can the NatApp be classified within the EU politics?

To analyse the acceptance of the NatApp among the farmers, a mixed methods study, including three different methods, is carried out. One category are quantitative online questionnaires, another category are qualitative face-to-face interviews and the third category will be an interactive workshop. Each of the methods reveals different results and conclusions of the requirements, expectations and concerns farmers have with regard to the daily use of an app.

The results so far show, that no such digital tool like the NatApp with the focus on AECM exists. Nevertheless, one challenge of the NatApp will be to keep up with the latest technical developments and policy reforms in agriculture (CAP 2023). Concerning the acceptance, the preliminary findings show that farmers are predominantly open to give the NatApp a try. Concerns arise mainly in the field of data safety, additional effort and no benefit towards a number of already existing farm management tools.
Weeds impact on yield is variable: an 8-year study on contrasted low-input maize-based cropping systems

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Irrigated Maize-Based Cropping Systems (IMBCS) are questioned for their negative impacts on the environment, particularly due to high use of herbicide since weed is a major threat for maize production. To improve the sustainability of IMBCS, a CS redesign with a reduced use of external inputs and herbicide is promoted to consider on the long term the interactions between crop rotation, tillage, cover crops, weeding... Because of the reduced use of inputs, redesign can lead to variable yield reduction but, in a redesigned IMBCS it is difficult to understand to which extent the yield reduction is due to higher weed infestation, particularly for the reduced tillage CS.

Seven redesigned IMBCS were conducted for an 8-year period on a cropping system experiment (Toulouse, France – see Giuliano et al., 2021 for more details on the experiment) and compared for their use of herbicide, yields and weed biomass at maize flowering to estimate the influence of weeds on maize yield. A Conventional Maize Monoculture (MMConv) was compared with:

- four CS that consisted in strong tillage reduction and cover crop introduction: MMCT (a direct sowing MM + Faba bean based cover crop), MMCTOM (a direct sowing MM + Faba bean cover crop and a massive compost spreading (100 t ha⁻¹) in 2014 and 2015), MMStill (strip tillage with a Vicia faba and Avena strigosa based cover crop) and MMStillPC (strip tillage with a perennial leguminous permanent cover crop).
- two CS implementing Integrated Weed Management (IWM) techniques consisted in strong herbicide and cover crop introduction MMLI (a ploughed IWM MM with Lolium hybridum and Trifolium incarnatum cover crop and mechanical weeding) and Maize-MSW (a maize managed similarly as MMLI rotated with soybean and winter wheat).
- In these CS, irrigation and Nitrogen (N) fertilization were also reduced.

MMConv had a 10.5 t ha⁻¹ yield but grouped together with MMCTOM (10.1 t ha⁻¹), MMLI (10.0 t ha⁻¹), MMStill (9.7 t ha⁻¹) and Maize-MSW (9.6 t ha⁻¹). MMStillVeg showed significant yield reduction (8.1 t ha⁻¹) as well as MMCT (5.8 t ha⁻¹) (p < 0.05). MMLI obtained a similar weed biomass at flowering (32 g MS m⁻²) than MMConv (23 g MS m⁻²) despite a 60% reduced herbicide use. Weed biomass on MMCT was significatively higher with 227 g MS m⁻² (p < 0.05) while that CS used more herbicide than MMConv. However, the four other CS had an intermediate but significantly higher weed biomass than MMConv ranging from 59 g MS m⁻² (Maize-MSW) to 100 g MS m⁻² (MMCTOM and MMStill).

The level of weed infestation impact differently maize yield in function of the CS (fig. 1). For MMConv and MMCTOM, no correlation was observed between weed biomass at flowering
and maize yield \( (p = 0.50 \text{ and } 0.69 \text{ respectively}) \). The Potential Maize Yield with no Weed infestation (PNY0W) of those two CS was similar to the mean yield obtain during the 8-year period (MMConv: 10.9 t ha\(^{-1}\) and MMCTOM: 10.0 t ha\(^{-1}\)). However, negative correlations were found for the other alternative CS with \( R^2 \) ranging from 0.2 (MMLI) to 0.4 (MMStill and MMCT) \( (p < 0.05) \) (fig. 1). MMCT exhibited the strongest impact of weeds on yield (PNY0W = 14 t ha\(^{-1}\), observed yield = 5.8 t ha\(^{-1}\)).

In IMBCS where N-fertilization, herbicide or tillage were reduced, maize yield negatively correlated with weed biomass. It was not the case in MMConv and MMCTOM where it can be hypothesized that a higher resource availability due to, respectively, higher mineral N fertilization and compost spreading, limited the negative impact of weeds, which was not the case on other CS that had less N available in soil.
Combining organic fertilisation and perennials in crop rotations boosts communities below- and aboveground

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Key words: Agricultural diversification, above- and belowground, biological pest control, Bottom-up

Diversification is promoting multiple ecosystem services important to crop production by strengthening biological communities in agroecosystems. Local within-field diversification practices include, among others, the addition of organic materials to the soil and diverse crop rotations. Both are linked to benefitting belowground communities by providing habitat structure and complexity as well as food resources for soil organisms. Enhanced abundances of soil organisms can have benefits for pest control services, by strengthening aboveground arthropod predator communities through the provision of alternative food resources. This bottom-up effect of belowground available prey on aboveground arthropod predators has, however, so far only been studied in small-scale experimental settings. Additionally, the effect of combined diversification practices on above- and belowground communities and their linkages remains unclear.

We conducted large-scale field experiments across 19 sites planted with conventional spring cereals in southern Sweden. Diversification treatments included fields that solely received mineral fertilizer rotated with annual crops (FminRa), fields treated with organic fertilizers rotated with annual crops (ForgRa) and fields that were treated with organic fertilizer where crop rotation included 3 years of perennial leys (ForgRl). Fields rotated with ley, had 3 consecutive years of ley in the crop rotation, but were at least 2 years without ley before sampling in order to capture longer term effects and avoid immediate pre-crop effects. All treatments had been implemented for at least 6 years. We sampled communities of soil macrofauna and aboveground arthropod predators across 3 crop development stages: tillering, heading and early ripening of the crop to capture seasonal changes in communities. Soil communities responded more strongly to the treatments than above ground predator communities. The soil macrofauna consistently increased in abundances with adding organic materials and crop rotations including perennial ley whereas predator communities were enhanced in abundances and diversity only under the combined treatment of organic fertilizers and crop rotations including perennial leys.

Diversification practices that enhance soil community abundance might enhance regulation of insect herbivores where the soil community provide alternative prey to the predators. Aboveground arthropod predators are efficient pest control agents especially during the early colonization of herbivores which might reduce the need to use of pesticides.
Characterisation and impacts of weed flora on maize crop in different organic cropping systems

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Concerns about climate change and environmental degradation are raising and gaining concerns in Europe and the rest of the world. In this context, the European Union has introduced the “Green Deal’s Farm to Fork strategy”, with the aim to produce high quality food while reducing environmental impacts. One of its main objectives is to increase the proportion of farmlands managed under organic farming, by reaching 25% by 2030. However, management of weeds should be considered as one of the most challenging issues in organic agriculture. Indeed, the chemical control lever is prohibited and the control of weed flora must solved by using a multitude of action levers. Indeed, cropping system (CS) management plays an essential role in weed control, influencing the weed community through planted seed density, the use of cover crops or intercropping, the temporal succession of crops (crop rotation), reduced used of fertilizer, mechanical weeding, etc (Colbach & Cordeau 2018; Adeux et al. 2019).

Since autumn 2018, a long-term organic farming experiment was launched where three different cropping systems are being tested within the experimental farm of the Walloon Agricultural Research Centre (CRA-W), Belgium. Within the first cropping system (CS1), soil is managed using conventional tillage (ploughing) and crop is fertilized using solely commercial exogenous organic fertilizer. The second cropping system (CS2) is managed with the use of conventional tillage but no external organic fertilizer is applied. Finally, the last cropping system (CS3) is managed without ploughing and without any fertilization involving external commercial organic fertilizer. For the management of their fertility, CS2 and CS3 rely on the introduction of more leguminous plants to increase atmospheric nitrogen fixation and on the establishment of associated crops in order to limit the development of weeds. In this project, the tested hypotheses are that (i) different CS would induce different weed communities and (ii) these communities would not have the same impacts on crops yields. To test these hypotheses different measurements have been performed. Weed community were collected in 2021 within maize crop, the crop cultivated commonly across the different CS. Weed density per species were determined at different moment of the cropping season. Furthermore, weeds and maize aboveground biomass were measured at the beginning of flowering stage of maize. Weeds diversity indices (Shannon diversity index, Species richness, Simpson’s Diversity Index...) were calculated. After only two years of management, a specific weed community seems to have developed within the CS3 (without tillage), as compared to the two other CS; it exhibited a greater Shannon diversity index. This weed community is characterized by more graminaceous species and a greater graminaceous biomass. At the same time, we observed the lower maize biomass within the CS3 compared to the other cropping systems.
Maize yields were two times lower within CS3 compared to CS1. Although a negative correlation was observed between the biomass of grasses and maize biomass, further analyses should be conducted to try dissociating the effects of the cropping system from the negative effects of the greater weed biomass. These results represent only the first year of collected data within this long-term experiment. In the future, these findings must be confirmed, but they suggest a strong importance of cropping practices and rotations on weed flora with potentially different effect on crop yield.
Does pesticide-free agriculture work? Evidence from the NOcsPS-field experiment in Brandenburg, Germany

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There is an increasing societal and political wish to reduce the intensity of chemical-synthetic plant protection (csPP). The EU’s “Farm-to-Fork strategy” aims at reducing the amount and risk of csPP by 50% by 2030. At the same time, global demand for agricultural products is increasing while the available arable land is estimated to shrink by 0.25% per year in the upcoming decades. To meet these different expectations, the NOcsPS (LAnnderwirtschaft 4.0 Ohne chemisch-synthetischen PflanzenSchutz) project develops and tests a mineral-ecological cropping system (MECS) using demand driven mineral fertilization (mF) while foregoing the use of csPP.

A field experiment with six components, including wheat and rye, was established at the Dahnsdorf experimental field in Southwest Brandenburg in 2019. Four experiment treatments are tested: conventional (CONV) and ecological (ECO) cropping as reference systems as well as MECS1 and MECS2 (reduced seed rate sown by single grain seeder). This study focuses on three out-of-six components of the crop rotation, i.e., winter wheat 1, which uses a cultivar with high resistance level (Achim), winter wheat 2, which uses the high yielding cultivar ‘RGT Reform’, and rye, using the cultivar “KWS Binnito”. Due to lower yield expectations, the two MECS-variants received 30% less mineral fertilizer compared to CONV. Among others we assessed (i) yield and its components, (ii) incidence and severity of fungal diseases, (iii) weed abundance, (iv) leaf area development and micro-climatic-parameters.

With regard to yield, the two MECSs performed inferior compared to CONV, but superior to ECO in rye and both wheat crops, both in the first and second season. Looking at the yield components we see that the yield differences between the cropping systems can be explained by the difference in the number of ears per m² (NE) in both wheats and rye. Further, in both wheat cultivars the weight per ear (WE) is also higher in CONV vs. MECS vs. ECO, whereas in rye there are only differences between ECO and the three minerally fertilized systems. Overall, higher yields were observed in 2020 compared to 2021, which can largely be explained by higher thousand kernel mass in 2020 in all four cropping systems except ECO. This also explains the smaller yield gap between ECO and both MECSs in 2021. The differences in yield, NE and WE are also reflected in the leaf area index (LAI) and above ground biomass development which itself are strongly influenced by the amount of available N. Furthermore, there is evidence that the lower sowing density in MECS2 led to a lower N uptake, which resulted in a stronger Nmin accumulation in the soil compared to the other systems. Further, the reduced sowing density in MECS2 led to a higher weed biomass. The abundant weed may...
also partly explain the higher severity in brown rust infestation in rye, as more weeds might have altered the micro-climate towards favorable conditions for fungal diseases. In wheat septoria tritici blotch was higher in 2021, but on a low level. Here, ECO showed the highest severity with “Achim” being less susceptible.

We conclude, that a MECS is actually an option as a new cropping system that breaks the dichotomy of conventional vs. ecological agriculture when crop management handles weeds by using a sufficiently high sowing density as well as selecting cultivars resistant to locally important fungal diseases.
Winter oilseed rape (Brassica napus L.) intercropping potential to reduce the impact of insect pest cohort

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Winter oilseed rape (WOSR – Brassica napus) is recognized as high quality oil in food processing, as a biofuel, and as animal feed in the form of oilcake. Moreover, it is of great agronomic interest in crop rotations. Besides the increase of its cultivated area globally, WOSR is one of the most pesticides and fertilizers dependent crop, making it a challenging but promising candidate for the transition toward a sustainable agricultural production. Typically sown in late summer and growing throughout winter and spring, it allows for interesting cultural practices such as intercropping with frost-sensitive companion plants.

Over the last years, mixed cropping systems involving oilseed rape and legumes drawn the interest of many researches. Indeed this practice may reduce the need of fertilization and weed protection, while allowing a yield increase in WOSR. Moreover, recent studies brought evidences of pest protection potential for this practice.

Here we present promising results of the intercropping system with faba beans on rapeseed pest cohort from a field trial. In addition, the first outcomes of a glasshouse investigation on the underlying mechanisms in crop protection will be exposed.

During winter 2019-20, B. napus was grown alone (i.e., Control) or intercropped with a mixture of faba bean Vicia faba L. and grass pea Lathyrus sativus L. (Fabales; Fabaceae); because of the unusually clement weather conditions, the faba bean did not freeze which allowed evaluating the impact of this companion plants on the insect pest complex.

Insect damage by the beetles Psylliodes chrysocephala, Ceutorhynchus napi, and Brassicogethes aeneus was assessed in both treatments. The larval density of P. chrysocephala was significantly lower in the crop grown with service plants. Egg laying and damage by C. napi were significantly reduced as B. napus was intercropped and the number of B. aeneus captured significantly lower in presence of service plants compared to the control. Furthermore, yield from oilseed rape was significantly higher in the part of the field with service plants than from the pure crop control.

The underpinning mechanisms are only partly understood, but intercropping winter oilseed rape with frost-resistant service plants seems to be an ecologically sound practice with very high potential to reduce insect pest pressure and secure crop yield. To bridge this knowledge gap a trial in semi-controlled conditions was designed. It is a first step to test the effect of visual and olfactory confusion of intercropping, to evaluate the impact of the companion plant on individual plant traits and to characterize the microclimate of such cultural practice. A glass house experiment was set up to evaluate the effect of companion plant on plant trait.
relative to insect resistance and xenobiosis. WOSR was grown in containers in three rows of three plants with (intercropping) or without (control) the addition of three rows of winter faba beans. Plant phenotypical traits such as stem elongation and diameter were monitored, WOSR total and specific glucosinolates were measured at different vulnerable stages. Microclimate parameters (temperature, humidity and light) and canopy reflectance were characterized for both plant populations.

With the current study, we aim at disentangling the impact of intercropping on both the insect pest complex and WOSR to eventually support the implementation of sustainable practices supporting both the yield and the environment.

Key words: Pollen beetle, cabbage stem flea beetle, rape stem weevil, integrated pest management.
Deciphering field-based evidences for crop allelopathy in weed regulation

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It is now essential to reduce the negative impacts of weed management and especially herbicide use. Weed-suppressive crop species/varieties hold promise for integrated and sustainable weed regulation. Competition for resources and allelopathy are the two main underlying mechanisms. Unlike competition, which is well studied and established, allelopathy by living crops remains a contentious mechanism. Although it is recognized that plants emit a large number of substances, the effective role of these molecules is very challenging to demonstrate in the field. A major difficulty to dissociate the effects of allelopathy from those of competition for resources.

Here we systematically and quantitatively review the literature, searching for field-based evidence of the role of allelopathy (by root exudation of living crops) in weed regulation, independently of competition. A focus is made on studies comparing different varieties of a given species, in order to help disentangling the effects of allelopathy from those of competition. Our critical literature analysis also aims to identify weaknesses and strengths in methodology, providing insights on optimal experimental designs and avenues for future research.

Our analysis shows that, in most articles, the role of crop competition is disregarded or not exhaustively studied. Consequently, contrary to authors’ conclusions, it cannot be determined whether weed regulation is due to allelopathy and/or competition. Overall, only 25 articles studied the differential effects of crop varieties on weed pressure in the field, explicitly considering allelopathy and competition. Among them, 13 articles considered that both allelopathy and competition explained varietal differences in weed regulation in the field, and five articles identified allelopathy as the only explicative mechanism.

In order to assess an effective role of allelopathy, we conducted a detailed analysis of these 18 articles reporting an effect of allelopathy (alone or combined with competition). We combined a qualitative (relevance of experimental designs and protocols) and quantitative approach (range of variation of the measured variables, correlation analysis). Among these articles, only seven could provide convincing field-based evidence of allelopathy. The most convincing evidence was provided when combining several methods (field measurements on weeds and crop varieties and assessment of allelopathic potential in field or laboratory, linked by a multiple regression), when results are consistent. However, although these seven articles were convincing, we discussed some methodological weaknesses.
To further investigate allelopathy in the field we recommend to (i) finely characterize crop competition by measuring traits in the field, (ii) assess crop allelopathic potential with Complementary experiments in controlled conditions or by quantifying allelochemicals in the field, and (iii) quantify the contribution of each studied trait/mechanism in explaining weed regulation in the field with multiple regression models. The consistent use of the suggested guidelines, as well as alternative approaches (e.g. creation of varieties with altered allelopathic compounds production, development of process-based simulation models) may provide a basis for quantifying the role of allelopathy in the field and, subsequently, for designing weed management strategies promoting weed biological regulation.

Funding: INRAE, COPRAA project (which was supported by OFB as part of the Ecophyto call launched by the French Ministries in charge of Ecology, Agriculture, Health and Research) and Partnership Hubert Curien (PHC) – Germaine de Staël

Reference:

Weed diversity mitigates yield losses of organic spring wheat (Triticum aestivum L.) through complementary effects in plant nutrition and water supply

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Keywords: biodiversity-yield relationship, intercropping, agriculture, land sharing

As crop competitors, weeds are known to reduce crop yield. However, weed control with herbicides and/or tillage is associated with far-reaching negative consequences for the field, such as habitat loss for a wide variety of species. Promoting diversity of weeds in the field represents an opportunity for biodiversity conservation that has received as yet little attention. In addition, high weed diversity may also have positive effects on yield parameters through complementarity interactions among plants. In an experiment with spring wheat (Triticum aestivum L.) in the Vogtland region of Saxony, Germany, we tested how weed diversity affects various yield parameters, as well as nitrogen and sulfur plant nutrition. For this purpose, spring wheat was cultivated under organic farming conditions, on a total of 100 study plots in monocultures, with manual weed control, and polycultures, without any weed control. Additionally, respectively 1, 3, 6 or 12 common weed species were sown in the polycultures, in order to achieve a gradient of biodiversity. Wheat biomass and nitrogen and sulfur nutrition were determined at milk stage of maturity, as well as yield parameters, such as dry raw yield, fresh raw yield, and dry grain yield. Furthermore, weed diversity was measured, using different biodiversity indices, such as species richness, Shannon diversity index, 1-Simpson concentration index, inverse Simpson index and weed evenness, which was calculated based on vegetation surveys and weed biomass determination. As a result, we found that weed diversity increased with increasing number of sown species. Furthermore, there was little crop loss in the polycultures compared to the monocultures. Regarding grain yield losses (comparison with monocultures), the biodiversity level with one additionally sown weed species, showed a clearly higher mean yield loss of 18.1%, compared to the level with 12 additionally sown species (8.7%), indicating a positive effect of higher weed diversity. When relating yield parameters to the different biodiversity indices and accounting for other environmental parameters such as solar radiation, we found that, among other biodiversity indices, weed evenness in particular had a significant positive effect on nitrogen and sulfur nutrition. Weed evenness caused a reduction in total weed biomass and thus reduced competition in nutrient uptake. The improved nutritional situation in turn had a positive effect on wheat dry matter yields. Abundance-related biodiversity indices of weed species were significantly positively correlated with different yield parameters (Shannon diversity index with fresh raw and dry grain yield, 1-Simpson concentration index and inverse Simpson index
with dry raw yield and grain yield). At high biodiversity values, yield in selected plots, even exceeded the one in monocultures. Additionally, we found that the weed flora had a positive effect on the water supply of spring wheat. The results of the project imply that positive biodiversity effects can be easily exploited in wheat production. Through an integrative approach, biodiversity can be promoted, without causing high yield losses and fluctuations.
IPMWORKS, a European network of pioneer farmers engaged to demonstrate cost-effective IPM-based strategies with low pesticide use

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INRAE

Keywords: peer-to-peer learning, holistic, Integrated Pest Management, pesticide

Integrated Pest Management (IPM) is based on a diversity of pest management measures (prevention, non-chemical control, best practices for optimizing pesticide efficiency, etc.). These are combined at the farm level to enable reduced reliance on pesticides, and therefore a decrease in the exposure of the environment and people to pesticides. Rare pioneer farmers throughout Europe are testing such IPM strategies and are succeeding in achieving good outcomes with low pesticide inputs. However, the majority of European farmers still rely heavily on pesticides, with major environmental and societal impacts, because most of them have not adopted a comprehensive, farm-level and holistic IPM strategy so far.

IPMWORKS is a network of farms involved in the demonstration of cost-effective IPM-based strategies, launched in 2020 within the H2020 European program. The objective of IPMWORKS is to promote the adoption of holistic IPM strategies, based on success stories experienced by farmers. Farmers joining the network both progress further in the adoption of IPM – through peer-to-peer learning, and joint efforts – and demonstrate to other farmers that holistic IPM “works”; i.e. allows a low reliance on pesticides with better pest control, reduced costs and enhanced profitability. IPMWORKS coordinates five existing national networks promoting IPM (DEPHY in France, LEAF in UK, DIPS in Germany, GROEN-AoZ in the Netherlands, and PESTIRE in Switzerland), and launched new hubs of farms in regions or sectors where IPM pioneers were not yet engaged in a relevant network. Advisors coordinating hubs have a major role in facilitating knowledge sharing, coaching farmers to find their own IPM solutions, and organising local demonstration activities. IPMWORKS stimulates access to the ‘IPM Decisions’ platform and provide information on the IPM methods. It collects data for comparing IPM strategies, and share results and dissemination material through channels widely used by farmers, broadcasting IPM success stories. It organises training, and produces training material, targeting both farmers outside the network and advisory services, in order to prepare for the future dissemination of the peer-to-peer learning approach and the general adoption of IPM throughout the EU. The final objective is to initiate a general change in agricultural practices throughout Europe, to reach the target of halving pesticide use, as planned by the Green Deal of the European Commission (Farm to Fork strategy). The demonstration of cost-efficiency of IPM is based on data describing the details of cropping systems and pest management in farms involved in the network. IPMWORKS will also produce a range of data of various nature for dissemination and communication purpose (videos of farmers’ testimonies, videos of demonstration events, leaflets describing cost-effective IPM-based strategies, etc.). During the ESA conference, the network will be presented, with first results about the motivation of IPMWORKS farmers regarding IPM, the level of IPM adoption
when joining the network, the level of pesticide use, and results of self-evaluation made by farmers regarding the quality of pest control and about economic profitability.
Effect of row spacing on plant architecture, yield and weed suppression of soybean (Glycine max (Merr.) L.) in a pesticide-free cultivation

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Keywords: soybean, pesticide-free, row spacing, mechanical weed control

For the pesticide-free cultivation of soybean (Glycine max (L.) Merr.), row spacing might play a decisive role in increasing competition against weeds by affecting inter- and intraspecific access to resources such as light.

The objective of this work was to compare a narrow row spacing (15 cm) – carried out as an equal distance sowing pattern – with a common wider row spacing (50 cm) in terms of its influence on plant architecture, growth and yield formation of soybean, as well as the occurrence of weeds at distinctive growth stages of soybean.

Two field trials (A) and (B) were conducted at the experimental station Heidfeldhof, University of Hohenheim (48°42'52"N 9°11'30"E, 401 m a. s. l.) in 2021. In each trial, the soybean cultivar Sculptor (Norddeutsche Pflanzenzucht Hans-Georg Lembke KG, Holtsee, Germany) was sown at a density of 72 seeds m\(^{-2}\) in two different row spacings: normal sowing (NS, 50 cm) with a higher intensity within the rows given the larger row spacing, and equal distance sowing (ES, 15 cm) with a more even plant distribution. Trial (A) reflected a farmer’s practice with mechanical weed control (harrowing and hoeing until 60 days after sowing), whereas in trial (B) both manual (hoeing, full season) and no weed control were applied in order to investigate in detail the competition between soybean and weeds. Measurements were conducted destructively at the growth stages (1) 5th-trifoliate, (2) flowering, (3) pod filling and (4) full maturity and included plant architecture as well as soybean dry weight (DW) and the number and DW of weeds.

In trial (A), soybean DW [g m\(^{-2}\)] tended to be higher in ES at stages 2 to 4, despite a significantly higher weed DW [g m\(^{-2}\)] at all measurement dates. However, weed DW was always below 80 g m\(^{-2}\) and weed density [plants m\(^{-2}\)] did not reach critical threshold control values (≤ 40). In trial (B), soybean DW [g m\(^{-2}\)] was higher in the weed-free plots at stages 2 and 4 compared to the weedy ones. Weed DW reached almost 140 g m\(^{-2}\) due to nests with tall-growing species such as Amaranthus spp., while weed density remained rather low at the same time (≤ 50) and no significant effect of row spacing was observed either. In both trials, the different plant architecture traits measured at pod filling stage showed a consistent increase in plant height and petiole length for the plants in NS, in addition to a smaller internode diameter and a lower number of branches. Harvest was done with a combined harvester in trial (A) and resulted in 2.3 t ha\(^{-1}\) for NS and 2.47 t ha\(^{-1}\) for ES. Trial (B) was hand-harvested and ranged from 3.3 t ha\(^{-1}\) (NS, no weed control) to 4.3 t ha\(^{-1}\) (NS, manual weed control).
Neither weed control measures nor row spacing affected the yield significantly.

In summary, narrow row spacing stimulated soybean plants to develop more branches (Plasticity effect) which, in turn, promotes an early canopy closure and thus might lead to higher weed suppression. However, further trials are needed, in particular with a higher weed pressure, to conclusively evaluate the potential of a narrower row spacing in pesticide-free soybean production in terms of yield stability and weed suppression.
Volatile mediated tritrophic interactions determine behavioral changes in the pest mite B. yothersii, in presence of the predator E. concordis, in citrus plants

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MIP, leprosis, vector control

Some mites of the genus Brevipalpus (Acari: Tenuipalpidae) have economic importance because they are vectors of viruses in several cultures, especially CiLV-C (Citrus leprosis virus C), transmitted by the species B. yothersi. Control consists mainly of eliminating the vector with the use of acaricides. In response to herbivory, the plant defense system is activated, and specific mixtures of volatile compounds are emitted, the so-called HIPVs (herbivore-induced plant volatiles), capable of attracting natural enemies of herbivorous arthropods. The effects of predators on pest populations go beyond predation, with non-consumptive effects (NCEs) being an important topic in arthropod ecology with potential applications for the management of pests and disease vectors. Behavioral changes in response to the presence of predators can impair the acquisition and/or transmission of the pathogen, since these processes are dependent on the time of access to food of the vector on the lesion of the virus in leaves, branches or fruits. Volatile organic compounds (VOCs) associated with arthropods seem to be involved in inducing the anti-predator response. For this reason, investigations on VOCs related to insect-insect and insect-plant communications have gained importance in pest management, both from a chemical and biological point of view. The objective of the present work was to study the alterations in the behavior of B. yothersi in an environment with signs of the presence of predators. Experiments were carried out using orange leaves, without symptoms of virus, consisting of 3 treatments: T1) without previous exposure to any mite species (control); T2) Previous exposure to the pest mite B. yothersi for 24h; T3) Previous exposure to B. yothersi and the predatory mite Euseius concordis (Acari: Phytoseiidae) for 24h. Immediately before the start of the experiment, all mites were removed from the leaves and 10 females of B. yothersi were introduced. The leaves were filmed separately for 2 h and the videos analyzed using Ethovision software. VOCs were collected in passive mode and the profile of compounds was determined by GC-MS. The results showed a contrast in the movement pattern of B. yothersi pest mites, as well as differences in the release of volatile compounds in the plant+pest+predator system. There was a reduction in the movement of the pest in T2 compared to T1. In T3, the average movement time was longer than in the 2 previous treatments, suggesting the influence of the signals left by the predator on the behavior of the pest. The presence of acetic acid, benzene and toluene was identified in all 3 treatments, which could be characteristic of the plant. Compounds present in treatments T2 and T3 (benzoic acid, coumarin and vanillin), were probably released by the pest or by the plant in response to the attack; and compounds present only in T3 (ethanol, N-benzylidene-Dimethylammonium chloride), are likely signs of the predator's presence.

Site-specific mechanical weed management in maize (Zea mays) in North West Germany

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In modern agriculture, the trend is towards a more environmentally friendly management. Weeds can reduce the yield of crops (Ngouajio et al., 1999) and they are distributed heterogeneously across the field and occur in patches (Metcalfe et al., 2019). In site-specific management, information is used in order to match the inputs to the sub-field conditions. With site-specific weed management, biodiversity can be increased because only the parts of the field with a harmful number of weeds are treated. Site-specific application of herbicides is well known and practiced, not so for mechanical weeding. But this offers the potential to decrease the negative effects of mechanical weed regulation, such as higher risk of soil erosion and newly emerged weed seeds after disturbing the soil (Woźniak, 2020).

In North West Germany, on the organic research station “Waldhof” (Osnabrück University of Applied Sciences) a field trial (0.3 ha in size) was conducted to test the influence of site-specific mechanical weed regulation on the yield of maize (Zea mays) and weed biomass. Each Plot had the size of 30 x 3 m and was setup as a randomized block design with four repetitions. For the site-specific management, each plot was separated into three subplots with a length of 10 m. Two decision-making systems were compared to a uniform weed management. The first was based on a Weed Cover Threshold (WCT) with the factor levels 0.25 %, 0.5 % and 1.0 % weed cover. The second treatment considered the Relative Weed Cover (RWC, Ngouajio et al., 1999). The RWC is the fraction of weed cover to crop cover. Three thresholds were compared: 0.1, 0.2 and 0.4 RWC. On May 14th 2021, eight maize seeds per m² were sown.

For the site-specific decision, the weed cover was sufficiently identified by drone using multispectral images and a Convolutional Neural Network. The classes "bare soil", "maize" and "weeds" were correctly classified with an overall accuracy of more than 85 %. Additionally, five to seven days before and after each weed regulation, the weed cover was estimated by visual assessment in six 0.1 m² frames per plot. Before the maize seeds emerged, all plots were treated with a torsion harrow, as common in organic practice, followed by site-specific hoeing at growing stage 12 and 15. Yield and weed biomass were estimated by hand cutting 1 m² per subplot.

At the time of the second weed management process, the thresholds for all treatments were exceeded, so all subplots were treated equally. During the last hoeing, differences in the weed population were observed within the field. Mainly the western part had higher weed density and therefore, more subplots were treated. In terms of yield and weed biomass, no differences between the treatments were found. Compared with uniform weeding, the WCT-decision-system showed 0 % (WCT 0.25 %) 25 % (WCT 0.5 %) and 43 % (WCT 1.0 %) reductions.
of weed in treated area. For RWC-treatment, reductions of 58 % (RWC 0.1), 67 % (RWC 0.2) and 100 % (RWC 0.4) were observed. These results show that weed density is distributed heterogeneously across the field.

A site-specific mechanical weed management can reduce the area of treated soil surface without losses in yield. With larger maize plants, more weeds can be tolerated because of increased competitiveness. The RWC decision system considers the crop cover, this leads to a smaller disturbed soil surface area. The results showed the benefit of this decision system comparison to a simple weed cover threshold.
Spatial targeting of alternative conservation strategies in farmland to preserve multiple aspects of biodiversity

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Agricultural intensification has resulted in large-scale loss of biodiversity, with potential consequences for both conservation of species as such and for ecosystem services provided to agriculture and the wider society. This has resulted in an urge to strengthen conservation in agricultural landscapes, but there is no consensus regarding how this should best be achieved. Conservation in farmland could focus on maintaining or restoring more or less permanent habitats outside arable fields (ex-field interventions). Alternatively, conservation could focus on in-field interventions by reducing pressures on biodiversity and making arable fields more benign to biodiversity. Organic farming is known to benefit local biodiversity, as a consequence of changes in the management of arable fields including the avoidance of use of inorganic fertilizers and synthetic pesticides and the ensuing changes in farming practices such as more complex crop rotations. It has been proposed that organic farming may not be a cost-efficient strategy to maintain biodiversity, compared to maintaining and increasing ex-field interventions in terms of e.g. semi-natural grasslands and incidental habitats such as permanent field borders. However, evaluation of the relative virtues of alternative strategies to conserve farmland biodiversity requires studies that focus on landscape scales, which is rarely done. We conducted a study in southern Sweden on in-field plant and pollinator diversity, demonstrating that organic farming resulted in a higher prevalence of flower resources in arable fields and also in a resulting low but albeit higher density of bumblebees compared to conventional farms. This has significant overall consequences for pollinator populations, because arable fields is one of the major land cover type in the landscapes of the studied region. Organic farms also provided more stable resources over the season, compared to conventional farms where bees suffered from late-season resource bottlenecks. Organic farming management strategies that slightly reduced crop density were able to maintain higher densities of pollinators without compromising yields. To evaluate the consequences for biodiversity across scales, we used a species-area model accounting for beta-diversity to upscale plant biodiversity under alternative strategies of organic farming uptakes and maintenance of semi-natural grasslands. We compared our results to the public spending used in terms of agri-environment schemes supporting semi-natural grasslands and organic farming under different scenarios. Our results demonstrates that while organic farming benefits biodiversity both locally and at larger scales, converting conventionally farmed land into semi-natural grasslands increased biodiversity more cost-effectively in terms of overall biodiversity conservation than organic farming, particularly in landscapes with little semi-natural grasslands to begin with. However, these analyses ignore the ecological infeasibility and/or potentially prohibitively large costs of transforming arable fields into semi-natural grasslands, suggesting that organic farming is a strategy that may contribute to overall biodiversity conservation. We conclude by discussing the possibility of using organic farming and
preservation of ex-field interventions as complementary rather than alternative methods of maintaining and restoring farmland biodiversity.
Intercropping suppresses plant disease - a global meta-analysis

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There is strong policy push for the idea that integrating diversity into agricultural systems will reduce the impact of pests, diseases and weeds, and reduce the need for pesticides. There is, however, uncertainty on the effect sizes that may be expected from enhancing diversity. We made a global meta-analysis on the effect of species mixtures on disease incidence in agriculture. From the global literature, we extracted a dataset of 92 trials reporting disease incidence in intercrops and their corresponding pure stands. Intercropping reduced disease incidence from 34% in pure stands to 21% in mixtures, equivalent to a 50% reduction in the odds of disease, from approximately 1:2 to approximately 1:4. The intercropping effect was consistent across continents but varied for different pathogens and crop species combinations. Growing species in more intimate mixtures (e.g. fully mixed or in rows) gave better disease suppression than growing strip intercrops. Several mechanisms underlie the disease suppressive effects of intercropping, including host dilution, barrier effects, effects on crop microclimate, and induced resistance, but their relative importance is unclear. Technical advances in agricultural practice and adjustments in supply chains, processing and marketing are needed to support a broader adoption of intercropping by farmers. This study shows that intercropping has high potential to reduce pesticide use in agriculture, but it is not a silver bullet and will need to be integrated in a broader tool box of interventions to support a transition towards an agriculture with less pesticides.
Session 3

Orals

Trade-Offs of Producing Protein from Crops and Livestock Systems
Nitrogen use in crop and livestock systems: from the farm to the global scale

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Livestock systems demand a significant amount of feed in the form of grass (which in 2010 accounted for 46% of total livestock ingestion), grains, oil crops, fodder crops, crop residues and by-products. Crop-origin feed covers ca. 50% of the global cropland surface and it accounts for 50–60% of the total protein crop production. Furthermore, livestock excretes 112 TgN/yr (part of it originating from synthetic fertiliser), which is equivalent to the synthetic fertiliser applied to crop and grassland systems worldwide (110 TgN/yr). Thus, achieving food security based on sustainable systems for the coming decades requires a detailed understanding of the complex links between crops and livestock systems as well as their integration into the agro-food system. Nitrogen use efficiency (NUE), when estimated at the animal system scale (that is, the efficiency of the transformation of vegetal into animal protein), has significantly improved during the past two decades, particularly for monogastric systems. However, the considerable growth in the demand for livestock products has offset this improvement, a paradigmatic example of the Jevons paradox: more feed is used, and more manure is excreted. Additionally, important structural changes in the configuration of crop and livestock systems have resulted in substantial losses of efficiency when analysed at the system scale. When crops and livestock are spatially disconnected, the agroenvironmental problems associated with nitrogen use can be multiplied. On the crop side, the lack of manure availability results in a constant need for new nitrogen as synthetic fertiliser. On the livestock side, large amounts of manure cannot be efficiently reused as fertiliser, and it is applied on small, closer croplands at excessive rates or is directly discharged to rivers. Indeed, some livestock systems that are very efficient when analysed at the farm scale lose a great deal of efficiency when externalities are considered. We need to work at the farm level while tailoring an answer and strategies at larger scales: regional, country and global.

Here we present an analysis of nitrogen’s origin (grassland and local and/or imported crops), availability and use (ruminants, monogastric and humans) in agro-food systems at the farm, province (NUTS3), country (Spain, France and China), continent (Europe) and global scales. Trends over the past 50 years have shown that these areas evolve differently, showing specialisation and an increase in external dependency of net importing regions as well as a significant increase in the share of protein allocated to the livestock sector. Farm-scale NUE improvements are in part offset when externalities are included (feed import and manure transfer). The system’s nitrogen surpluses are frequently not adequately reused for balanced crop fertilisation, resulting in regional pollution of air as well as fresh- and coastal waters. Sustainable agro-food systems need to advance approaches only considering NUE at the crop and animal scales, thus allowing study of the system scale. With this aim, recent research explores 1) crop–livestock reconnection including the relocation of feed production and the reduction of external dependency, 2) the use of alternative feed sources such as wastes from the agro-food system, and 3) demand-side changes. The efficiency of these strategies is
analysed. It is concluded that a combination of them all, considering nested spatial and systems scales, is paramount to ensuring food security and environmental quality.

**Short Biography**

Luis Lasaletta is a researcher at CEIGRAM (Universidad Politécnica de Madrid). He has worked at universities and public institutions in Spain, France and the Netherlands. He studies the sustainability of agro-food systems connecting crop, livestock and food distribution systems from an integrative perspective. His work includes nutrient budgeting (N and P) and modelling approaches combining spatial, system and temporal scales. He belongs to the European Nitrogen Experts Panel and is leading several international initiatives on NUE and nutrient budgets quantification.
Potential for the introduction of Soybean into crop rotations in the Normandy region, France

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Europe is looking for alternatives for soybean importations and needs more local production of protein crops to meet the growing demand for proteins both for feed and food. One strategy to meet this demand could be to expand the soybean production areas (Karges et al, 2022). However, some preliminary information is required before starting producing a new crop. Firstly, farmers lack technical and economic references such as adapted technical management or potential yield but also the impact on gross margin of crop rotation. Then advisors, also needs similar information when working with farmers. Finally, collectors may need the potential total volume potentially produced in a given area to identify the storage needs or the resources required to collect or sell the grains.

The aim of this study is to present the main results of a research project (Soja made in Normandy) aiming at assessing the potential for soybean in the Normandy region (France), where soybean has not been cultivated yet. In order to assess the potential for soybean, the research was conducted in two steps: on the one side, an analysis of potential soybean yields and on the other side an ex-ante production and economic assessment. In the first step, soybean yield was simulated per soil type for the last ten years using the STICS crop model. The results were compared with two-years results of the experimental trials ongoing in the region. In the second step, the ex-ante assessment of soybean production and gross margin, we applied the methodology developed by Marraccini, et al (2020) using the RPG explorer data on crop succession in the region (Martin et al., 2021) at the parcel level to estimate the maximum potential for soybean insertion within local crop rotations. Further, we calculate and map the maximum production potential for the area. Finally, we compared at the parcel level for the whole region the gross margins of ongoing and crop rotation including soybean to understand and map the potential economic impact.

Results showed that from a climatic point of view 100% of the region was suitable for soybean cultivation as it is possible to sown at a minimal soil temperature of 10°C and cumulate enough temperature to harvest by the end of September in good conditions. From a soil quality side, there were two types of soils that are well adapted to soybean growing: deep loam and moderately deep silty loam which represented 57% of the territory. STICS simulations a potential yield between 1.8 & 2.7 t/ha 0% humidity in function of years and soil types.

The most common rotation was Rapeseed (18-25%)-winter wheat (25-30%)-Barley (18-25%)-winter wheat (25-30%). When applying the rules of soybean introduction in the ongoing crop...
rotation the total surface that could be allocated to soybean is equal to 13500 ha each year at the regional level.

The gross margin analysis (ongoing results) will provide additional information to identify the most suitable crop rotations were introduce soybean.

First field results show that soybean can be cultivated in Normandy, even if yields could highly impacted by summer drought.


Crop management factors affecting faba bean yield in European agriculture: A meta-analysis

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The food, feed, ecological and economic values of faba bean (Vicia faba L.) are well documented. Faba bean has the potential to produce more protein per hectare than any other grain legume besides soybean, and it is adapted to cool climates where soybean grows poorly, such as summers in northern Europe and the winter growing season in Mediterranean climates. However, in Europe, the production, yield and yield stability of faba bean suffer greatly from environmental stresses, including the shortness of the growing season in northern Europe and terminal drought and heat stresses in southern Europe. Farmers often treat faba bean as a low-input break crop rather than giving it the inputs it needs to be productive. As a result, the mean productivity of faba bean is twice as great in the moderate climates of north-western Europe than elsewhere in the continent. Furthermore, biotic stresses and management practices contribute to the variability of yield in the crop, leaving greater room for genotype x environment x management interactions. This indicates the need for specific choices of cultivar, cropping system, sowing season and agronomic practices targeted to each cropping environment. In view of this, as part of the ERANET SusCrop Project ‘LegumeGap’, we conducted a quantitative literature analysis on the role of crop management factors in faba bean production in Europe.

We conducted the literature search in the CAB Abstracts database, using keywords related with faba bean production and crop management factors to identify potentially useful peer-reviewed articles and grey literature from European countries. The initial search identified 4,866 articles, of which 230 useful articles were thoroughly analyzed. The database was supplemented with literature from Australia, Canada and the United States, where grain legumes including faba bean are widely grown.

Zero-tillage was associated with a ~17% yield increase in comparison with conventional tillage, whereas other tillage practices showed no consistent value. Irrigation, even in climates where drought stress is uncommon such as England, led to yield increases of 10% to 50%. Relief of soil compaction increased yield by an average of 28%. Nitrogen fertilization in research experiments never showed an economic benefit, but inoculation with appropriate Rhizobium bacteria showed improved yields in almost all experiments, up to 50% when there was no history of grain legumes in the field. Provision of honeybees for pollination improved yield by an average of 21%. In all cases, zero effect was sometimes found and maximum impacts greatly exceeded these values.
Other practices affecting yield include appropriate control of pests, weeds and diseases, which is difficult when few plant protection chemicals are certified for use on grain legumes. Crop rotation is important for all of these aspects and intercropping of faba bean with cereals or oilseeds helps to restrict the spread of pests and diseases, although it makes weed control even more difficult. Combined treatments often show interactive effects on the yield. The economic, agronomic and ecological benefits of these practices have not received much attention in European agriculture.

The literature survey shows the potential benefit to farmers of treating faba bean as a crop that repays appropriate attention and investment in management tools. In this way, the gap between potential and achieved yields can be narrowed. Furthermore, it demonstrates the need for breeding of cultivars for broader adaptation to reduce the susceptibility to biotic and abiotic stresses prevalent in Europe.

Keywords: Crop management, yield gap, yield instability, protein security
Diversification of Mediterranean winter cereal cropping systems through intercropping with grain legumes: a path to low-input agriculture

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Abstract: Mediterranean arable agriculture, cradle of paradigmatic grain legumes, has evolved in the recent decades towards the simplification to monospecific winter cereal-based cropping systems, highly reliant on external inputs such as fuel, synthetic N fertilizers and pesticides. In the Mediterranean basin, abiotic factors such as scarce and variable precipitations, high evapotranspiration and high temperatures during grain filling limit crop productivity. Continuous winter cereal cropping has led to limitations such as high N needs and reliance on specific active ingredients for weed control. In that context, cropping systems diversification through intercropping represents an interesting strategy to overcome some of these limitations while valuing alternative crops such as grain legumes for different purposes. Intercropping can reduce N fertilizer needs, enhance weed control of cropping systems, while increasing grain quality in low-input scenarios (Corre-Hellou et al., 2011; Bedoussac and Justes, 2010; Bedoussac et al., 2015). However, to our knowledge, few initiatives have been devoted to assess intercropping for grain production in Spain.

Therefore, in the framework of the EU Biodiversify project (PRIMA call), in autumn 2020 an on-farm field experiment testing intercropping alternatives was established in the Ebro valley (Sucs, Lleida, Spain; 41.700225, 0.447945) in a surface irrigated area, in collaboration with farmers and other local stakeholders. Durum wheat/winter pea (Triticum durum Desf./Pisum sativum L.) and durum wheat/chickpea (Cicer arietinum L. pedrosillano type) intercrops – based on a replacement design – as well as the respective sole crops were compared under two scenarios of synthetic N fertilizer availability (0N, control; 75N, 75 kg N ha$^{-1}$ as top-dressing) in a completely randomized design with 3 blocks. A control without herbicide was implemented within each intercropping treatment as a sub-plot. Management practices, with active participation of farmers, were carried out by commercial machinery.

The Land Equivalent Ratio (LER) for grain yield was significantly higher in 0N compared to 75N for both wheat-chickpea and wheat-pea intercrops, but it was only higher than 1 in the wheat-pea 0N scenario (1.05). The LER of the total aerial biomass at physiological maturity was greater than 1 in both intercrops under 0N scenario. The proportion of N in biomass derived from biological N fixation was higher in intercropped pea (66%) than sole cropped (52%), as an average of flowering and physiological maturity stages (p=0.031). Although grain N content was similar for pea and chickpea cultivated as sole crops or intercropped with durum wheat, the proportion of nitrogen in the grain derived from biological fixation was significantly higher in the intercropped pea (73%) compared to sole pea (51%). Weed ground coverage at flowering stage of wheat-pea intercrop was not significantly different between the treatment without herbicide (21%) and the chemically treated (16%). Consequently, the performance of each species of the mixture was not affected by herbicide application in terms of biomass at flowering and grain yield. Contrarily, the performance of both species of wheat-chickpea mixture was reduced by the absence of herbicide with a lower productivity.
Wheat-pea intercropping could be an alternative to sole crops leading to higher productivity in systems without synthetic nitrogen fertilizer inputs and representing a way to reduce herbicide use. Choosing an adapted mixture is a key aspect of intercropping success: in our case wheat-pea reached satisfactory productivity, while wheat-chickpea productivity was negligible. As a consequence, in autumn 2021 this last mixture was replaced by a durum wheat-faba bean (Vicia Faba L.) mixture. The results of the two cropping seasons will be presented at the ESA congress 2022.
Ways to increase protein production in organic farming systems by mixed cropping of grain legumes

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In Switzerland, the demand for sustainably produced plant-based proteins increases. This is on one side due to more vegetarian and sustainable human diets but also because, from 2022 onwards, ruminants may only be fed from fodder produced on organic certified Swiss farms. In this context, the project PROMISE funded by BLW and BioSuisse aims to investigate mixed cropping systems with pea-lentil and pea-barley mixtures and their impact on the protein production. In addition, benefits and challenges within crop rotation on N-availability and weed dynamics in subsequent crop at Swiss conditions are assessed.

Due to lodging of peas (Pisum sativum L.) and lentils (Lens culinaris Medik.), pure stands often are difficult to harvest leading to yield losses. Additionally, poor weed competition can result in severe yield depression in organic farming systems. An environmentally sound way to deal with both challenges is the establishment of mixed cropping systems. In the project PROMISE, field trials with pea-lentil-mixtures and pea-barley-mixtures in comparison to pure stand of each crop were conducted to measure the impact of mixed cropping systems on grain and protein yields, lodging, weed pressure and protein content.

Field trials were conducted in 2020 and 2021 at two sites in the Swiss Midlands with pea-barley-mixtures and lentil-pea-mixtures. In 2020 nine pea varieties (Respect, Spartak, Sofia, Protecta, Mythic, Milwa, Rodnik, Astronaute, Rocket) were tested in pure stand as well as in combination with three lentil varieties (Anicia, Rosana, Kleine Schwarze) and ten pea varieties (Astronaute, Impuls, Karioka, Milwa, Natura, Salamanca, Respect, Bluetooth, Protecta, Volt) in pure stand and in combination with the barley variety KWS Atrika. Based on the results from the year 2020, a selection of varieties was made and new cultivars added for the lentil-pea-mixtures resulting in six pea varieties (Respect, Protecta, Mythic, Milwa, Bluetooth, Impuls) and three lentil varieties (Anicia, Dimitra, Kleine Schwarze) for the trials in 2021. From preliminary results, it is concluded that lentil-pea mixed cropping systems are able to outperform overall system grain yields (2020: 20 dt/ha; 2021: 27 dt/ha) in comparison to pure stands of lentil (2020: 9 dt/ha, 2021: 6 dt/ha). In 30 out of 36 tested pea-lentil mixtures over two years the land equivalent ratio (LER) values were above 1.0.

Also pea-barley mixtures on average performed better in regard to grain yield in comparison to pure pea crops. However, results showed a strong cultivar effect on mixture performance. Total protein yield in the pea-lentil-cropping system (2020: 3.4 dt/ha; 2021: 3.5 dt/ha) was higher in both years compared to the pure stands of lentil and peas, respectively. The exceptions were pea varieties Rocket in 2020 and Protecta in 2021, which had a higher protein yield in pure stands than in mixed cropping system. Generally, the total protein yield was
increased by 32 % (LER 1.32) in 2020 and 46 % (LER 1.46) in 2021 in pea-lentil-mixtures averaged over all treatments compared to pure crops with only lentils or peas. Averaged over all pea-barley-mixtures, protein yield was 4.76 dt/ha in 2020.

Lodging of lentil in lentil-pea-mixtures and lodging of pea in pea-barley mixtures was considerably reduced compared to pure stands.

Thus, mixed cropping systems could be an option to increase and equilibrate yields compared to pure stands (especially as observed under the challenging growing conditions with long periods of rainfall in 2021). The equilibration of yields over years could increase attractiveness of grain legume production for organic farmers. Before general conclusion are possible, additional trials at Swiss growing conditions are needed.
Soybean resilience to drought at different development stages

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Climate change is projected to increase the frequency and intensity of extreme drought events that can affect plant growth. This is particular relevant in spring-sown grain legumes such as soybean that tend to have less stable yields than winter crops (Reckling et al., 2018). Soybean is adapted to a large range of temperature conditions, and the cultivation is moving towards Northern Europe (Karges et al., 2022). Little is known about the response to drought at different growth stages under European conditions. The objective of this study was to quantify the resilience of soybean to drought by measuring crop responses and recovery dynamics at the vegetative and flowering growth stages. A field experiment was conducted with soybean, during 2020 and 2021 on sandy soils in Müncheberg, Germany, and applying four water regimes (irrigated, rainfed, early-drought, and late-drought stress). Drought stress was simulated by covering the plots during the event of rain with large 8 x 8 m rainout shelters. Plant height, chlorophyll fluorescence ratio (ChlF ratio), chlorophyll content (Chlc), and leaf surface temperature (LST) were measured at different intervals after the simulated drought events until pod filling. Soybean resilience was quantified using the rainfed treatment without any simulated stress as control and applying the method by Elsalahy et al., 2020. Yield and yield components were quantified at the end of the growing season. In the year 2020, soybean received, from May to September, 25% less precipitation than in 2021. Despite doubling the amount of irrigation to 280 mm, in 2020, the measured indices showed, on average of all treatments, a significant reduction by 28%, 31%, and 19%, of plant height, ChlF ratio, Chlc, respectively, but a 24% increase in LST. As a consequence, grain yield was decreased by 40% in 2020 than in 2021. Importantly, in both years, no significant difference was observed between the irrigated and rainfed conditions on any of the measured indices. This finding indicates that irrigation maybe not required for soybean when the rainfall distribution is almost stable during the growing season. But, the effect of periodic drought during the vegetative stage or flowering stage was significant and contrasted between the two years. Particularly, the yield after the early and late drought events was reduced, compared to the control, by 66% and 29% in 2020, and 9% and 27% in 2021, respectively. The divergent response of soybean to drought at different growth stages between the two years highlights that other factors such the pre-/post-drought soil moisture, drought intensity and duration may also affect soybean resilience. Merely, after the early drought in 2021, Chlc was significantly recovered with 40% at the end of the growing season, indicating a partial recovery of the photochemical apparatus after releasing drought. Strikingly, in both years, no recovery was observed in LST, indicating that failure of soybean in restoring LST within the physiological functional range can be crucial for their resilience capacity. These findings provide fundamental insights into how soybean restores its growth and photosynthetic performance at different growth stages to deal with episodic drought. It also emphasizes the importance of leaf thermal trait to the recovery and resilience of soybean, therefore should be considered in breeding programs.
Reference:


RECKLING M. et al., 2018, « Grain legume yields are as stable as other spring crops in long-term experiments across northern Europe », Agronomy for Sustainable Development, 38.
Productivity and chemical composition of different forage legumes integrated in crop rotation

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Integrating forage legumes in crop rotation has significant impact on farming sustainability in terms of resource use and environmental effects. Legume supported systems have a high potential for mitigating climate change through the reduction of fossil fuel use and GHG emissions, as well as increasing carbon sequestration. Their pre-crop effect, N provision, potential to improve nutrient balance and soil structure, and enhanced biodiversity contribute to farms’ sustainability. Some legumes are better at fixing nitrogen than others. Forage legumes, such as alfalfa and clovers are the best choice for cover crops as they can fix substantial amounts of N surplus under the right conditions. The aim of this research was to examine the productivity and chemical composition of alfalfa (Medicago sativa L.) and red clover (Trifolium pratense L.) integrated in crop rotation under agroecological conditions of Serbia. The experiment was carried out on six localities. Soil and plant material were sampled in the second production year of legumes. Red clover had higher average yield of fresh weight, 24.4 t ha⁻¹, and dry matter, 4.9 t ha⁻¹ than alfalfa, which had yield of fresh weight 19.0 t ha⁻¹ and dry matter 4.4 t ha⁻¹. This is a consequence of alfalfa sensitivity to soil acidity, since the soil of a large part of the examined localities had an acidic reaction. Red clover has lower demands towards soil fertility and reaches good productivity even on poorer soils. However, alfalfa achieved a higher N content in dry matter (3.36%) compared to red clover (3.02%) in all localities. Also, alfalfa accumulated more nitrate, 175.2 mg kg⁻¹ compared to red clover, 168.8 mg kg⁻¹, since it has a highly branched root system, which reaches deep into the soil and absorbs nitrates from deeper soil layers. The content of P, Ca and S was higher in alfalfa. The average K content in alfalfa dry matter (1.56%) was lower compared to red clover (1.59%), but the differences were not statistically significant. The average content of Mg in the dry matter of alfalfa was 0.28%, and red clover 0.29%, and the difference is not statistically significant. There were no significant differences in the content of microelements between the legumes, except for boron and manganese. Alfalfa had higher B, but lower Mn content, compared to red clover. No differences were found between the contribution of alfalfa and red clover to soil enrichment with nitrogen. The average values of nitrogen content in the soil ranged from 0.15% to 0.16%.

Crop choice is often related to the goals the farmer is looking to achieve with the rotation, but must respond to a number of fixed conditions such as soil properties.

Keywords: alfalfa, red clover, crop rotation, chemical composition.
Sustainability knowledge exchange – farm consultants’ perspectives on challenges and solutions to engaging farmers, and the role of sustainability assessments

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Keywords: agricultural extension; knowledge exchange; sustainability assessment

The co-design of future crop and livestock systems with stakeholders requires farmer engagement around a holistic view of farm sustainability, encompassing environmental, social and economic aspects to maximise benefits and avoid unintended consequences. Specific issues are posed for farm knowledge exchange (KE) providers when shifting from advising farmers on increasing production to driving the delivery of sustainability goals (Kipling and Becoña, 2019).

The Open Spaces for Local Production project in Monmouthshire, Wales, explored challenges and solutions around sustainability KE from the perspective of farm consultants, via qualitative analysis of questionnaire responses and structured discussions within a workshop in February 2022. The workshop also gathered consultants’ views on the utility of on-farm sustainability assessments in addressing barriers to engagement, the potential issues with applying such assessments, and the key characteristics they should have. These exercises used the Global Farm Metric sustainability assessment (Sustainable Food Trust, 2022) as a concrete example to focus discussions.

The questionnaire reached 84 consultants in Wales, with 41 responses returned. Data included views on challenges to sustainability KE, forming the basis of workshop discussions. Ten consultants attended the workshop, focusing on solutions to the challenges and gathering views on sustainability assessment. Consultants used post-it notes and discussions to share and explore responses, ensuring the inclusion of contributions from less vocal participants.

To avoid ‘forcing’ data into predefined categories, challenges to sustainability KE and the solutions discussed were grouped using a grounded theory approach. Data samples were analysed by two different researchers to correct for bias associated with the personal perspectives of individual analysts.

Sixteen challenges were identified and associated with solutions, from professional standards for farming and consultancy, to tiered approaches to engagement, and tougher regulations.
Groupings of challenges and solutions added depth to previous categorisations of challenges to adopting climate-friendly farming in Wales and their solutions (Kipling et al, 2019), highlighting practical, knowledge, cognitive and interest-based issues, and solutions ranging from control to empowerment. Findings support a systematic, informed approach to change in Welsh agriculture, and provide an improved framework for designing implementation strategies in other countries.

Workshop consultants voted on whether sustainability assessments could address individual challenges to engagement. More consultants thought that three challenges would be addressed by sustainability assessment than were unsure or thought assessment would not help: Mindset of farmer; Farmer knowledge and understanding; Consultant knowledge, experience and perspective. Three challenges (Cost and financial pressure; Worry about external interference; Fear of engaging with public) were expected to be unaffected, and for nine most consultants were unsure of the impact of assessment. The findings indicate many benefits of sustainability assessment to consultants depend on design and implementation. Ongoing analysis (March-April, available for presentation) will categorise consultants’ views on challenges to applying sustainability assessments and the characteristics of an ideal assessment. Findings provide critical insights into how sustainability assessments can best support the co-design of future crop-livestock systems given the unique challenges to sustainability KE.

Reference:


Catch crops for increasing nitrogen use efficiency in rotations with faba bean

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Locally grown legumes may reduce the need for the import of protein in Denmark. Additionally, in current scenarios soybean is often cultivated at the expense of the natural forests and with high climate impact due to transportation. In Denmark, the area under faba bean (Vicia faba L.) cultivation has increased in recent years and its use is expected to spread further. However, little is known about the environmental aspects of faba bean cultivation i.e., nitrate (N) leaching in the year(s) following the faba bean cultivation.

Nitrate leaching is a big concern in many European countries. To address the high nitrate leaching losses due to agriculture, numerous preventive measures have been put in place in Denmark. Mandatory cultivation of catch crops for taking up excess soil N in autumn is one of the key instruments to accomplish for the European Union (EU) Water Framework Directive for protection of water bodies. Apart from reducing N leaching, subsequent mineralization of the catch crop residues can result in an increased N availability for the following main crop. To account for this residual effect, a mandatory reduction in the amount of nitrogen that can be applied to the succeeding crop has been implemented. However, accurate quantifications of the residual effects of legumes are still required to prevent excess nitrogen input. The present Danish estimates for leaching reduction due to catch crops are based mainly on crop rotations with cereal cropping while little is known about their capability in legume cultivation. For faba bean especially, a late harvest may be a challenge for the development of effective catch crops during early autumn before growth conditions deteriorate.

To improve our understanding of the effect of catch crops on the residual effect and N leaching, we set up a field experiment on a sandy loam in Foulum, Denmark, with two rounds of faba bean cultivation. Catch crops of perennial ryegrass (Lolium perenne L.) and chicory (Cichorium intybus L.) in faba bean were established by underseeding in spring while catch crops of winter rye (Secale cereale L.) was seeded after harvest. For comparison with standard cereal cultivation, spring barley was grown in other plots both with and without a following catch crop. The catch crops in barley cultivation were perennial ryegrass underseeded in spring or fodder radish (Raphanus sativus L.) seeded after harvest. Spring barley was fertilized with the recommended rate of 155 kg/ha. To account for any residual effect, this amount was reduced by 30 kg/ha when grown after either faba bean or after a previous catch crop. As a legume faba bean was not fertilized with nitrogen. We compare nitrate leaching and the residual effect in the spring barley (yield and N uptake) over a period of 3 years (2020 to 2023).

Results obtained so far indicate that underseeded catch crops in faba bean have little or no effect on yield. When grown without catch crops, leaching from faba bean did not differ from that of spring barley with around 50 kg N leaching in 2020/21. The use of catch crops
substantially reduced nitrate leaching (to 2-12 kg N/ha) in both spring barley and faba bean. Spring barley yields were significantly increased when grown after faba bean despite the reduction in fertilizer input to account for the residual effect. This suggests that the residual effect was higher than 30 kg N/ha. The experiment is ongoing to confirm these findings, and determine residual and leaching effects under different climatic conditions.
Trajectories of crop-livestock integration in the context of specialisation in Northwest Vietnam

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By enhancing the exchange of materials and energy between livestock and crop systems within and between farms, crop-livestock integration contributes to improving productivity, increasing the value of plant resources, maintaining soil fertility, and improving the sustainability of agricultural systems and territories. The Vietnamese agricultural systems, driven by public policies and private sector investments, have evolved rapidly with a strong intensification of production systems (use of mineral fertilizers, improved seed and breed, industrial feed, biosecurity). The fast intensification is combined with a specialization of farms and territories, along with the appearance of large intensive farms (industrial farming). These recent changes therefore raise the question of the future of crop-livestock integration in the development of the Vietnamese agricultural sector. The loss of crop-livestock integration practices will impact the sustainability of agricultural systems and the territories. This study aims to understand the trajectories and the main change regarding crop-livestock integration practices at the farm and beyond the farm level to understand the potential future of the integrated crop-livestock systems in the territory. Diên Biên District (Province of Diên Biên) is located in North-West Vietnam and presents a diversity of farming systems with a wide rice valley surrounded by mountainous massifs. The importance of bovo-bubaline livestock for the local economy, the land resources, and the ongoing changes in agriculture raise interest in the development of agriculture, and livestock in particular. A typology focusing on the 3 dimensions of crop-livestock integration (feed, fertilization, animal labour) has been developed based on previous work classifying farms according to the degree of feed intensification and crop-livestock integration. It distinguishes six groups of farms according to the orientation of their production (animal, crop) and the degree of integration of both production systems. We studied the changes in farming systems over the last 20-30 years through individual open-ended interviews. For our sample, we selected 23 farmers, with the support of local agricultural development officers to be representative of the diversity of farms, in 5 communes of Diên Biên district. 3 to 4 interviews were conducted per farm type. The diversity of crop-livestock integration practices is the result of past and recent transformations, depending on the personal situation of the farmers (ethnic group, history, family...), the territorial context (topography, land resources), and the economic and political context (market instability, incentives). One of the trajectories observed shows that the lack of land resources in the rice valley motivated farmers with the investment capacity, to convert to animal fattening, with a high use of concentrates, especially for non-ruminant activities (pigs). This conversion is associated with a decrease in on-farm feed production. Although manure is often collected in these farming systems, it is not always used locally. These recent farming systems show a low degree of crop-livestock integration and also challenge the organisation of crop-livestock integration at the territorial scale. This reconstruction of the past evolutions of the crop-livestock integration will be used to construct
scenarios for the evolution of crop-livestock integration practices on farms, but also at territory scales.
Can intercrop complementarity and facilitation be predicted from simple functional traits?

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Intercropping has strong potential to increase the land- and resource-use efficiency of crop production. Several recent meta-analyses demonstrate that the average productivity of intercrops is around 20-30% higher than monocrops. However, the variability around the average is large: these meta-analyses suggest that land equivalent yields of intercrops can range from half to double the yield of monocrops. The evidence so far indicates that the highest productivity gains are made in regions with long growing seasons that allow for substantial temporal niche separation between different intercrops. However, in parts of the worlds with short growing seasons, including much of sub-Saharan Africa, then such temporal niche separation between crops is not possible. In short season contexts, we hypothesise that morphological and physiological differences between crops will be important to determine intercrop productivity.

Here, we present the results of a field experiment in which we grew 9 crop species in different combinations across three different sites (two sites in Kenya and one in Nigeria). Crops were grown in intercrop, monocrop, and single plant treatments to enable us to distinguish between net competition, net complementarity, and net facilitation in intercrops. We explored the extent to which the interplay between competition, complementarity, and facilitation was determined by two key traits, height and specific leaf area (SLA). Height and SLA were chosen due to their association with life history strategies relating to competition avoidance or stress tolerance.

We assessed intercrop productivity in terms of biomass and grain yields. Our results indicated that around 30% of the variability in intercrop productivity among different species combinations can be explained by height and SLA alone. Land equivalent grain yields were maximised by pairing a tall species with a high SLA and short species with a low SLA. In contrast, biomass yields were highest when both species in the intercrop were similar in height. This difference suggests that in addition to height and SLA, a crop’s relative resource allocation to biomass vs grain yield under different conditions may also play an important role in determining intercrop productivity.

Overall, our study demonstrates the potential of taking a functional trait approach to explaining intercrop productivity. Using traits to identify which crop combinations will be most productive could help farmers to make more informed crop and layout choices. It is promising that we could explain 30% of the variability in this study using just two traits, and we anticipate that future research accounting for additional sources of variability (including more traits, trait by environment interactions, and intra-species trait variability) will achieve a greater predictive power for intercrop productivity.
How to develop sustainable farming systems valuing the rhizosphere effect?

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Wheat, rhizosphere effect, on-farm diversity, reduced tillage

In a context of agroecological transition, root-soil interactions are expected to reduce synthetic inputs use and address current environmental challenges facing intensive crop production (Bakker et al. 2012). The interface between roots and soil, called rhizosphere, is linked to plant nutrition and health through complex interaction loops leading to increased resource use efficiency and regulation services compared to bulk soil. Indeed, the rhizosphere hosts microbial communities that modify biogeochemical cycling, plant growth and tolerance to environmental stress. Farming practices modify the nature and intensity of rhizosphere Functions through the crops’ selected by the farmers and their associated management practices. Yet, gaps of knowledge about rhizosphere functioning in agroecological systems (reduced tillage and biodiversity-based) and scarce R&D interest by professionals prevent farmers from the conversion to alternative practices. Relevant rhizosphere evaluation methods and indicators are therefore required to produce knowledge and impulse a transition (Mira et al. 2022).

The aim of the study is to evaluate rhizosphere functioning on field conditions along a double gradient soil practices x diversification level (Tiemann et al. 2015). Our hypothesis is that the modification of soil microbial functions allowed by crop diversification and soil management will change the value of the rhizosphere effect. Therefore, we characterized the rhizosphere effect of winter wheat (Triticum aestivum var. LG Absalon) for ecological functions involved in nitrogen (N), phosphorus (P) and carbon (C) cycling. Accordingly, we compared 8 different plots discriminated along a crop diversification gradient and receiving either reduced tillage or ploughing by farmers in Brittany, France. Fertilization rates, amount of fungicide used and edaphic properties were analyzed to select farms with similar environmental conditions. On each plot, at heading development stage, bulk soil and rhizosphere samples were collected and analyzed using ISO 20130:2018 standard for 3 different enzymatic activities involved in N (arylamidase), P (acid phosphatase) and C (β-glucosidase) cycle. The values were used to calculate the Rhizosphere Effect Indicator (Mira et al. 2022) corresponding to a Welch t-test allowing significance testing of the results. Linear models were used to identify relationships between variables (one-way ANOVA and regressions).

We estimated a significant rhizosphere effect on the plots which allowed comparisons between the different situations. A significant positive relationship between crop diversification and the rhizosphere effect was observed for ary lamidase and β-glucosidase activities, with more than 55% of the variation explained by the diversification level. More particularly, enzymatic activities harbored systematically no rhizosphere effect for the plots with low crop diversification. On the contrary, the values of the indicator were not modified.
by soil management practices (ANOVA - P value > 0.05). Based on these results, we can consider that on-farm biodiversity shape the rhizosphere effect suggesting opportunities for agroecological transition. We also discuss how the methods used in the study could be harnessed by advisors to evaluate rhizosphere functioning on farms and relate the rhizosphere effect to crop performances.


Inoculation of indigenous Bradyrhizobium strains enhanced soybean productivity in Northeast German agroecological conditions

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In Europe, commercial inoculants are frequently used to inoculate field-grown soybean. However, nodulation efficiency has frequently been low (Schmidt et al. 2015), prompting the need to explore strategies to increase soybean productivity in these areas. Indigenous strains adapted to local conditions could be used to develop more effective inoculants to improve biological nitrogen fixation (BNF) and increase domestic soybean production. According to Hungria and Vargas (2000), genetically stable rhizobium strains to harsh soil conditions may enhance BNF and increase soybean grain yield compared with commercial inoculants. In the present study, we evaluated the ability of indigenous Bradyrhizobium strain(s) to enhance soybean grain and protein yield in field conditions in northern Germany.

We set up two field trials in 2020 and 2021, in which three indigenous Bradyrhizobium strains (GMF14, GMM36, and GEM96) plus a reference strain (Bradyrhizobium diazoefficiens USDA110) and a noninoculated control were tested in combination with three soybean cultivars (Merlin, Sultana, and Siroca) of different maturity groups. The three strains were previously isolated from arable fields in Northern Germany. Liquid cultures of each strain with a concentration of 108 cells ml⁻¹ were inoculated to each soybean cultivar. Water supply (rainfed and irrigation) was introduced as an additional factor from the start of flowering, with irrigation plots receiving extra water based on crop water demand.

In both experiments, there were significant strain and cultivar effects on nodulation but their interaction effects were inconsistent. Irrigation increased nodule weights significantly but only slightly increased the number of nodules formed. Overall, while irrigation increased grain yield, there was only a minor increase in grain protein content. Inoculation increased protein content and grain yield by an average of 24% and 32%, respectively, when compared to the noninoculated control in rainfed conditions. While USDA110 consistently improved grain yield when inoculated to Sultana and Siroca, GMM36 and GEM96 inoculation to Sultana and Siroca produced comparable yields. Our findings indicate that inoculating locally adapted soybean cultivars with indigenous isolates improves nodulation, grain, and protein yield independent of water supply. We observed enhanced effects of the strains when combined with specific cultivars, implying the importance of careful strain and cultivar selection for increased soybean productivity.
Reference:


Planting season and legume species affect grain and forage yield in Kernza intermediate wheatgrass perennial intercrops

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Intermediate wheatgrass Kernza (IWG, Thinopyrum intermedium (Host) Barkworth & D.R. Dewey) is a multifunctional novel perennial grain and forage crop with the potential to provide ecosystem services and increase the cropping system resilience. Intercropping IWG with legumes increases the nutritive value of the harvested forage but may compromise Kernza grain yields. With the goal to quantify the effect of different management practices, we installed an experiment on a Plano silt loam soil, at the University of Wisconsin-Madison Arlington Agricultural Research Station, Wisconsin, USA. The mean annual temperature is 6.7° C, and precipitation during the growing season until harvest (April-July) was 512 mm in 2018 and 560 mm in 2019. In spring (April 2017) and fall (September 2017), we planted 4 IWG monocultures (“control”, “weed removed by hand” once in spring and once in summer, and “nitrogen fertilization” using urea in split applications during the spring in 2017 and 2018 at rates of 45 or 90 kg ha-1) and 5 IWG-legume intercrops (with “lucerne” Medicago sativa, “red clover” Trifolium pratense, “Kura clover” Trifolium ambiguum, “berseem clover” Trifolium alexandrinum or “soybean” Glycine max). Both planting seasons were planted at two row-spacings (57 cm and 38 cm), and we collected grain and forage data for two subsequent years. Kernza grain yields were variable among the cropping systems planted in the fall (670-1050 kg ha-1) but they were not statistically different. When cropping systems were planted in the spring, the Kernza grain yield was lower in lucerne and red clover intercrops than in other treatments. Planting IWG in the spring yields similar in the following as in the fall (p=0.07), but a year of annual crop production is lost. Regarding the IWG monoculture cropping systems, neither N fertilization nor weed removal significantly affected on the grain yield. Probably, it was due to high N content at the beginning of the experiment (5.1 ppm of NO3-N and 21.1 ppm of NH4-N at 0-15 cm) and that most of the weeds were annuals. Most of the IWG-legume intercrops had similar grain yields to IWG monoculture but included legumes in the systems. Legumes usually increase the nutritive value of the harvested forage, so they have a positive effect on the total income harvested by the system. In our study, berseem clover and soybean legume forage yields were low (145 and 176 kg ha-1, respectively in the first year). Therefore, they did not provide the benefits targeted with intercropping. Instead, IWG intercropped with Kura clover or red clover were good alternatives in at least one planting season: at spring planting season IWG-kura clover intercrop yielded 656 kg Kernza grain ha-1, 4921 kg IWG forage ha-1 and 825 kg legume forage ha-1, whereas at fall planting season, IWG-red clover intercrop yielded 897 kg Kernza grain ha-1, 3801 kg IWG forage ha-1 and 444 kg legume forage ha-1. They were the best candidates to achieve both grain and forage aims simultaneously in each planting season. On the other hand, planting in narrow or wide row spacing didn’t affect Kernza grain yields. This suggests that the increase in yield per row in wide row spacing compensates for the fact that there are fewer rows per area. In the second year, IWG grain yield declined consistently in all the treatments. All the cropping systems had very low yields.
regardless of the management (54 – 254 kg ha\(^{-1}\) in IWG monocultures and 2 – 221 kg ha\(^{-1}\) in IWG-legume intercrops). Dual-purpose IWG-legume intercropping systems are promising but more research is needed to design mixtures capable of improving forage harvest yield without compromising grain yields.
Regional patterns of crop sequences and diversity in high-latitude organic and conventional farming systems

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Keywords: crop rotation; organic farming; arable land-use; crop diversity

Farmers often use crop sequences as a strategy to respond to environmental pressures, and to control and boost crop productivity. To diversify cropping systems by varying crop types in space and time is recommended to support ecosystem services and crop productivity in a sustainable way. While studies have previously focused on data collected in experiments, our understanding about the structure of crop sequences on farms at high latitudes is limited. The aim of this study was to determine and evaluate the distribution of crops and identify typical crop sequences in organic and conventional farming in Sweden during a 10-year period using spatial and temporal data from the EU Integrated Administration and Control System (IACS). The IACS gathers direct information from farmers about time, location and crops grown on their fields. Specific objectives were to determine the distribution of arable crops at national and regional scale, and to evaluate the structural characteristics and diversity in organic and conventional farming using crop types and crop sequences. In addition, we investigated the position of winter wheat and spring barley (the two main cereal crops) in crop sequences by assessing the preceding crop characteristics to understand farmers’ management strategies in organic and conventional production systems.

The study area was Sweden, consisting of about 3 million hectares (ha) agricultural land with 2.6 million ha arable land and 0.45 million ha permanent grassland. The dominating arable crops are grass/clover ley (45%) and cereals (40%) where wheat and barley are the most commonly grown cereal crops. By using large-scale field data from IACS, the crop sequences could be followed on 40% of the total arable land area (349,891 fields extracted) during 10 consecutive years (2005-2014). This enabled a systematic approach to describe crop sequences and diversity in organic and conventional farming systems in five regions. The results show that the distribution of arable crops varies across the five regions representing a general agricultural productivity gradient of the country. The most productive region is dominated by 63% cereal cultivation followed by oilseeds (11%) and root and tuber crops (9%), while in the least productive region leys of more than 2 years and pastures (43%) are dominating together with leys of 1 to 2 years (24%) and oats (15%) as other frequently grown crops.

As leys can be cultivated over several years, this affected the diversity of crops with a decreasing number as the region’s productivity decreased.
Increased diversity of crops used in organic compared to conventional sequences is reflected by cultivation of non-cereal crop types. In the most productive region, organic crop sequences have on average 4.9 main crop types over the 10-years in contrast to 4.5 in conventional crop sequences.

By investigating the preceding crops to winter wheat and spring barley, we explored the management strategies of organic and conventional farmers. Across regions, typical pre-crops to winter wheat are leys, oilseeds, oats and grain legumes. For spring barley, spring cereals and oats are the most common pre-crops together with leys. In the least productive region and especially in organic systems, ley is the typical pre-crop. The results show that the preceding crop types to winter wheat are usually selected from a different crop type, i.e. for their pre-crop effect, as compared to those for spring barley that more often is another cereal crop.

We demonstrate that compiling and visualising IACS data can offer valuable insights on agronomical trends and practices currently occurring on farms. Our study also suggests that farmer’s information on crop sequences should be analysed in more detail together with other farm-level factors.
Diversifying European crop rotations with legumes: potential contributions to sustainable diets

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As a dietary source of protein and minerals, grain legume crops such as beans and peas are increasingly recognized as sustainable and healthy alternatives to animal-source foods. In Europe, legume production has suffered a decades-long decline due to policies supporting intensive cereal production that favored simplified wheat-maize crop rotations. Along with their well-known environmental benefits, recent research has suggested that locally produced grain legumes could increase availability of plant protein for direct consumption in Europe, thereby contributing to sustainable diets. Yet, no prior work has evaluated the potential of growing grain legumes to fulfill the protein needs of European diets. Our study addresses this gap in knowledge by quantifying the extent to which regional European cropping systems could meet current and future protein demand by diversifying existing crop rotations with legumes for human consumption. Building from 2018 European crop maps at high spatial resolution, we simulate the addition and substitution of legumes for fodder crops and fallows in typified rotations at the farm scale, and assess the potential effects of legume-based diversification of crop rotations on protein yield at a regional (NUTS 1, 2, 3), national (NUTS 0), and EU level in 2030. We select the most suitable legumes for rotations using biophysical suitability factors, including climate and soil conditions, crop growing season requirements, rotational compatibility, and contributions to protein production and crop diversity. We then estimate the percent of human protein consumption that could be satisfied at the baseline and in 2030 under several diet scenarios: current consumption (high meat), projected consumption (high meat), fully plant-based diet (no meat), EAT-Lancet/flexitarian diet (low meat). We hypothesize that by adding food legumes to current crop rotations, Europe could achieve protein self-sufficiency for human consumers under low-meat and no-meat diet scenarios. Under meat-rich diet scenarios, protein self-sufficiency would likely decrease proportionally with the fraction of legume protein allocated to animal feed. We expect the impact of legume diversification scenarios for protein self-sufficiency to be greatest in regions with high protein demand and low baseline legume production. Increasing the proportion of legumes in regional crop rotations would not only improve crop diversity, but would also reduce European dependence on imported legume crops (i.e., Brazilian soybean) to fulfill demand for dietary protein. Diversifying European crop rotations and diets with grain legumes could advance multiple aims of the EU Farm to Fork Strategy while strengthening sustainable food systems globally.
Increased protein production from diversified maize-based cropping systems with soybean in a Mediterranean irrigated context

Genís Simon-Miquel¹; Dr. Moritz Reckling PhD²; Dr. Daniel Plaza-Bonilla PhD¹

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The European Union is currently depending on 30-40 million t of soybean imported from overseas to satisfy the 71 % of its high-protein crop produce demand, mainly used to livestock feeding (Murphy-Bokern et al., 2017). This situation leads to social, environmental and economic problems. Moreover, the recent increases in N fertilizer prices (urea price has tripled during 2021) might pose a threat to the current production systems in the EU agriculture, highly dependent on synthetic N fertilisation. In this context, the EU protein plan aimed to boost the production of protein crops to tackle the current EU protein deficit (European Commission, 2018). The present work had the objectives to assess the impact of introducing soybean into Mediterranean irrigated cropping systems in terms of the pre-crop effects, protein yield and synthetic N fertilizer use efficiency. Two single and two double grain cropping systems were assessed in an irrigated on-farm experiment set up in Sucs (Lleida, Spain) from April 2019 to December 2021. The single cropping systems were continuous maize and the introduction of soybean in one out of three years (soybean rotation). In the double cropping system, barley-maize and barley-soybean systems were assessed. For each crop in the systems, grain yield and grain N concentration were measured. Protein yield for each crop and cropping system were calculated. Finally, a ratio between the protein yield and the amount of synthetic N fertilizer applied to each system was computed. Soybean had positive pre-crop effects on the following crops. In the single cropping systems, a 15% yield increase, on average, was found in the maize following soybean compared to the continuous maize (14749 vs. 13756 kg ha⁻¹ in 2020, and 14142 vs. 11450 kg ha⁻¹ in 2021). The trend observed in the double cropping systems was similar, with barley yields following soybean being 20% higher, on average, opposed to those following maize (8230 vs. 7516 kg ha⁻¹ in 2020, and 8588 vs. 6502 kg ha⁻¹ in 2021). In addition, a 7.5% increase in the barley protein content was observed in the barley-soybean system compared to the barley-maize system. At the cropping system scale, protein yields in the single cropping systems were slightly higher with soybean in rotation compared to continuous maize, with 1039 and 993 kg protein ha⁻¹ year⁻¹, respectively. In the double cropping systems, protein yields were higher in the system with soybean, yielding 1308 and 2076 kg protein ha⁻¹ year⁻¹ in the barley-maize and soybean-maize systems, respectively. The higher values in the barley-soybean system can be related to both the soybean phase (56% of the protein yield), producing twice the protein than its maize counterpart, and the barley phase (44% of the protein yield) that benefited from the soybean pre crop effect. This pre-crop effect accounted for 207 kg grain protein ha⁻¹ year⁻¹ extra on the barley-soybean compared to the barley-maize system. The synthetic N fertilizer use efficiency in the single cropping systems was greater with soybean in rotation compared to continuous maize with 8.9 and 6 kg grain protein kg synthetic N⁻¹, respectively. The barley-soybean double cropping system had a much higher synthetic N use efficiency compared to the barley-maize (49.9 and 8.1 kg grain protein kg synthetic N⁻¹, respectively). Our research
showed that increasing protein yields under irrigated Mediterranean conditions can be achieved through an intensification and diversification of the system, with two crops harvested each year instead of one, and especially when the second one is soybean. Such intensification also carries a significantly reduction in the synthetic N fertilizer use and increase in the N fertilizer use efficiency when soybean is introduced in the cropping system.
Sheep grazing winter cereals: impact on crop production

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Grazing "winter cereals"

Reintegrating grazing livestock into arable farms can have positive impacts on the organic matter content and other quality parameters of the soil. Recognition of this has resulted in an increased interest in grazing winter sown cereals, a practice that was common in Europe when mixed farms were more widespread. This practice provides additional grazing during the winter and early spring. However, the farming community has key questions on the quantity and quality of the cereal forage available for grazing, and the impacts of grazing on the quantity and quality of the grain and straw yield. To explore these questions, an experiment was established in Aberdeenshire, NE Scotland in 2021 with sheep grazing winter barley. Forage biomass and feeding value were assessed every few weeks from November until early May in the winter barley field and in a neighbouring winter wheat field. In the winter barley field, three replicates of four grazing treatments were established. The treatments were no grazing and grazing for 1 or 2 days. Grazing took place in mid-March 2021, with little vegetation observable after 2 days.

The peak biomass production for the winter barley prior to grazing was 1200 kg DM ha⁻¹ in early January, while for winter wheat the peak biomass was in early March. At the time of grazing in mid-March, the forage biomass of the winter barley had reduced due to winter kill to 700 kg DM ha⁻¹, although this was still approximately twice as much as was available on the winter wheat field. The D-value of both the winter wheat and barley(273,517),(725,545) and the metabolizable energy was over 14 MJ (kg DM)⁻¹. The crude protein content of the winter wheat was 267 g (kg DM)⁻¹, 50 g kg⁻¹ higher than the winter barley. Comparable figures for good grass silage are 70%, 11.5 (MJ kg DM)⁻¹ 160 g (kg DM)⁻¹ for D-value, metabolizable energy and crude protein content respectively (QMS, undated). After March, the feeding value of the winter barley declined, while for the winter wheat, the feeding value remained stable until mid-May when sampling stopped.

The mean yield of the ungrazed area was 8.7 t ha⁻¹. Although there was no significant difference of grazing intensity on the yield on the winter barley, the yield of the area grazed for 1 day was approximately 1 t ha⁻¹ lower than the area that was ungrazed. The yield of the area that was grazed for 2 days was 8.2 t ha⁻¹, 0.5 t ha⁻¹ less than the ungrazed area. Grazing had no significant effect on the 1000 grain weight. The mean 1000 grain weight ranged from 45.4 g for the ungrazed area to 47.1 g for the area that was grazed for 1 day. Similarly, the effect of grazing on the straw yield was insignificant, but the yield of the area grazed for 1 day was highest at 2.4 t ha⁻¹, while the straw yield for the 2 day and ungrazed areas were 2.0 and 1.9 t ha⁻¹, respectively.
This year, we are repeating the experiment, with a winter wheat trial on the same plots as the last year’s winter barley. In addition, a new grazing trial will be established in the winter wheat field, and in a winter barley field. These trials are running alongside participatory farmers collecting data from their own fields.

Acknowledgements Funded by H2020 Mixed (https://projects.au.dk/mixed) and the Scottish Government Strategic Research Fund

References

Can Europe produce enough plant-based proteins? An assessment of yield gaps of grain legume crops

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Yield potential, fababean, peas, and soybean

In Europe, a transition from animal-based to plant-based proteins is encouraged for a more sustainable food system. This shift requires an increase in European, high quality plant-based protein production suited for human consumption. Important candidate crops for such an increase are fababean (Vicia faba L.), peas (Pisum sativum L.) and soybean (Glycine max L. Merr). Grain legumes could also be beneficial for sustainable cropping, as they e.g., diversify farming systems and reduce fertilizer input through their biological nitrogen fixation (Zander et al., 2016). Only 2% of the cropland in Europe is used for soybean cultivation, and also yields are often low (due to e.g., unfavourable climate, and unfavourable economic results compared to other crops). Therefore large quantities of soybean are imported in Europe (mainly for animal feed). Fababean and peas are currently grown each on less than 1% of European cropland.

As a first step in quantifying opportunities to increase grain legume production it is important to quantify the yield gaps (Yg), i.e., difference between actual and potential yield, on existing grain legume areas. Here we quantified Yg of soybean, fababean and peas in Europe for main producing countries. A bottom-up approach was used, following the Global Yield Gap Atlas protocol (https://www.yieldgap.org/), which allows the use of location-specific weather, soil, and agronomic data from local experts as input for crop modelling to estimate water-limited potential yield (Yw) in case of rainfed systems, and potential yield (Yp) in case of irrigated systems. Crop growth model SSM (Simple Simulation Model) was used for soybean and peas, DSSAT (Decision Support System for Agrotechnology Transfer) for fababean. Actual yields (Ya) were obtained on the finest spatial level from national statistics. A spatial framework was used for up-scaling those location-specific estimates of Ya, Yp, Yw, and Yg to regional and national levels.

We investigated soybean for France, Italy, Moldova, Romania, Ukraine; results from Austria, Croatia, Hungary, and Serbia are upcoming. We found that yield gaps of rainfed soybean production on current area are relatively small, i.e. 0.2 to 0.9 t ha-1, but also both Ya and Yw are relatively low, 0.9 – 2.0 and 1.8 – 2.2 t ha-1 respectively, especially compared to those obtained in the American continent (Ya: 2.3 – 3.2; Yw: 3.2 – 5.4 t ha-1). Under irrigated conditions European soybean yield gaps are somewhat larger (Yg: 1.2 – 3.2; Ya: 1.8 – 3.5; Yp: 4.2 – 4.9 t ha-1).
The main producing fababean countries investigated were France, Germany, Italy and United Kingdom. Unlike soybean, there is much more scope for increasing rainfed fababean production on current area, as Yg ranges from 1.8 – 3.2 t ha\(^{-1}\) (Ya: 1.8 – 3.7; Yw: 5.0 – 5.7 t ha\(^{-1}\)). For peas yield gaps for France, Germany, Lithuania, Romania, Spain, and Ukraine are under investigation.

Finally, we will compare the three legumes based on their grain protein content, to assess how to best contribute to the European demand for plant-based protein. Results indicate that European soybean production on current area can be enhanced only modestly, and that substantial increase must come from area expansion. Climate change in combination with new cultivars could potentially add to the suitable areas for soybean cultivation in Europe (Guilpart et al., 2020). Fababean and likely peas as well seem to offer greater scope to increase production on existing areas.

We thank national agronomists who contributed to this work – https://www.yieldgap.org/partners-europe


Zander, P., et al., 2016. Grain legume decline and potential recovery in European agriculture: a review
Field beans drive higher rotational protein production in a plant-based system compared to a mixed system which includes livestock, but at the cost of lower nutrient use efficiency

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Livestock can play an important role in protein production and cycling of nutrients in farming systems, however alternative crops are being explored as sources of plant-based protein (Sajeev et al, 2020). It is therefore important that we can accurately assess the efficiency of food production and the nutrient management implications of farming systems which will typically produce mixtures of livestock and plant-derived nutrients. Food production from rotational systems can be difficult to assess because while some crops may have high yields, they may not be as nutritionally valuable as those which have lower yields. Accounting for nutritive value from both crops and livestock should also be easily comparable between farming systems. We have explored the implications of contrasting nutrient supply and management with and without livestock by utilising data from two mixed (ley/arable) organic rotations which included livestock with two entirely plant-based organic rotations. All rotations had a six-year long cropping sequence, with each crop grown every year. Mixed rotations had a three-year grass and white clover ley which was grazed by sheep and/or cut for silage and received additions of organic cattle manure. The ley was followed by a cereal and then swedes. The final crop in the mixed rotation sequence was spring oats undersown with the grass and white clover mixture. Plant-based rotations had a one-year grass and red clover ley, followed by either wheat then potatoes, or potatoes then wheat. Both were followed by one year of faba bean, barley and finally oats, which were undersown with the grass and red clover mixture. Other cereal crops and faba beans were undersown with white clover. Otherwise, plant-based rotations did not receive any external inputs of nitrogen (N) and had occasional phosphorus (P) and potassium (K) inputs once per rotational cycle. Using this data, we have calculated the total protein, fat, starch and sugar production. Farm-gate nutrient budgets of N, P and K for each rotation system were constructed and the results of both assessments were used to calculate the N, P and K efficiency of protein, fat, starch and sugar production from our contrasting rotational systems (Castelli et al, 2017).

Results showed that production of protein, starch and sugar was greater in the plant-based rotational systems than those which were mixed, however livestock in the mixed rotations drove significantly higher production of fat than the plant-based rotations achieved. Efficiency of N utilisation was lower than that of P or K across all rotations; this was largely driven by the inclusion of biological nitrogen fixation from legumes as an input of N. Farmgate balances of N showed surpluses in excess of 50 kg ha⁻¹, raising concerns regarding sustainability of nutrient management in these legume-driven systems in the long term (Berry, 2003).
were no differences in efficiency of fat production from applied macronutrients between the mixed and plant-based rotations, however efficiency of starch and sugar production from applied P and K was greater in the mixed rotations. P balances showed modest deficits of 1-6 kg ha-1, however deficits were significantly greater in the plant-based rotations. K balances also showed deficits of 10-13 kg ha-1, but there were no significant differences between the plant-based and mixed rotations. Given the low-input nature of the rotations considered in this analysis, small deficits were not unexpected however they do raise concerns of depletion of P and K should management continue in the same fashion over the longer term. Overall, the analysis showed trade-offs between production of protein, fat, starch and sugar, and where legumes were included in rotations, even low-input systems were susceptible to surpluses of N.
Session 4

Orals

Crop Diversification and Digitalisation to Support Transformations in Production
„Environment Controlled Agriculture” - an approach for highly diverse plant production based on digitisation and automation.

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To counter the pressing global challenges and fulfil the SDG’s the way we grow food has to be transformed, in order to cope with climate change effects and protect the environment. Thus embedding sustainability into the agricultural productions systems, focussing not only on maximising yield but also on safeguarding and efficient use of natural resources.

The general approach over the last 12,000 years of human development was increasing efficiency by reducing diversity; we call it specialisation and standardisation. With this approach, humankind managed to grow more with less input. However, the massive drawback of reducing diversity is that standardisation reduces the resilience against (unforeseen) disturbances. Just remember how the Phytophthora Infestants has caused the potato crisis in Ireland, halving its population in the mid-19th century.

Now, another basic rule is to increase resilience it requires diversification. This applies also to increase the resilience of agricultural production systems. On the other hand, diversification in agriculture means many more interventions, cultivation systems, machines, species and fruits – with different physiological developments, ripening times, storage characteristics. In short, diversity will make farm management extremely challenging.

In order to keep up or improve our currently high yielding production systems, to feed the growing world population, is yet another challenge. To make use of the potential of the natural environment without destroying it, to make most of the farmed land, without depleting the natural resources, its potential needs to be addressed very precisely, not over exceeding it. Thus for lowest possible environmental impact at highest possible yields the challenge is to match very precisely, a multitude of interventions in time, amount and space.

One approach to this challenge is to move agriculture indoors, to control the environment of the production - the Controlled Environment Agriculture (CEA). The opposite approach is to adapt agricultural production to the environment – an Environment Controlled Agriculture (ECA). The basic logic of this approach is to set diversity as the overall management goal. Thus, not only adapting agricultural production to natural heterogeneities in order to harmonise the outcome, to increase evenness of crop stands and synchronise the senescence for ideal harvesting conditions. No, the basic idea is to allow or even foster the differences, to develop production systems that can deal with varying crop developments, multiple crops or varieties next to each other, or within a common patch. The challenge of ECA is to develop highly flexible and adaptive control and machinery systems, that make it possible to control this tremendous multiplicity and diversity, and which at the same time enable productivity and profitability of the farm. This is where digitalisation comes into play. Digital technologies are
not the solution of the problem, but very powerful tools. Cutting-edge technologies like XAI or field robotics set out the promise to address these very complex and challenging problem statements.

While the society needs to set the goals, based on scientific knowledge, including integrated & climate smart farming systems fostering the resilience to the impact of climate change and the ecological and economical sustainability of agricultural production, capacity building is required to ensure global access to knowledge, skills and technology.

**Short Biography**

Cornelia Weltzien is head of ATB Department “Engineering for Crop Production” and chair of Agro Mechatronics at the TU Berlin. After studying agricultural engineering at the University of Applied Sciences Cologne she completed her postgraduate studies in mechanical engineering at Technical University Braunschweig. In 2008 Prof. Dr.-Ing. Weltzien obtains her doctorate at the Institute for Agricultural Machinery and Fluid Technology. Before joining ATB she was part of interdisciplinary advanced engineering teams in the industry. Her expertise is precision agriculture, automation of agricultural processes, smart systems, and digitalisation in agriculture. Prof. Dr.-Ing. Weltzien is a nationally and internationally recognized elite researcher in the field of digital agriculture.
Data assimilation for crop yield prediction

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Keywords: crop modelling, data assimilation, drought

Crop yield predictions at short-term are important for management decisions such as irrigation and fertilization. Crop yield predictions on the mid-term may benefit land management practice, food prices, food security and agro-economic risk mitigation. Mechanistic numerical crop modeling combined with remotely sensed land surface observations for crop yield prediction received increasing attention in the past two decades. Traditionally, predictions are made based on calibrated crop models by applying optimization techniques on the model setup and on the model parameter space. Novel approaches consider a larger number of uncertainties for an optimal prediction than it is possible for parameter optimization approaches. In data assimilation, Bayes theorem is applied considering uncertainties in initial conditions, model structural and parameter uncertainties, observational uncertainty and uncertainty in the model forcing data. Ensemble Kalman Filter and Particle Filter are two of the more frequently used data assimilation methods for crop modeling. While they both have in common an iterative optimization approach and require an ensemble of model realizations to run, the number of realizations, filter characteristics and suitability for a given problem differ. This review addresses advantages and draw-backs in the application of the Ensemble Kalman Filter, its variants and of the Particle Filter for assimilation of remotely sensed observations in crop models. An overview on currently available remotely sensed satellite observations for regional scale application is given. The analysis includes a review on previous successful assimilation systems for physical soil moisture state observations and biophysical vegetation indices. The outlook provides the framework description for a crop drought early-warning system through assimilation of bio-physical variables at the field-to-regional scale in Brandenburg, Germany.
Silage Maize Yield Estimation: UAV-based Assessment of Relevant Crop Parameters

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Christian-Albrechts-University Kiel

Maize, Yield prognosis, UAV-application

In Germany, Maize silage (Zea mays L.) is the predominant substrate for methane production in biogas plants due to its high yield potential. In contrast to the eco-friendly intention of using renewable energies, maize cultivation is often linked with N (nitrogen) overfertilization. This is due to an inadequate estimation of crops N requirements and soil N supply, both varying between years, locations and site-specifically, leading to significant N losses to atmosphere and groundwater.

The project 'N-efficiency in maize' (NeffMais), funded by the German Agency for Renewable Resources, aims to tackle this problem. Insights derived from large data sets of old and new field data will be combined with recent measurement technology to enable further modelling. As a first approach, we analyzed which crop parameter are the most relevant to describe final yield and tested if they can be provided using UAV.

Data of five different years and three trial sites were used to assess at different development stages the correlation of different crop parameters with final dry matter yield. Among the tested predictors, Green Area Index (GAI) and plant height correlated closest with final dry matter. Furthermore, they were able to describe a large share of the final yield variation already relative early in season.

To derive UAV-based GAI data, multispectral data (Sequoia camera by Parrot) were calibrated by destructive sampling. Based on triannual data, a robust and precise vegetation index-model to predict whole-season GAI was developed and successfully evaluated with independent data. R² values > 0.8 in evaluation and calibration are in line with findings of Peng et al. (2021). A newly introduced vegetation index was able to avoid a decrease in precision in later growth stages as described by Peng et al. (2021). In order to test an approach to measure plant height via UAV, manual measurements were accompanied by UAV-overflights with a high-resolution RGB-camera (Duet T by senseFly). By the generation of large 3D-point clouds, plant height and crop height variation at the plot level could be derived.

The UAV-based assessment of these yield-relevant parameters might not only allow to predict final yield quantity, but also its quality, as the combination of plant height measurements and vegetation indices enables the assessment of canopy nitrogen weight (Yu et al. 2021). Furthermore, the RGB-based analysis makes it possible to disentangle plant and crop height which may be relevant for considering transpiration. Therefore, the Duet T-camera could additionally contribute crop temperature measurements as a third UAV-based data source.
beside spectral and RGB-data. These findings are a step forward to the smart use of remote sensing and digitalization for site- and year-specific adapted and thereby more sustainable Maize cultivation.

Literature


Crop diversification experiences across Europe - Relative importance of key factors (barriers, drivers, lock-ins, etc.) and description of the pathways to crop diversification

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Crop diversification - Cognitive mapping - Levers and barriers – Players

In the context of the H2020 project DiverIMPACTS - Diversification through Rotation, Intercropping, Multiple Cropping, Promoted with Actors and Value-Chains Towards Sustainability - a diversity of crop diversification experiences (CDEs) in Europe was documented by identifying and analysing their main factors of success and failure.

An in-depth qualitative survey was carried out in eleven European countries, on 23 CDEs, classified as driven by agronomic innovations (multiple cropping, intercropping) or by value chain innovations (minor crops introduced in the crop rotation and implying the development of a new value chain for both food and non-food production). The open-ended interviews were conducted with various stakeholders involved in the CDEs and were transcribed and translated in English. A cognitive mapping approach (CMASOP) was used to process the interviews and to highlight the concepts and relationships between these concepts which were the most frequently cited. Quotes linked to highlighted relationships were used to document practices and worldviews, and to identify the main levers and barriers to crop diversification in the agri-food system.

This study confirms that the implementation of crop diversification requires innovation on farms and beyond, throughout the value chain.

Farmers and other value chain actors face various barriers to crop diversification: technical (sorting and storing the harvest of multiple cropping, access to adapted machinery), sociotechnical (lack of knowledge), economic (need for financial resources, market conditions, input availability, low willingness to pay, risky production), and regulatory (ban on pesticides needed for cover crop destruction and reduced tillage, destruction date for catch crops).

The results show that the wish to be profitable is the main incentive for farmers to implement new practices of crop diversification. However, it can also be risky and take a long-time before reaching the profitability. Indeed, farmers often need to invest in new equipment (when it is available) and experience the cultivation of crops for which knowledge is still often missing.

This gap of knowledge is reduced by the many interactions between actors, which are shown to be a major factor of success to crop diversification. In our presentation, a special attention
will be paid to this dimension. The exchange of knowledge can be formal or informal. Exchanges between farmers are of prime importance, nevertheless they also often involve a variety of actors such as advisors, researchers, value chain actors, etc. A good coordination between farmers and all value chain actors is also required to manage the storage, sorting, processing, and transportation phases. Furthermore, researchers and advisors should keep on working on technical barriers and knowledge sharing in collaboration with farmers. Consumers among other actors are also involved in the market demand and can boost the development of new value chains.

Finally, policy makers should also adapt regulations to foster the combination of several crop diversification strategies and practices, which could favour the sustainability of farming systems and improve their acceptability by the society.
Modeling the impacts of climate and nutrient management on soil nitrogen cycling and balance in a diversified cropping system

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Over the last decades, agricultural farms in Germany have become large (from 11.1 ha in average size to 60.5 ha in 2016), with high input use of synthetic nutrients and pesticides and highly mechanized. Moreover, crop rotations have been greatly simplified over the last 50 years and the proportion of land under monocultures has increased. Despite their high crop productivity, the current agricultural systems have led to a series of environmental problems such as increased nutrient leaching to water bodies and increased greenhouse was related emissions, drastic decline in biodiversity and increased yield risk in a changing climate. Crop diversification together with new spatial arrangements can contribute to improve cropping systems to become more sustainable and resilient in the future. Spatio-temporal crop diversification offers multiple benefits in terms of delivery of ecosystem services related to nutrient cycling, soil fertility, and pest control while maintaining or improving crop yield. Moreover, the use of management zones, to divide the field in smaller field sizes to account for within field heterogeneities of soil chemical and physical properties, can contribute to better resource and crop allocation and increase resource use efficiency. Smaller field units also contribute to an increase in plant and farmland species biodiversity. However, limited studies have explored how the diversified cropping fields and smaller field arrangements may affect N cycling and N balance and how responses may vary depending on environmental changes in spatially heterogeneous soils.

Agroecosystem models are a powerful tool to aid on the design and evaluation of diversified cropping systems as they offer the flexibility to explore cropping system responses to the multiple environment and management practices. Virtual experiments can be conducted that otherwise will not be possible in reality and their results can inform subsequent field experimentation. Crop growth and development are calculated based on environmental (solar radiation, daylength, temperature, rainfall) variables and nutrient (particularly N). Simulated soil N dynamics include, crop N uptake, N retention, N leaching, and nitrous oxide emissions. Therefore, the main goal of the current study is to explore how climate patterns and management, particularly N fertilization, can impact the dynamics of N cycling and N balance of a spatio-temporally diversified cropping field. For this, an agroecosystem model within the SIMPLACE (Scientific Impact assessment and Modelling Platform for Advanced Crop and Ecosystem management) modeling framework was calibrated and validated for a 5-year crop rotation in a heterogeneous soil. The crop rotation includes winter and summer crops (winter wheat, winter barley, rapeseed, soybean and maize), spatially arranged in “patches” (small field subunits of ~0.5 ha size). Input data for model calibration and validation includes the experimental data (e.g. soil characteristics and initial conditions, crop growth and development, management and daily weather) collected from the patchCROP experiment in
Tempelberg, Brandenburg. The crop rotation was simulated for a 30-year period and findings on soil N cycling and N balance dynamics for the crop rotation system as affected by climate patterns and nutrient management will be presented. This presentation is the second part of the “System based Analysis of N cycling in a spatio-temporal diversified cropping system”. 
UAV-based estimation of biomass and N-uptake from multispectral canopy reflectance data in different winter cover crops

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One achievement, agricultural science and practice has made in the last decades, is the use of remote sensing techniques, to improve yields and management strategies within bigger scales and in higher precision. Monitoring of canopy characteristics such as green area index (GAI), nitrogen uptake or dry matter (DM), during the vegetation period is of major interest to understand physiological processes and to derive management decisions. Cover crops serve as a nitrogen stock for the succeeding cash crop during the winter months (Thorup-Kristensen et al. 2003). Gaining the information about the possible nitrogen buffer from spectral reflectance non-destructively, could be one advantage for sustainable agriculture. Objective of the current study was the prediction of canopy characteristics of winter cover crops and their mixtures from UAV-based multispectral reflectance data.

With data of a two-year trial (2018, 2019) in Kiel, Northern Germany, the multispectral sensor Sequoia (Parrot) was calibrated for the winter cover crops oilseed radish, saia oat, spring vetch and winter rye as monocultures as well as in mixtures. Therefore, the camera was mounted on the UAV Ebee (Sensefly) for a frequent sampling of canopy reflectance data. Parallel to each flight, destructive measurements were conducted and analysed for GAI, nitrogen (N) and carbon (C) concentrations. The reflectance data of the four bands (green, red, red edge and NIR) at the corresponding sampling points were extracted from the images and four vegetation indices (VI; NIR/red, NIR/RE, NDVI, NDRE) were calculated and tested for their predicting power of canopy parameters.

The common Simple Ratio (NIR/red) was the most appropriate VI for predicting GAI, N and C of the cover crop monocultures, regarding the adj.$R^2$ and mean absolute error (MAE). With $R^2$ ranging from 0.83 to 0.52 for winter rye and oilseed radish, respectively, prediction power of GAI was not as promising as other authors showed e.g. for wheat (Bukowiecki et al. 2019). Since the regarded cover crops differ in their structural properties, the spectral signal varies species specific (Kira et al. 2016). Hence, calibration coefficients need to be calculated for each species and mixture separately.

Establishing a sufficient calibration for winter cover crops was challenging, because the quality of reflectance data in winter months is strongly dependent on weather and light conditions. Furthermore, a general calibration of cover crop mixtures, which is the common way of cultivation in agricultural practice to address several functional traits, turned out to be difficult. Effects of competition within the mixture and environmental conditions, led to a cover crop composition deviating to the initial mixing ratio of the seeds. Regardless of the...
wide variety of mixing possibilities, it is feasible to establish a mixture-calibration, but insecure predicting canopy characteristics for another year or site.

With little less inaccuracies compared to cash crops, prediction of cover crop canopy characteristics by multispectral reflectance data was possible for monocultures. Further research needs to be done, to derive a general calibration method for mixed stands.

Reference:


Estimating harvest index and nitrogen concentrations of crops using a limited set of globally available variables

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Reliable estimates of crop nitrogen (N) uptake and offtake are critical in estimating N balances, N use efficiencies and potential losses to the environment. Calculation of crop N uptake and offtake requires estimates of yield of crop product (e.g. grain or beans) and crop residues (e.g. straw or stover) and the N concentration of both components. Yields of crop products are often reasonably well known, but N concentrations and amounts of crop residues are not. While a harvest index can be used to interpolate the quantity of crop residue from available data on crop product yields, harvest indices are known to vary across locations, as do N concentrations of residues and crop products.

The increasing availability of crop data and advanced statistical and machine learning methods presents us with an opportunity to move towards more locally relevant estimates of crop harvest index and N concentrations using globally available data. The aim of this study is to investigate whether improved estimates of harvest index and N concentrations of crop products and crop residues can be based on crop data readily available at the global scale, including crop yield, fertilizer application rates and estimates of yield potential. Using maize as our first crop, data from the literature and from data requests from 31 countries were used to test various prediction models. Logarithmic and linear mixed-effects (“mixed-effects”), and random forest models were applied to widely available predictor variables (crop product yield, fertilizer application rates, yield potential and location) to predict maize harvest index, and N concentration of crop products and residues. Predictions from our mixed-effects and random forest machine learning models provided reasonable levels of prediction accuracy (R² of between 0.35 and 0.69), with the random forest method having greater accuracy. However, the mixed-effects models provided greater interpretability of results through explicit predictor variable coefficients. Choice of model will depend on the objective of the user.

The prediction methods for the variables used in this study can be used to create nutrient balances estimated with more locally relevant crop residue yield, crop product N concentration and crop residue N concentration. So far, the method was applied to N, but could equally be applied to other crops and nutrients, which we are currently undertaking. This will enable obtaining more locally relevant estimates of crop nutrient offtake to improve nutrient balances at a national, continental or global level, as part of strategies towards more sustainable nutrient management.
Best practices for scanning and processing field vis-NIR spectra of agricultural soil: a procedural and instrumental comparison

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In the last decades, the use of visible and near-infrared (350 – 2500 nm) spectroscopy (VNIRS) to characterise agricultural soils has gained increased interest. The absorption of light in this range by several soil components, such as organic matter, clay minerals, and iron oxides, makes VNIRS a potential alternative to tedious and expensive laboratory analyses, especially with regard to increased demand of high-resolution soil data for precision agriculture in the future.

During the last decade, portable and handheld devices have been developed to obtain VNIR soil spectra directly in-situ. However, operational questions are still open, in particular concerning the reliability of different portable instruments and the best practice to collect soil spectra in the field. Accordingly, the main goal of this study is to propose best practice for soil spectra acquisition in the field by comparing two different portable instruments. Therefore, we used a miniature spectrometer (NeoSpectra-Scanner, Si-Ware Systems, Egypt) with a range of 1350 – 2500 nm and a research grade portable spectroradiometer (PSR+ 3500, Spectral Evolution, Lawrence, USA) with a range of 350 – 2500 nm. Soil samples were scanned according to the following procedures in five replicate scans: on both sides of a 20 cm helical corer (a and b); on the undisturbed soil surface around the corer hole, avoiding stones, (c); on the soil surface with coarse material removed (d); and the smooth soil surface by compacting and smoothing the soil (e). As reference for the more established soil spectroscopy practices, the same soil samples were also dried and sieved (< 2 mm) and then scanned indoor in triplicates using the two instruments (procedure l).

In total, 134 sampling points in 9 experimental agricultural fields in Switzerland were scanned, and soil samples were analysed for texture (sand, silt, clay), C content (organic C (OC), organic matter, carbonates), N content (Ntotal, C/N ratio), pH, cation exchange capacity (CEC) and total and exchangeable nutrients (P, K, Mg, Ca).

Spectral outliers were removed and several pre-processing methods were applied, namely standard normal variate (SNV), multiplicative scatter correction (MSC) and Savitzky-Golay smoothing in three variants (without, using the first or the second derivative). With the raw and the pre-processed spectra, a partial least squares regression model was built for each of the six scan procedures (a–e, l) for clay, sand, OC, Ntot, C/N ratio, pH and CEC. For each model, the dataset was split into a calibration and validation set by using the data from one field to test the calibration built with the data from the remaining fields. This was repeated nine times and the resulting model parameters (R², RMSECV, RMSEP, latent variables) were averaged.
The selection of the ideal amount of latent variables was facilitated in the pls package based on the one-sigma heuristic and with 8-fold stratified internal cross validation.

Preliminary results showed that the PSR+ spectrometer provided the best results for clay content (R2 0.95, RMSEP 3%) and OC (R2 0.81, RMSEP 0.33 %), with the scan procedure along the core (a and b) leading to better prediction than the dried and ground laboratory scan procedure (l). Conversely, for the NeoSpectra Scanner, the best results were obtained on the laboratory scans (l) (R2 0.96 and 0.76, RMSEP 4.3% and 0.4% for clay and OC, respectively). For the in-situ procedures, the scans by the NeoSpectra at the soil surface resulted in the best fits (clay: R2 0.79, RMSEP 6.7%, procedure d, OC: R2 0.62, RMSEP 0.45%, procedure e). Overall, the PSR+ performed better than the NeoSpectra, although the latter has potential as a low-cost alternative for selected parameters (clay, OC).
Analysis of site-specific N balances in heterogeneous croplands using digital methods

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Keywords: Nitrogen surplus; Soil heterogeneity; Digital technologies

Aim: This study examines whether spatially variable N-balances occur on uniformly fertilized fields and whether digital technologies are able to determine the input data (yield, N uptake) for N balancing with sufficient accuracy. Furthermore, the causes of the influence of small-scale variable soil properties on yield and potential nitrogen losses (N surplus) were investigated. The aim of this study is to precisely localize N surplus and nitrogen loss potentials through a high spatial resolution.

Method: The spatial variability of N balance parameters was determined on five heterogeneous arable fields in southern Germany, using digital methods (combine harvester yield sensing systems, tractor mounted multispectral sensor, satellite data, vegetation indices, and models). The effect of different data sources (input data, algorithm, vegetation index, models) on the N balance was investigated. Various soil properties (0-30 cm), such as humus content, N content, and available water capacity, were used to identify the causes of spatial variation of N surpluses. In order to validate the quality and accuracy of the digital systems, a comparison with ground truth data (biomass sampling) is carried out. The data were transferred to grids of the same resolution (10 x 10 m) by interpolation using block kriging. A correlation analysis based on the grid elements was performed to determine the relationships between the plant and soil variables.

Results and discussion: The digital methods identified larger areas with high environmentally hazardous N surpluses on all studied fields. These results imply that a field-uniform N balance masks the actual N loss potential caused by spatial variability in soil properties. Site-specific N balancing identified zones with high N loss potential (N surplus up to more than 100 kg ha⁻¹), even if, on average, N inputs and N outputs are almost balanced. The results show that all the digital methods tested are suitable for identifying high and low yield zones, but lead to significant differences in mean values and ranges (min-max). N surplus determined in test plots correlated best with N surplus calculated using tractor mounted multispectral sensor data (up to r = 0.67). Acceptable correlations of values and similar patterns were found only between sensor-based and satellite-based methods. Soil organic carbon and soil total nitrogen content was closely correlated in all fields (up to r = 0.97) and were most closely positively correlated with yield and N uptake (up to r = 0.62) and negatively correlated with N surplus (up to r = −0.62). The higher the SOC and TN, the higher the N uptake and lower the N balance. Especially in drinking water protection areas, it is advisable to carry out N balancing at the site-specific scale level using digital systems and high N surpluses should be classified as
environmentally hazardous and require management adjustments, especially in mineral N fertilization. Another management adjustment could be to remove low-yield areas with high N balances from arable farming (e.g. sow grass).

Reference:


Potato plant dry matter estimation using stereo vision

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Above-ground biomass of the potato plant during growth and development is an important parameter for the general status of the crop. Local deviations in biomass or an unexpected deceleration in accumulated dry matter may indicate crop stress. The crop biomass also plays an important role for variable nitrogen applications and optimized irrigation. However, manually determining the biomass either by eye or destructive plant samples is a difficult, time-consuming process, or, in the case of the former, error prone. We present an algorithm and preliminary results for estimating the above-ground dry matter of potato plants using images from a stereo vision camera mounted on a field robot.

Potato plant samples were collected on the 13th and 16th August 2021 at Aarhus University, Flakkebjerg, Denmark, and used for training and testing, respectively. 19 plant samples were collected with dry matter ranging from 30 g to 157 g. Depth and RGB images covering the area surrounding each plant sample were collected before and after plant sampling. The image-pairs were collected using the stereo vision camera MultiSense S21 (Carnegie Robotics, Pittsburgh, PA, USA), which were mounted nadir on the field robot Robotti (AgroIntelli, Aarhus, Denmark). The collected images were processed offline in MATLAB.

The depth and RGB images were converted to coloured 3D point clouds (PCs) using a pinhole camera model. The PCs of a given sample before and after sampling were aligned using the iterative closest point algorithm (Besl & McKay, 1992) followed by resampling both PCs into the same regular grid of 3x3x3 mm3. The “after” PC were subtracted from the “before” PC to produce a “change” PC. The z-axis in the “change” PC corresponded to the change in height between then point clouds, and the intensity of the points corresponded to the change in excess green minus excess red (Meyer & Neto, 2008). The sampled potato plant was segmented in the “change” PC by clustering points with an intensity greater than deltaExGR. Clusters with more than C points were regarded as part of the sampled potato plant. Clusters with less than C points were included, if their centre of mass were inside the convex hull (CH) of the large clusters. Two estimates of the volume were explored: 1) volume of the CH of the segmented point cloud, and 2) sum-of-columns (SoC), where each point was considered a column with a base area of 3x3 mm3 and a height given by change in height between the “before” and “after” point clouds. Finally, the estimated volume was fitted to the measured dry matter using a linear model.

The preliminary results showed that the SoC volume generally had a lower RMSE than the CH volume in leave-one-out cross-validation on the training set. The SoC volume further showed a more stable RMSE across the parameters C and deltaExGR. On the test set, the SoC volume from the “change” point cloud (R2 = 0.58, RMSE = 19.5g) performed almost as well as the SoC volume derived from fully segmented point cloud (R2 = 0.62, RMSE = 18.5g).
The proposed algorithm shows potential for estimating the above-ground dry matter of potato plants. In future work, it may be used for estimating new growth by performing weekly measurements compared to a reference point cloud of bare soil and to detect possible crop stress.

Reference:


Opening the black-box: Explainable Artificial Intelligence for agricultural transformations

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Keywords: XAI, machine learning, deep learning, model

Artificial intelligence (AI) is a powerful tool for effectively utilizing digitalized information in agriculture. While several studies showed promising potential of AI application for agricultural prediction, most previous studies evaluate model performance based solely on how accurately the model predicts the outcomes (i.e., prediction ability). However, this is often not sufficient because decision making for agricultural transformation requires the reasons behind the prediction. It is crucial for decision makers to know why and how the model predicted so, and they need to assess whether the model prediction makes sense agronomically. I believe that AI cannot be used as a reliable source for high-stake decision making for changing agricultural activities without explanation and trust, even though AI-based prediction is accurate. Therefore, revealing what the AI model learned from data is an inevitable next step for making AI tools as a reliable tool for supporting agricultural transformations in real-world. Here, I present an overview of the recent advancement in the field of AI science to overcome the issue, based on my recent publication (Ryo et al. 2021, Ecography) while showing some examples.

Explainable AI (XAI) is an emerging subfield of AI science, aiming to make the model behavior and prediction explainable and interpretable for the users. Within the XAI domain, several so-called interpretable machine learning tools have been proposed. Interpretable machine learning tools can be classified as either global or local interpretation and either model-specific or model-agnostic. Based on intensive literature review, I identified that model-agnostic methods are particularly promising. These methods can be used as post-hoc for analyzing any kinds of machine learning algorithms. Global model-agnostic methods such as permutation variable importance and partial dependence plots can explain which predictor variables are important for the model and how the predictor variables are associated with the response variable. Local methods such as local interpretable model-agnostic explanations and Shapley additive explanations can explain which variables were key to make a specific prediction. These methods even make it possible to compare conventional statistical modelling approaches including multiple linear regression with machine learning algorithms like random forests and artificial neural networks in a standardized fashion, helping us evaluate the context dependence and nonlinear patterns.

I argue that the advantage of XAI tools is not limited to model interpretation, but XAI tools are useful for advancing the understanding of agricultural systems. One can use an XAI for novel pattern discovery from the large data and then integrate the finding into a mechanistic model:
For instance, XAI can quantify how climate extremes and global change factors affect annual crop yield, and how these impacts can be mitigated by management strategies by combining historical records of crop yield and Earth Observation datasets at the national and/or larger scales. Another example is to quantify how crop diversification can positively affect crop yield and its stability. Since these patterns are likely to be strongly context dependent and site-specific, typical statistical models are not suitable, but XAI can nicely explain the patterns. Collectively, XAI is one of the key data analytic tools for supporting agricultural transformation given the rapidly increasing opportunity for collecting and analyzing various kinds of digitalized information, which in turn, clarifying realistic strategies for crop diversification.

Reference:

Ryo et al. (2021) Explainable artificial intelligence enhances the ecological interpretability of black-box species distribution models. Ecography 44, 2.
An inverse modelling solution to solve the problem of unavailable subsoil information

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Keywords: Crop growth, Vadose zone, Inverse modelling

Under the ongoing and prospective climate changes, vegetation functions will heavily depend on its resilience to drought. Under water-stress, numerous studies have shown that vegetation shifts water uptake from deeper soil and rock moisture, and groundwater. Consequently, evaluating plant growth demands for a deeper understanding into the subsoil characteristics as an important influence in water replenishment and thus, in plant growth and yield formation.

Purely empirical studies are costly, cumbersome, and limited to point-scales and proximal sensing is limited to the upper 30 cm below-ground (Bönecke et al., 2021), deeming soil information at deeper layers as scarce or inaccurate. Process-oriented modelling can be employed to widen the spatial horizon and for this purpose, extensive model applications have already been carried out, corroborating the importance of achieving a robust subsoil parameterization for yield modelling (Wallor et al., 2018). Most modelling tools require soil information as an input and focus on yield formation as a process and output. Through an inverse modelling approach, this study aims to show how a process-oriented model can be employed and parameterized for predicting subsoil characteristics from yield variability at a field scale. Initially, weather information and 15 soil point measurements at three depths (0-30, 30-60, and 60-90 cm below-ground) were collected at an agriculturally managed field of about 60 ha (Booßen, Germany) and fed into the process-oriented, agroecosystem model HERMES2Go (Kersebaum et al., 2019), developed for simulating and predicting crop yield given the water- and nitrogen-dynamics between soil-plant-atmosphere. Plant parameterization was carried out for different crop varieties, given yield measurements collected at these 15 points. Subsequently, through an inverse modelling approach, the HERMES2Go model was fed the weather inputs and plant characteristics for another 35 points at the same location in order to draw conclusions about the subsoil physical properties (e.g., the field capacity and permanent wilting point). Corresponding subsoil measurements up to 90 cm below-ground were collected for these 35 points and were used for validation of the inverse modelling.

The effect of subsoil characteristics on the model’s predictive capacities was confirmed, and the method proposed here showed potential to increase the spatial density of subsoil information determined at single points, as well as improve the accuracy of proximal sensors where direct information was missing. In a further step, such a method could aid in rendering continuous subsoil parameters for neighbouring, geographically similar areas by integrating...
proximal- and remote sensing information about topsoil and plant yields, respectively, into the modelling approach.
Robots and precision weeding techniques for effective weed control in sugar beets

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Weed control is one of the main challenges in sugar beet cultivation. The presence of weeds closely related to sugar beet complicates clean weeding of the crop and leads to intensive herbicide use. In order to limit the environmental risks associated with sugar beet production, the project aimed to reduce the use of herbicides through the use of new precision weeding techniques and robots. This project evaluated several weeding methods from herbicide band application combined with a camera-guided hoeing machine to a spot spraying system, including a strictly mechanical weeding with a weeding robot.

Started in 2018, this project has brought forward the continuous progress of new weed control techniques. Indeed, yearly feedback to manufacturers has allowed continuous equipment improvement throughout the years. In 2021, the final year of the project, the ecoRobotix ARA sprayer, the FarmDroid FD-20 robot, and the combination of band application and mechanical weeding provided effective weed control. These weeding techniques showed similar remaining weed densities before harvest as the farm-specific weed control strategy. The powerful action of the hoeing machine was able to deal with well-developed weeds such as ryegrass in the inter-row. In combination with a band herbicide application, the hoeing machine reduced the amount of herbicide used by 60%. This reduction was more heterogeneous with the ARA sprayer of ecoRobotix, allowing 21 to 84% herbicide reduction depending on the weed pressure in the field. Since the ARA only treats developed weeds, herbicide savings are reduced when high weed pressure. The FD-20 robot of FarmDroid impressed with its rapid improvement through technical adjustments between the first (2020) and second (2021) trial year. However, weeds close to the sugar beets plants (2 cm) cannot be mechanically eliminated. The addition of a spot sprayer would allow this robot, which is currently only profitable in organic farming, to control weeds growing near the sugar beets and thus extend its use for conventional farming.

This project has demonstrated the great potential of these new technologies in sugar beet weed control. However, improvements are still necessary on these tools, which will play a central role in reducing pesticide use on sugar beets and other crops.

Keywords: hoeing, resource efficiency, pesticide reduction, spot spraying
Intercrops: how does management effect performance?

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SRUC

Intercropping cereal-legume management

Intercropping is a potential management option for intensifying crop production, while at the same time minimising the negative impacts of crop production on the environment. Low input intercrops managed in the same way as the comparable sole crops typically outperform the sole crops by 20% (Li et al, 2020), thus addressing the need for increased production from existing agricultural land. On the other hand, cereal-legume intercrops that rely on the legume for the supply of nitrogen yield 20-25% less than the sole crop cereal receiving typical nitrogen inputs. Research has largely focused on comparing intercrops with sole crops; however, for intercrops to become established in farming systems, farmers require more information on how to manage the crop. Here, using published data, we explore the effect of sowing rates and nitrogen application rates on the yield and the components of yield from pea-cereal intercrops under cropping conditions relevant to Europe. The “all database” option in Web of Knowledge (WoK) was used to identify the papers for review, using the search terms: ((("cereal pea" OR "pea cereal" OR "pea with cereal" OR "cereal with pea" OR "cereal and pea" OR "pea and cereal") AND (intercrop* OR mix* OR bicrop* OR bi-crop* OR (bi AND crop)) NOT (genomi* OR tropical OR africa*)), where cereal was substituted by barley, oat and wheat. The date of the search was 25th June 2019 and after removing duplicates, and papers which did not contain relevant data, we were left with 19, 10 and 6 papers that contained extractable data for the barley, oat and wheat intercrops respectively. In relation to the sowing rates, the relative proportion of the pea in the yield for cereal pea intercrops is likely to be lower than the proportion of pea sown, although this will be affected by other management factors, soils and climatic conditions. In pea-oat mixtures increasing the seed rate above 100% of the sole crops has no impact on the total yield. However, sowing extremely high rates of seeds in barley pea mixtures does increase the absolute yield. Nitrogen fixation by the legume will be reduced with increasing rates of nitrogen fertiliser, which will in turn make the legume less competitive. The impact of applying low (less than 50 kg N ha-1 yr-1), medium (50-100 kg N ha-1 yr-1) or high (> 100 ha-1 yr-1) was assessed relative to no nitrogen applied. At low rates, there was a possibility that yields could be reduced or showed little change from those receiving no nitrogen. At medium rates, yields tended to increase by between 5 and 35%. There were few observations where high rates of nitrogen had been applied, but the impact on yields varied between 5-15% increase to a 45-55% increase. However, unsurprisingly as the rate of N applied increase, the proportion of the legume in the yield decreased. The choices made by the farmer as to how the intercrop will be managed are influenced by whether the crop is being grown for feed or food, and the desired relative quantities of pea to cereal in the harvested yield. Seed rates and nitrogen applications affect the total yield and the relative yield of the cereal and pea.
An additional factor that the farmer can manage is the choice of variety, and although all the varieties have been bred to sown as sole crops, some will be better suited than others to the intercropping environment.

Acknowledgements Funded by H2020 ReMIX (https://www.remixintercrops.eu/), and Scottish Government Strategic Research Fund

Reference:

Li C, Hoffland et al. (2020) Nature Plants, 6, 653-660
Session 1

Increasing the Resilience and Resource Efficiency of Cropping Systems
The dormant seeding of rainfed lentil can improve productivity and water use efficiency in arid and semi-arid conditions

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Dormant seeding (DS) has become popular in dry areas because it provides a longer growing season and optimum temperature during the early spring to grow crop. Long-term daily weather data for the period of 1984–2014, were collected for ten locations in northwestern Iran with a cold semi-arid and arid climate. The SSM-legumes model was used to investigate the effect of dormant seeding versus different fixed spring sowing dates as well as cultivars on the yield and water use efficiency (WUE) of lentil. The results showed that, the highest average grain yield across all the study locations was obtained for DS management and decreased around 49% when sowing date was delayed to 4 April. Furthermore, with a delay in sowing date, the decline in grain yield of short- cycle and long- cycle cultivars was 42% and 58%, respectively. On average, WUE for short- cycle cultivar was much higher than long-season cultivar (6.2 and 4.0 kg ha-1 mm-1, respectively). The combination of short-cycle cultivar × DS management resulted in 30% and 29% increase in grain yield and WUE, respectively when compared with a long-cycle cultivar× DS management. This conclusion was reached because DS sowing and short-cycle cultivar increased yield and its stability due to the proper establishment and appropriate growth conditions of lentil in late winter and early spring. DS also resulted in better use of precipitation and escape from the heat and drought stresses in late spring and early summer, provided that there is no frost risk in the target regions. Overall, the results of the simulations for all the study locations suggested that sowing lentil using DS is indeed superior over the other fixed spring sowing practices because it not only shortens the frost risk to seedlings but also provides optimal conditions for the growth and use of rainfall and soil moisture as well as lentil growth.

Keywords: Cultivar, Frost risk window, Modelling, Sowing date.

References


Managing drought risk on chickpea under dormant seeding in a changing climate: Deficit irrigation and genotype impacts

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Agricultural production is facing unprecedented challenges to ensure food security by increasing productivity and in the meantime lowering environmental risk, especially in Iran. To enhance productivity and eco-efficiency of chickpea in the North western Iran, we optimized the Genotype (G) × Environment (E) × Management (M) interactions to propose the optimal agronomic management practices and genotypes for eight representative sites, with the SSM-legume model. We modelled the effect of future climate change on chickpea grain yield and water use efficiency for three genotypes, eight locations (as environment) and nine irrigation regimes (as management). Projections of future climate was conducted using the baseline period of 1980–2010 and five Miroc5 general circulation models for 2040–2070 under two RCPs using The Agricultural Model Intercomparison and Improvement Project (AgMIP) methodology. The results showed that the greatest WUE (9.20 kg ha−1 mm−1) was obtained in the interaction of ILC482× rainfed× in arid and cold environment. On the other hands, the optimal combination of G × E × M was a late-maturity (Hashem) × 60 mm irrigation at pod filling stage (SI POD-60) × arid and cold locations/ climate type (2311 Kg ha-1). In the future, the top-mentioned G × M interaction in semi-arid and temperate environments (E) and ILC482 genotype × SI POD-60 mm × semi-arid and temperate was simulated as the best-yielding combination of G × M × E in the upcoming period (2233 kg ha-1). Moreover, in arid and cold environment, ILC482 × rainfed conditions had the highest grain yield (2222 kg ha−1) and WUE (9.80 kg ha−1 mm−1) due to optimum growing season such as higher reproductive growth duration (4 d), days to maturity (10 d) and appropriate distribution of rainfall compared to other environments. This provides the best opportunity for farmers to exploit rainfall and decrease the amount of irrigation and costs.

Keywords: Environment, Productivity, Rainfall, Semi-arid

References


Effects of field data quality on crop model calibration

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Keywords:
crop model improvement, targeted field experiments, prediction accuracy, model evaluation

Process-based crop simulation models (CSMs) are valuable tools for assessing genotype by environment by management (GxE) interactions and quantifying climate change impacts on crops. Ex-ante evaluations of adaptation options to environmental stress require well-validated CSMs that are continuously improved and evaluated. Ideally, this would require comprehensive, high-quality data from field experiments that have been designed with requirements for modelling in mind. We collected detailed data on weather, soil and crop development in one season of barley (cv. RGT Planet) field experiments at Taastrup, Denmark. The resultant dataset meets the highest standards for crop model improvement as defined by the modelling community. To evaluate the importance and impact of data quality on model calibration results, the CSM APSIM was calibrated with a low, a medium, and finally with the high-quality dataset generated in the Taastrup field experiments. The low-quality dataset represents a typical situation of limited data availability for CSM calibration (e.g., limited soil description, few in-season phenology and biomass measurements). In a medium quality dataset usually better soil descriptions, phenology and biomass measurements at different crop stages are available, yet in lower temporal and spatial resolution than in a high-quality dataset. Phenology was predicted accurately with all datasets, but the highest accuracy was achieved using the high-quality dataset (normalized root mean square error (nRMSE) low and medium: 0.03, high: 0.01). The LAI prediction was especially poor with the low and medium quality dataset. Even though the prediction was more accurate with the high-quality data the overestimation was still notable (nRMSE low: 0.49, medium: 0.41, high: 0.28). Final grain yield was underestimated with the low and medium quality dataset but slightly overestimated with the high-quality dataset, which facilitated the most accurate yield prediction (difference between modelled and observed yield: low: -6%, medium: -3.13 %, high: +1.38%). Findings from this study support our basic hypothesis that calibrating a CSM with high quality data increases the prediction accuracy. However, our results show that calibrating LAI and grain yield (complex traits) require more comprehensive datasets than calibrating phenology. By generating such a high-quality dataset, we contribute to meeting the need for detailed and comprehensive datasets fit for model calibration and evaluation purposes. Such data sets are especially rare for barley in northern Europe. We also found that APSIM does not satisfactorily reproduce translocation processes, an issue that requires further field experiments and model improvement.
Reference:


Effects of different preceding crops and N fertilization on wheat roots, soil water and yield

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Growing wheat after wheat often causes a substantial yield decline compared to rotational cropping. An infection with the fungus Gaeumannomyces graminis var. tritici (Ggt) and a subsequent reduction of nutrient and water uptake of wheat plants due to the early senescence of the wheat roots is assumed to be the most common cause. However, yield decline in wheat grown after wheat is also found without a visible Ggt infection. To clear up possible mechanisms leading to this yield decline, wheat root growth, take-all disease severity and grain yield as well as soil water content in three crop rotational positions (wheat monoculture (WM), first (W1) and second wheat (W2) after oilseed rape) and with varying N fertilization (no N (N0) and optimal N fertilization (Nopt)) were investigated. Wheat roots were sampled with the destructive soil core method in four soil depths (BBCH 73) to determine root length density (RLD). The proportion of blackened wheat roots was determined after harvest to calculate the take-all-index (TAI). The soil water content was determined with a Sentek Diviner probe down to 1.5 m soil depth every 14 days throughout the season.

In 2020, wheat yield was similar among the crop rotational positions. The soil water content was lowest in W1 with Nopt in 30-90 cm soil depth. The RLD in 90-120 cm soil depth was significantly higher for N0 compared to Nopt. Possibly, the plants rooted deeper under N0 than Nopt to access nutrients, especially nitrogen. Among the rotational positions, the highest RLD was found in W1 (significant in 60-90 cm soil depth) which corresponds to the lowest soil water content, possibly explaining the higher yield. There was no significant interaction between crop rotational position and N fertilization for RLD.

In 2021, there was a significant interaction between the crop rotational position and N fertilization for wheat yield. The yield in both N fertilization regimes was significantly higher for W1 compared to W2. Additionally, the yield in WM was significantly higher than in W2, possibly due to the so-called “decline effect” in WM. The TAI in both N treatments increased from W1 over WM to W2. There was a close negative correlation between TAI and yield for both, N0 ($r^2 = 0.77**$) and Nopt ($r^2 = 0.94***$). Overall, growing wheat after oilseed rape seems to be more advantageous than after wheat because of an increased RLD and lower root rot occurrence.
Effects of reused water containing Pharmaceutical and Personal Care Products on rice germination

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Water scarcity is one of the greatest challenges of the 21st century. The reuse of treated wastewater in agriculture is a common practice in many countries. In recent years, a new pollutants category emerged, the Pharmaceutical and Personal Care Products (PPCPs). It is a group of pollutants, found in treated wastewater effluent with concentrations ranging from nanograms to micrograms for litre, due to the low efficiency of conventional and natural based wastewater treatment. A large number of researches were carried out on the PPCPs ecotoxicological effects. Barbera et al., (2020) reported that ibuprofen and caffeine affected the Oriza sativa L. growth and observed a translocation of these molecules to the rice grain. Considering carbamazepine (CBZ), sulfapyridine (SFP) and caffeine (CAF) (Kahl et al., 2017) the most common PPCPs present in treated effluent, the aim of this study was to evaluate the molecules effects on rice germination. For the germination trials, sterile distilled H₂O (Control), CAF (60 and 120 µg L⁻¹), CBZ (200 and 400 µg L⁻¹) and SFP (4 and 8 µg L⁻¹) were used separately or mixed using both the concentrations of each pollutant. Seeds of O. sativa CV Selenio were placed on a piece of Whatman® Filter Paper in a Petri dish (9 cm). The germination temperature was kept at 24 °C. Mean germination time (MGT) and the time to 50% germination (T50) were calculated according to Cavallaro et al., 2014 while Seedling vigor index (SVI) was calculated as follow: SVI= [Mean root length +Mean shoot length] × Percentage of seed germination. Data were subjected to analysis of variance (ANOVA). Mean comparisons were performed according to the Fisher’s LSD test.

T50 was affected by the studied treatments. Compared to Control, CBZ400 caused a significant T50 delay equal to ~19 hours (18%), while no significant differences were observed between SFP4, CBZ200 and SFP8. CAF120 showed no differences with Control, but an advance of germination (equal to 28 hours) was observed if compared to CBZ400. Compared to Control, hypocotyl length was significantly stimulated by SFP8 and CBZ200 (respectively +54% and +44%) while the other solutions showed no significant differences. A significant CBZ treatments (200 and 400 µg L⁻¹) effect was observed on epicotyl length. CBZ (200 and 400 µg L⁻¹) positively influenced epicotyl length (respectively +67% and +54%) compared to Control. The other studied treatments showed no differences. SVI was significantly higher in CBZ200 (+54%) and CAF120 (+48%) as compared to Control. No differences were observed for the other studied treatments.

In conclusion, the PPCPs studied had a different effect on rice germination. When mixed, PPCPs showed no difference with the Control. Among the single solutions, CBZ (200 and 400 µg L⁻¹) and SFP8 stimulated seedling growth while CAF120 reduced germination times. Since
PPCPs used are some of the most common molecules found in the treated wastewater, further studies are necessary to investigate PPCPs role in treated water when reused for agriculture.

Reference:


Nitrate leaching and soil mineral nitrogen from differently managed clover-grass leys under organic cultivation in North-Western Germany

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Nitrate leaching, organic agriculture, clover-grass management

As a crucial nutrient for plant growth and crop yield, nitrogen (N) management in organic agriculture can be challenging due to limited livestock densities and no use of mineral N fertilisers. Clover-grass leys have a high potential for biological N fixation, which is the most important renewable N source in organic agriculture. They are increasingly used as green manure crops (e.g. organic farms without livestock) resulting in large N inputs and high potential for N losses (Dahlin and Stenberg, 2010). After ploughing, the risk for nitrate leaching from clover-grass leys increases depending on time of termination and N demand of the following crop. Thus, the impact of differently managed clover-grass leys (e.g. cutting regime, time of ploughing) on soil mineral N (SMN) and nitrate leaching needs to be investigated for optimising N efficiency and preventing N pollution of the environment. A field trial was established in 2020 on a Plaggic Anthrosol with loamy sand as soil texture near Osnabrueck, Germany (52.31°N; 8.11°E) with a mean annual air temperature of 9.9°C and a mean annual precipitation of 823 mm. The field trial was cultivated organically according to the EU organic regulation. In a randomized block design with 4 replications, 4 different clover-grass treatments (mulching vs. harvesting combined with ploughing clover-grass in fall vs. the following spring) were integrated to observe the effect on SMN, nitrate leaching and yield performance of clover-grass and the following crops. No additional fertiliser was added to clover-grass stands. After fall ploughing of clover-grass stands, winter rye was sown as a cover crop. In the following spring, both -the overwintered clover-grass stand and the cover crop- were terminated and followed by silage maize. Clover-grass yield and protein content were determined during the vegetation period. For analysing nitrate concentrations in the leaching water, ceramic suction cups were installed in 80 cm depth below the root zone in each plot. During the winter season, the percolating water was continuously collected and analysed bi-weekly for nitrate. SMN samples were taken at the beginning of the vegetation period, after harvest and at the end of the vegetation period in 0 to 90 cm depth. In 2020 and 2021, there was no significant difference (p = 0.05) in clover-grass yields between stands after mulching and harvesting. But beneficial sowing and weather conditions in 2021 led to significantly higher clover-grass dry matter yields (sum of five cuts: 113.9 dt/ha) compared to 2020 (sum of three cuts: 39.8 dt/ha). From the third (2020) and fourth (2021) regrowth period, the proportion of clover increased significantly in the harvested compared to the mulched stands (2020: +17.3 %; 2021: +27.9 %), whereas no difference in protein content was observed between mulched and harvested stands. SMN in 0 – 90 cm depth after the last harvest was significantly higher in mulched stands (50.9 kg N/ha) as in the harvested stands (33.0 kg N/ha) in 2021. Ploughing clover-grass in fall led to higher SMN at the end of the vegetation period in
2020 (terminated: 26.1 kg N/ha; intact stands: 13.9 kg N/ha) and in 2021 (terminated: 58.6 kg N/ha; intact stands: 39.6 kg N/ha) which resulted in significantly higher nitrate loads up to 123.4 kg/ha in 2020.

Reference:


Effect of digestate application and crop precedent on wheat yield, grain N concentration and N uptake efficiency

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Keywords: anaerobic digestate, crop rotation, winter wheat

Certain conventional farming practices are degrading agricultural soils around the world. Resorting to several strategies such as crop rotations and organic fertilization can oppose this tendency. Rotating annual crops is an ancient practice that has been revamped due to increasing proof of ecological and economic benefits for farmers when compared to monocropping. A system that employs crop rotations should be more efficient at utilizing and recycling nitrogen (N). More so when rotating crop species with contrasting morphological traits and nutritional needs (e.g. cereals versus legumes), resulting in a better management of soil fertility. Anaerobic digestate is a by-product of a renewable energy production system that can be used as an organic fertilizer. Since it is very diluted, one can dry the digestate, mitigating several environmental and logistical issues involved in its application. The objective of this study was to assess how different N fertilization treatments (liquid digestate, acidified solid digestate, chemical N fertilizer, and control) and crops grown in the previous season (pea and triticale) affects the productivity and efficiency of a cropping system of winter wheat. Wheat grain yield and N concentration was determined in the 2020-2021 season for all treatments, along with soil mineral N concentration at sowing and at harvest. Results for differences in means of grain yield, N concentration and N uptake efficiency (NUpE) are presented. Preceding wheat with pea increased both yield and N content of wheat compared to triticale as a preceding crop. N fertilization form did not affect the wheat yield, but influenced N concentration of wheat grain. While all 3 treatments originated higher N levels in the grain than the control, only the solid digestate was up to par with the mineral N fertilizer. There were no observed differences in the NUpE of wheat due to fertilization type nor crop precedents. Results have shown the importance of the rotation design, since it can further increase wheat yield and grain N concentration without resorting to higher amounts of fertilizer N. This study has also demonstrated the potential of digestates as organic fertilizers for wheat cropping as a substitute of mineral N fertilizers. Overall, we have found that there are viable alternative practices that make winter wheat cropping systems more environmentally sustainable. This work was funded by the European Union under the Circular Agronomics project (H2020 research and innovation project N. 773649). IRTA thanks the support of the CERCA Program from the Generalitat de Catalunya.
Recycling calcium phosphite as phosphorus fertilizer

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Phosphorus (P) is a crucial nutrient for crop productivity. However, mineral reserves for P fertilizer production are decreasing so it is urgent to develop P recycling methods. This study tests the possibility to use calcium phosphite (Ca-Phi), a discharged industrial by-product, as P fertilizer considering that the P amount in Ca-Phi currently produced in Switzerland corresponds to 5-10% of the Swiss P fertilizer import. A greenhouse experiment was conducted where four different species of green manure (GM) crops were cultivated in presence of Ca-Phi in a clay and a sandy soil in order to oxidize the phosphite to phosphate for the following maize crop. More precisely, the objectives of this study were to test the effect of added Ca-Phi on: (i) phosphite concentration in GM and maize biomass, (ii) a set of indicators of biological soil fertility, and (iii) the availability of P to crop growth. Before sowing the GM crops, 38 kg P ha⁻¹ were added as Ca-Phi or as triple super phosphate (TSP), the later representing a reference fertilizer. A control treatment without any P input was also set up. In order to isolate the effect of the GM crops, the same fertilization treatments were also carried out in bare soils, i.e. without the GM crop. After 8 weeks, the aboveground biomass of GM crop was mixed with the soil of the same pot and then repotted in order to simulate the incorporation of GM residues in the field. Maize was then sown and the aboveground biomass was harvested after 8 weeks. The aboveground biomass of GM crop and maize were weighed and the phosphite concentration was measured. At the end of GM and maize growth, soil was analyzed for microbial carbon (Cmic), organic carbon (COrg) as well as the available P (P-NaHCO₃). Aboveground biomass yields of GM crops and maize did not differ between P treatments so that there was any effect associated to recognized phosphite phytotoxicity, possibly because soil P was not limiting. Concentrations of phosphite in the GM biomass varied according to the species and the type of soil, while no trace of phosphite was observed in the aboveground biomass of maize. The effects of Ca-Phi and TSP on Cmic and COrg mineralization were comparable and specific to the two contrasting soil types. At the end of GM and maize growth, Ca-Phi increased P-NaHCO₃ as much as the TSP in the sandy soil, but more than TSP treatment in the clay soil. This result for the clay soil is probably due to a slower P release from Ca-Phi than from TSP. Overall, this study shows that, under contrasting soil conditions and different GM species, the phosphite was oxidized during the GM growth and that Ca-Phi addition did not have a negative impact on biological fertility.
Compost in organic farming - learning from tea bags

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Organic farming is highly dependent on closed nutrient cycles. Composts made of green waste and biowaste can help closing nutrient cycles as well as compensating nutrient deficiencies particularly in organic arable farms. In the project “Optimum production and agronomic use of compost from organic and green waste in organic farming” comprehensive investigations in field trials and in composting plants are supplemented with surveys of farmers about composting. Agronomic and environmental effects of different composts will be evaluated under differing site and cultivation conditions in organic farming.

Microbial biomass, diversity and activity are all involved in regulating soil ecosystem services such as plant productivity, nutrient cycling and greenhouse gas emissions. Organic matter decomposition can serve as an indicator for soil biological activity. Fertilization regime has a great effect on soil microbial community. In a compost long-term experiment and in three on-farm strip plot experiments at three organic farms in Bavaria in Germany, the biological activity was studied. To compare the decomposition of organic matter by soil microbial community in soils with different organic fertilizers (biowaste and green compost with two different degrees of maturity, manure, biogas digestate, farm composts) the Tea Bag Index Method - TBI was used. TBI uses commercial tea bags as standardized litter bags to quantify decomposition rate (k) and stabilization factor (S) of litter in soils. As tea type, rooibos and green tea from Lipton (Unilever) were used, which are all provided from one charge to fulfill standardized conditions for experiments made with the Tea Bag Method.

Generally, the organic fertilizers increased the microbiological activity in comparison to unfertilized control. In accordance with other studies investigating mass loss with the tea bag method, we found that green tea decomposed at faster rates than did rooibos tea. The different site conditions of the experiments (e.g., temperature, precipitation, soil moisture and properties) affected the decomposition. Further investigations are needed to differentiate the effect of different organic fertilizers.
Resource Valorization Through Organic Fertilization On A Camelina Sativa Rotation

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The agricultural sector is heading towards the implementation of more sustainable agronomic practices to promote environmentally friendly crop production. Environmental sustainability in agriculture can be promoted through efficient resource management and crop rotation. In this regard, the objective of this study was to provide on-field data of the effect of applying two types of organic fertilizers on a crop rotation system of Camelina sativa (L.) Crantz to evaluate the agronomic performance and soil properties. Field experiments were carried out during three growing seasons, from 2015 to 2018. The experimental design consisted of the crop rotation camelina–barley–camelina and three fertilization treatments (composted sludge fertilization, dewatered sludge fertilization, and control treatment without fertilization). Camelina and barley were cultivated in a non-irrigated block design with three replications of each treatment including the control.

The findings from this investigation revealed that camelina's yield in the first and third seasons was limited by relatively high temperatures and low rainfall, which delayed the crop’s growth and did not show any differences between the fertilized treatments and the control. Regarding camelina’s yield components, composted sludge presented a significant difference with respect to the control and the dewatered sludge in the number of silicles plant−1. In relation to the number of seeds plant−1, the dewatered sludge fertilization presented the highest values, being 17% higher than the control. Results also showed a significant increase in the thousand seed weight in both organic fertilizations with respect to the control, but this difference obtained between the organic fertilizers was not significant. The application of organic fertilizers did not significantly increase camelina’s height compared to the control. This effect could be due to the limiting water availability during the experiment period. Nevertheless, the findings of the thousand-seed weight and plant height were in agreement with studies applying mineral fertilization, being the average values of thousand-seed weight and height 1.3 g and 114.4 cm, respectively. Furthermore, it was seen that nitrogen fertilization applying organic fertilizers enhanced protein synthesis obtaining high protein content in camelina’s seed. Therefore, potential use for camelina crop could be animal feed. With respect to soil fertility, the combination of crop rotations and appropriate fertilization leads to the maintenance of nitrogen and organic carbon at adequate levels. In this study, organic matter content in the soils was positively increased with organic fertilization. After the crop rotation, no significant change was observed in the content of nutrients, meaning this crop rotation system had not depleted the soil’s nutrient content. Although an increasing tendency in heavy metals concentration was observed after the three-year investigation, the levels remained below the critical values established by the Spanish government for heavy metals in soils.
Despite the undesirable weather limitations, camelina’s yield components and seed quality showed, to some extent, a positive response to organic fertilization, while ensuring suitable soil characteristics. This study highlighted the potential use of the composted sludge and the dewatered sludge as organic fertilizers for the cultivation of camelina as an alternative to chemical fertilization to promote resource valorization.
The impacts to heat stress and thermo-priming on seed fatty acids profile and on root exudation

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UMR INRAE-UNICAEN 950 EVA

High temperatures are one of the most deleterious abiotic stresses on yield and seed quality in oilseed crops such as Oilseed rape (OSR) and Camelina. High temperatures also lead to altered root development and exudation in oilseed rape plants. In the perspective of providing strategies to help crops face more frequent heat waves, the application of a gradual temperature increase prior to an intense heat stress event at the onset of seed filling has been investigated as a putative thermo-sensitization protocol to maintain crop performances i.e. yield components and seed quality, and the root system functioning in terms of prospection (root growth and development) and exudation.

Our results indicated that there was no effect on the yield of camelina and OSR. In Camelina, the total oil content increased with temperature, but this was not the case in OSR. In fact, in contrast to camelina, the quality of the fatty acids (FA) profile in OSR was impacted by stress, in the cohort of the filling seeds at the time of the stress exposure. Thus, in OSR, a decrease in the concentration of mono-unsaturated FA (C18:1) was observed. The ω6:ω3 ratio also increased as a consequence of higher C18:2 over C18:3. But these modifications were alleviated upon the thermo-sensitization protocol. A priming effect was also observed on the ω6:ω3 ratio which value remained similar to the control while it increased under the intense heat stress alone. Our results also indicated alleviating effects of the gradual temperature increase over deleterious effects of the intense heat stress alone, on the rates of pre-harvest sprouting in OSR (lower) and the amounts of carbon and nitrogen exuded in the two species (reduced).

Moreover, in both crops, the amounts of organic acids exuded were also impacted upon the stressing protocols. In OSR, these amounts and in particular those of malate decreased upon intense heat stress while in camelina, the total amount of organic acids exuded was not impacted but the quantity of malate exuded increased. Thus, these results provide insights on how heat stresses can trigger specific signals such as root exudates that can promote or select soil microorganisms (e.g. Plant Growth Promoting Rhizobacteria (PGPR)) in the perspective to develop interactive adaptation strategies under heat stress. Overall, our study demonstrates that a gradual temperature increase acts as a thermopriming strategy allowing plants to be acclimated. This could be used in breeding schemes to create thermo-primed parental lines.
Phosphorus (P) is an essential element for plant nutrition. The current fertilization strategies rely on mineral fertilizers, obtained from non-renewable and finite resources, whose production will peak in the coming decades. In a scenario of world population growth, reducing dependence on mineral fertilizers while maintaining/increasing agricultural productivity is essential. To this end, fertilizers strategies should involve P recycling by using agricultural residues. The aim of the work is to evaluate the efficiency of different agricultural residues as P fertilizers in a rainfed crop rotation cycle representative of Mediterranean regions: wheat-sunflower-pea. Two experiments under field conditions were carried out in south Spain for 3 years involving as treatments: composted olive oil mill, horse manure vermicompost, and mineral P fertilizer which were applied at 30 kg P ha\(^{-1}\), and a control without fertilizer. The same rates of potassium and nitrogen were applied to all the treatments. Phosphorus fertilizer was applied before sowing only to the first crop (wheat). Fertilization with composted agricultural residues was effective as P source for crops. In the first experiment, the highest grain yield of wheat was obtained with olive oil mill compost. However, in the second crop of the rotation (sunflower), the horse manure vermicompost showed a significant increase (41%) relative to mineral fertilizer and non-fertilized control. In the second experiment, vegetable waste vermicompost led the highest grain yield of wheat. Phosphorus uptake by pea in the first experiment was increased significantly with olive oil mill and vegetable waste vermicompost (mean value of 11.1 kg ha\(^{-1}\)) compared to mineral fertilization and non-fertilized control. Olsen P in soil amended with organic P sources maintain their value of 7.2 mg kg\(^{-1}\), slightly higher than control without fertilization at the end of both crop rotations. However, mineral fertilization led to the highest Olsen P values in soil, which however decreased over time more quickly than organic fertilizers. It can be concluded that the composted agricultural residues studied can be used as effective P sources for crops, and thus may contribute to decrease the dependence on mineral P in agriculture and consequently to the sustainability of agricultural systems.

Keywords: phosphorus, crop rotation, organic fertilizers

Funding: Spanish Ministry of Science and Innovation and the European Regional Development Fund of the European Union through the National Research, Development and Innovation Program (Plan Nacional I+D+i). Projects AGL2017-87074-C2-1-R and PID2020-118503RB-C21
Organic management increases litter decomposition rates in banana fields

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In agroecosystems, the decomposition of crop residues is a fundamental process to ensure the turnover of nutrients and their assimilation by crops. This process is conditioned by various factors: climate, litter quality and the abundance and diversity of decomposer organisms. Agricultural practices play a major role in altering these factors. This is particularly the case for monoculture systems that are intensive in chemical inputs such as herbicides. In these cropping systems, the lack of plant cover and diversity can alter soil moisture and temperature, and suppress habitats for decomposer organisms. In addition, there would also be contamination of litter with pesticides which could make the litter toxic or less palatable to decomposer invertebrates.

In this study, we tested the effect of conventional versus organic farming practices on the decomposition of banana leaves, in situ in banana plantations. We selected 6 banana plots under organic management and 6 plots under conventional management. Litter mass loss was measured by the litter bag method and the effect of soil macrofauna was estimated by using different mesh sizes: 0.1mm for decomposition due to micro-organisms and 10mm for decomposition due to micro-organisms and macrofauna. The litter bags were filled with either leaves from banana plants killed by glyphosate injection or leaves from mechanically killed banana plants. Glyphosate injection is a practice commonly used in conventional management for the destruction of banana plants in case of plot renewal. A total of 264 litterbags were deposited and distributed equally between organic and conventional management plots. The temperature and relative humidity of air, plant diversity, soil vegetation cover and the abundance and diversity of decomposer invertebrates were measured to characterize organic and conventional plots.

Our results showed a significantly higher litter mass loss in the organically managed plots than in the conventionally managed ones. The higher vegetation cover in the organic plots seems to best explain this difference in decomposition rate. Indeed, the dense plant soil cover in the organically managed plots would allow a higher moisture content, accelerating microbial decomposition. In addition, the proportion of mass loss due to soil macrofauna is higher in the organic plots. This result suggests that conventional agricultural practices, especially the use of herbicides, had a cascading negative effect on litter decomposition through microclimatic conditions and a reduced macrofaunal activity. On the other hand, glyphosate contaminated banana leaves did not show a significantly different mass loss than mechanically killed banana. This result indicates that the use of glyphosate for the chemical destruction of banana plant is less damaging for the decomposers than field application of glyphosate for weed control.
Phenotyping Nitrogen Efficiency in 40 Pre-Breeding Clones of Potato (Solanum tuberosum L.)

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Nutrient efficiency; hydroponics; nitrogen deficiency stress; organic breeding

Nitrogen is well known as a key factor in plant production. It is one of the most abundant elements in plant biomass and an essential component of amino acids, proteins, nucleotides and nucleic acids. As important a role as it has in growing field crops, such as potatoes, intensive nitrogen fertilisation can be a threat to other natural resources. While a suboptimal amount of N can cause stagnation in plant growth and subsequently yield losses, too much nitrogen cannot be taken up by the plants, therefore finding its way into surrounding bodies of water, causing damages to the environment.

By default, many agricultural areas are deficient in one or more nutrients essential for plant growth. To avoid accidental overfertilisation, while still maintaining high quality yields, nutrient efficient plant varieties are essential. As potatoes have a very small and shallow root system, they cannot mobilise nutrients from deeper soil layers and are therefore especially prone for nutrient deficiencies.

In order to identify potato genotypes with high nitrogen efficiencies, we conducted several high-throughput phenotyping experiments on 40 potato clones from an organic pre-breeding project as well as standard varieties. The experiments were conducted utilising a greenhouse-based hydroponic system with a nutrient solution based on the composition of a full-strength Hoagland Solution with some of the nutrient sources modified for our purposes. Two nitrogen treatments, a control treatment and one under nitrogen deprivation conditions, were used for phenotyping each genotype for its reaction to nitrogen deficiency stress. At the end of each four-week trial period, the remaining nitrogen in the nutrient solution as well as sprout and root biomass were measured. Analysis of the sprouts’ nitrogen contents was conducted for all potato pre-breeding clones as well as standard varieties. To be able to compare the genotypes’ reactions regarding nitrogen stress with each other, we calculated their nitrogen use efficiencies (NUE) as well as the stress tolerance indices (STI) and found significant differences between the pre-breeding clones’ responses to nitrogen deficiency stress.

In subsequent experiments, the genotypes will be tested via genome-wide association studies to identify reoccurring genetic markers for nitrogen efficiency. Using the resulting markers, the breeding process could be streamlined and accelerated, enabling potato breeders to supply especially organic farmers with a wider spectrum of nutrient-efficient potato varieties.
Expression of AMT1; 1 and AMT2; 1 genes in barley is induced by mineral nitrogen at anthesis stage in field conditions

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Ammonium transporter, Barley, Conventional, Organic

Barley (Hordeum vulgare) is an important cereal for food and feed. Nitrogen is crucial for the productivity and the future varieties and management systems need to be more efficient in nitrogen uptake and utilization. The aim of this work was to determine the effects of growth stage and mineral N-fertilizer rates and organic fertilizer on HvAMT1; 1 and HvAMT2; 1 expression patterns and to determine the correlation with N content and 1000 kernel weight. Barley leaves were collected in 2019 from a long-term field trial. AMT genes were downregulated compared to the unfertilized treatment until anthesis, mineral fertilizers having stronger effect. Relative expression of HvAMT1;1 and HvAMT2;1 was the highest in the anthesis stage, being accordingly 3.6 and 2.5 times higher compared to average of other growth stages analyzed. HvAMT1; 1 was expressed 2.8 times more than HvAMT2; 1 at the same time. Positive correlation between N content in leaves and AMT gene expression was observed in anthesis. Also, expression of both genes was positively correlated to 1000-kernel weight. Overall, HvAMT1; 1 and HvAMT2; 1 activity is responsible for nitrogen uptake and it is valuable candidate for breeding programs.
Effects of legume green manuring, N fertilization and reduced tillage on yield, water and nitrogen use efficiency

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Maize is one of the main irrigated crops in northern Spain. The traditional cropping system used has been intensive monoculture, which has numerous negative effects on the physical-chemical and biological properties of the soil. A promising practice to increase the sustainability of farms is the use of legumes as green manure. The aim of this work was to evaluate the combined impact of introducing a legume green manure prior to maize, together with different tillage systems and mineral N fertilization rates on crop yields and water and nitrogen use efficiencies (WUE and NUE) under Mediterranean irrigation conditions. The study is being carried out in Agramunt (NE Spain). A long-term tillage and N rate fertilization field experiment established in 1996 under rainfed conditions was transformed into irrigation with maize (Zea mays L.) monocrop as cropping system in 2015, and into a diversification experiment in 2018. Maize monocrop (MC) against a vetch green manuring-maize double cropping (DC) with three tillage systems (conventional tillage, CT; reduced tillage, RT; no-tillage, NT) and three mineral N fertilization rates (0; medium, 200 kg ha⁻¹ in MC and 150 kg ha⁻¹ in DC; high, 400 kg ha⁻¹ in MC and 300 kg ha⁻¹ in DC) were compared. Yields in DC were similar to those obtained in MC. The best results were obtained in NT or RT. No differences were found for high or medium rates of N fertilization. NUE was higher in the DC treatments, more so when this system was used with medium N fertilization rates. For this parameter, no significant differences were found between the tillage systems. The use of NT generated the highest WUEb (for biomass) and WUEy (for grain). The use of DC resulted in a significant increase in WUEb. On the other hand, the highest WUEy values were found in the MC system. For both WUEb and WUEy there were no significant differences for the use of high or medium rate of N fertilization. The results of this study indicate that in Mediterranean agroecosystems, the use of vetch as a green manuring together with no tillage systems and reduction of nitrogen fertilization can be a good strategy to maintain crop yields, while saving nitrogen fertilizer, and to improve NUE and WUEb.
Changes in Soil and Yield after 10 Years of Organic vs Mineral Fertilizers

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In semiarid environments, soil organic matter (SOM) building is critical for preventing soil degradation and for maintaining soil fertility. Both reducing tillage intensity and the addition of organic residues have been recognized as sustainable practices that usually lead to an increase in SOM content. However, the combination of both techniques in the field still constitutes a challenge in some areas. We evaluated the effects of minimum tillage practices (MT) in combination with different crop nutrient sources (i.e. traditional mineral fertilization (MIN) vs organic amendment application (ORG)) in a long-term field trial. Soil organic matter, i.e. C and N contents were measured and SOC and SN stocks calculated. In addition, wheat yield and biomass and other soil properties were measured (pH, soil nutrients (i.e., Olsen P, exchangeable K, and mineral N)). Data analysis and ANOVA was performed in different ways: analysing the year effect for the management (ORG vs. MIN) applied, analysing the Management effect every year as independent periods, analysing the management effect considering year as a replicate and analysing the management effect considering the time passed from the organic fertilization application.

The wheat yield was significantly higher under the ORG treatment than under the MIN, although climatic conditions along the 10 years (e.g., rainfall) exerted a great influence too. Plots under organic amendment application did not accumulate significantly more soil organic matter than those mineral-fertilized, probably due to the low protective capacity of coarse-textured soils. The organic amendments increased soil nutrients content mainly right after their application but the levels were adequate for the whole crop rotation. We encourage the implementation of conservation practices in combination with organic amendments application in semiarid areas because yields were satisfactory and these systems do not rely on mineral fertilizers and nutrients from organic wastes are recycled.
Modelling long term impact of diverse cover crops in dryland on fallow efficiency and soil nitrogen dynamics

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Keywords: Crop diversification; ecosystem services

Conventional dryland cropping systems rely upon frequent and lengthy fallow periods to conserve soil water and mineral nitrogen and thus stabilize crop production. However, fallow efficiency is typically low, and frequent fallowing is linked to soil organic matter depletion and decreased system productivity. Cropping system diversification by incorporating cover crops has been touted as a means to stem soil organic matter loss and improve the management of soil water (Bommarco et al. 2013; Garland et al. 2021). Cover crops have been an integral component of ecological intensification providing a wide range of ecosystem services including soil water conservation, reduction in N leaching, weed suppression and disease/pest break, N supply and retention, and overall improvement in soil functions (Daryanto et al. 2018). However, research on the ecosystem service benefits of cover crops has been limited to predominantly high rainfall regions where crop production is not primarily limited by water availability. In water-limited environments, where capture and storage of highly variable rainfall is the main driver of crop yield and profitability, the adoption of cover cropping has been constrained by soil water and mineral N availability and climate variability. Guidelines for best cover crop management practices are generally limited in water-limited environments. This study aimed to provide a baseline for cover crop selection towards maximizing fallow efficiency and soil N accumulation in subtropical dryland rotations in the northern grains region of Australia. The objective of the study was to determine the long-term impact of dryland cover cropping using cover crops with diverse functional traits in mono- and polycultures on soil water and N during fallow periods. A legume (Fababean; Vicia faba), a brassica (Forage rape; Brassica napus), and grass (Forage oat; Avena sativa) cover crops were managed in different sowing proportions of 100% monoculture of each species, 2-species, and 3-species across 3-site-year experiments. We measured cover crop biomass production, leaf area index (LAI), cover crop N uptake, and soil water and mineral N content at different phases of a typical dryland rotation during fallow periods. The long-term impacts of these cover crops were then investigated using The Agricultural Production Simulator (APSIM). Models in APSIM were calibrated and validated with the field data and applied in a 40-year long-term simulation.

Across all cover crops, the model simulated soil water, cover crop biomass accumulation, N retention in biomass relatively well (R2 > 0.6, d-index > 0.6). A long-term simulation estimated that grass-legume mixtures provided the best compromise between biomass production, N supply and retention, and fallow efficiency. Brassica-associated cover crops consistently had the highest biomass production but led to greater pre-emptive soil water and N risk at end of the fallow period (i.e., immediately before cash crop sowing). The potential of using cover...
crops that mitigate soil water and N trade-offs presents an opportunity for the diversification of cropping systems in the northern grains region of Australia. In particular, grass-legume cover crop mixtures may offer the greatest potential towards minimizing the adverse effects of fallowing and maintaining stable crop production.

Reference:


Effect of climate change on peach (Prunus persica L.) bloom period in Southern Spain

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Climate change projections indicate a rise in spring temperatures for different scenarios. In the same vein, phenology analysis forecasts an advance of peach bloom dates. However, blooming is a two-phase process requiring chill and heat. Peach cultivars present a wide range of chilling requirements, from low to high chilling necessities. We hypothesize that genotype x environment interaction defines the climate change impact on blooming. To test our hypothesis, we used a phenology model to explore the effect of climate change on low chill (LC) and high chill (HC) peach varieties in southern Spain. We analyzed phenology with a sequential model predicting the timing of bloom. In the model, a certain number of chilling portions need to be fulfilled first, and then bloom occurs once a certain amount of thermal time has been accumulated.

Synthetic weather data were generated using LARS-WG6 software. The synthetic series were generated from 20 years of weather records from a public weather station located in Córdoba, Spain (37.83 N, 4.87 W). In the bloom analysis, we compared the baseline weather with two climatic scenarios, RCP45 and RCP85 from the HadGEM2-ES global circulation model. Results showed a delay of 6 (RCP45) and 10 (RCP85) days of bloom start for LC and a 90 % (RCP45) and 100% (RCP85) bloom failure for HC. The end of bloom was also delayed in LC for the two climatic scenarios but at a smaller magnitude. Hence, the model predicted a contraction of the bloom period (4 and 6 days for RCP45 and RCP85). Therefore, at the study site, climate change will potentially minimize the risk of frost damage in LC. However, it will shorten the pollination period through a reduction of bloom time. The final effect on the fruit set will depend on pollinator abundance and the weather conditions during bloom. Our results show that climate change's impact on blooming is genotype x environment dependent. The effect of pollination period changes on yield needs to be further explored by combining crop models with pollinator dynamic analysis.
Nitrogen application in grass seed production using sensor information and the critical nitrogen dilution curve

Prof. René Gislum; Dr. Anders Krogh Mortensen PhD; Dr. Birte Boelt PhD

Aarhus University

There is a general consensus that grass seed yield is positively correlated to nitrogen (N) status (%) at stem elongation (Gislum et al. 2005). Sensor technology in combination with statistics/chemometrics has been proven to predict plant N status (Flowers et al. 2010), seed yield (Gislum et al. 2009) and biomass in perennial ryegrass using images (Mortensen et al. 2015). The Critical N dilution Curve (CNC) in grass seed crops describes the relation between biomass and N status during the spring/summer growing season and is used to show if N is limiting biomass production and consequently yield (Gislum and Boelt, 2009). By combining the aforementioned information, we have been able to set up and test a system to calculate the amount of N necessary to assure N will not be a limiting factor. This method has been successfully tested in field experiments at Aarhus University. The purpose of the oral presentation collect and present results from several field experiments conducted in perennial ryegrass and red fescue for seed production.

The results showed a large effect of years, not only on seed yield, but on how the method was able to predict an additional N application rate. In most experiments the method saved N without compromising the seed yield, however there were results where the method underestimated the N optimum application rate. We are confident that the reason for underestimation an additional N application rate is due to favourable growing and yield performing conditions in the period from application of the additional N until seed harvest. The period from late May until harvest is very important for creating the final seed yield and our method and other methods using similar systems has no influence on yield formation in this period.

Our conclusion is that we believe in our method and the results, however we must be realistic in our expectations when it comes to performance of sensor systems and optimising N applications in general as the biological cropping system is very complex and difficult to predict.


The security of an edible potato produced by integrated technology

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Additionally to the components that determine the nutritional value, potato tubers contain undesirable substances, i.e. certain natural components or those resulting from disturbances in the plant’s metabolism. These substances may also originate from a contaminated environment and are referred to as antinutritional components e.g. nitrates (V) and toxic components e.g. nitrates (III). According to the guidelines of the FAO/WHO experts Committee for food additives (JECFA 2002) and the Commission Regulation (WE) number 1822/2005 from 8th of November 2005 the total content of nitrates (V) in the potato tubers should not exceed 200 mg·kg\(^{-1}\) of the fresh matter.

The tendency to accumulation of nitrates (V) and (III) of 18 polish and foreign varieties of an edible potato obtained by the integrated production system, characterized by different length of growing seasons, were compared. These experiments were carried out during two growing seasons (2020 and 2021) in Kuyavian-Pomeranian (Poland). During the growing process, the plant health products were applied according to the rules of IOR (Institute for Plant Protection) and soil application of fertilizer in accordance with the guidelines for edible varieties. During the drought seasons, the irrigation with the use of Irtec Hippodrom pivot irrigation was applied. The markings of nitrates (V) were conducted with ionoselective method with the use of multifunctional tool: CX – 731 Elmetron brands in the potatoes directly after the harvest, as well as after 6 months of storage. The samples of potato (10 kg from each plot) were stored in chambers, at constant temperature +4 °C and relative air humidity of 95%.

Regardless of the experiment factors, the average content of nitrates (V) and (III) in tubers marked directly after the harvest, was relatively low and stood at as much as 62,88 and 0,632 mg kg\(^{-1}\) respectively. The lowest content of nitrates (V) and (III) was discovered in Wega variety: 28,40 mg·kg\(^{-1}\) i 0,18 mg·kg\(^{-1}\), whereas the highest amount of nitrates (V) and (III) was discovered in Tacja variety 95,62 and 0,98 mg·kg\(^{-1}\) respectively. No examined variety exceeded the acceptable standard of nitrates (V) content in the fresh matter of tubers. It was also proved that the content of nitrates (V) and (III) in tubers was significantly dependent on the growing season. The considerably lowest content of nitrates (V) and (III) was indicated in the varieties belonging to the mid-early groups 47,81 mg·kg\(^{-1}\) and 0,53 mg·kg\(^{-1}\) respectively, while the highest content – very early groups 87,93 mg·kg\(^{-1}\) and 0,92 mg·kg\(^{-1}\). Among three examined very early varieties, the lowest amount of nitrates (V) and (III) was discovered in Impresja variety: 81,08 i 0,932 mg·kg\(^{-1}\). In the group of nine examined early varieties, the tubers of Wega and Golden Marie were characterized by the lowest content of nitrates (V) and (III). In the group of five mid-early varieties, the tubers of Tajfun and American Rose had the lowest content of noxious nitrates. In the present research the mean content of nitrates
(V) after 6-mo storage, irrespective of the experiment factors, decreased by 23.3%. The highest decrease of the nitrates content has been observed for very early potato varieties (26.7%), consecutively for early varieties (22.3%) and mid-early (20.8%). The changes in the content of nitrates (III) after 6-mo storage were lower than in the case of nitrates (V). A decrease in the content of these nitrates was observed on the level of 10.5% approximately. The conducted research proved that low amounts of nitrates in the potato tubers can be obtained by introducing the limits to mineral fertilizing and irrigating. The consumption of 300 g of each variety tubers does not prove to be harmful for the consumer’s health.
The evaluation of photosynthetic features of potato on the basis of genetic factors and cultivation technology

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The photosynthesis is a basic physiological process of a plant. Each restriction on the intensity of this process causes a decrease in the amount and quality of the yield. The photosynthetic properties of two mid-early potato varieties (‘Denar’ and ‘Gardena’) coming from three strictly field trials have been compared. These experiments were carried out during two growing seasons (2020 and 2021) in Poland. In the experiment A doses of mineral nitrogen (nitrochalk 27%: N): 50 and 100 (the doses of were applied before planting) whereas 150 kg·ha⁻¹ (100 kg·ha⁻¹ before planting and 50 kg·ha⁻¹ directly before the emergence of plants) were used. In the experiment B there were used plant protections options: i) complete chemical protection applied with the use of fungicides according to the IOR (Institute for Plant Protection); ii) one treatment with a systemic fungicide; iii) the dressing of tubers before planting with the silver stabilised hydrogen peroxide and the use of chemical protection with fungicides according to IOR. In the experiment C there were: irrigated and non-irrigated. In each section there were used: i) seaweed biostimulant; ii) a soil applied hydrogel (supersorbent). The fluorescence of leaves parameters were defined: the maximum efficiency of PS II photosystem in the darkness (Fv/Fm), the minimum value for fluorescence of dark-adapted (Fo), the maximum value for fluorescence of dark-adapted (Fm). The measurements in potato vegetation: BBCH 59 and 61. Moreover, the general content of chlorophyll ‘a’ and ‘b’ and carotenoids in the leaves was measured. ‘Gardena’ was characterized by higher Fv/Fm parameter value in comparison with parameters defined for ‘Denar’. This variety indicates a higher efficiency of PS II photosystem. It is confirmed also by a greater content of chlorophyll and carotenoids pigments in ‘Gardena’ variety. The mineral nitrogen was affecting the growth in the content of all the pigments in the leaves (chlorophyll a, b, the total chlorophyll, the total carotenoids), as well as a higher efficiency of fluorescence in comparison with the test control. The best effects were obtained in this range after applying nitrogen of 150 N·ha⁻¹ especially in the year 2020 which was characterized by better weather conditions. There was obtained an increase by approximately 45% in the total content of chlorophyll pigments and carotenoids. ‘Gardena’ was characterized by higher content of chlorophyll pigments and carotenoids by 33% in comparison with ‘Denar’. Moreover, ‘Gardena’ was reacting definitively better to the plant protection in the form of one treatment with a systemic fungicide. The similar relations were obtained for the fluorescence indicators. The best effects in this range were acquired thanks to the application of complete chemical protection with the use of fungicides in accordance to IOR in 2020. Among the factors affecting the soothing of abiotic stress in potatoes, the highest efficiency of photosynthesis (Fv/Fm and Fm) was obtained after the application of biostimulant. Better
impact of hydrogel was proved on the non-irrigated treatments. The use of irrigation affected a decrease in the content pigments in the year 2021 which was characterized by unfavorable weather conditions. It has been found that there is a possibility of using the fluorescence parameters of chlorophyll in order to estimate the tolerance of potato varieties to a drought stress. The varieties differentiated on the biggest scale the indicators of photosynthetic efficiency of plant. The increase in the parameters of fluorescence contributes to a prolongation of the potato growing season. It may affect the yield of tubers and their qualitative parameters.

Effects of cover crops with contrasting properties on soil structure and subsequent early sugar beet with varied N fertilization

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Institute of Sugar Beet Research

Cover crops can improve soil structural properties through the interaction of cover crop roots with the soil mineral phase as well as by the input of additional organic material into the soil. Different cover crops, however, have differing properties regarding above- and belowground biomass production as well as root architecture, which may lead to varying extents of potential soil structure benefits following cover crop growth.

In this study, four cover crops with different properties (oil radish, saia oat, spring vetch and winter rye) were compared to a fallow control treatment in two field experiments in subsequent years in Central Germany regarding soil structure (as shown by the parameters soil pore volume, penetration resistance, and aggregate stability), soil Nmin and soil water contents in the topsoil as well as subsequent early sugar beet growth, either with optimal or no N fertilization.

The cover crops showed large differences in above- and belowground biomass, with rye and radish having the highest and vetch the lowest values. There was no effect of the cover crops on soil water content in spring, while topsoil Nmin content in April and May was increased compared to fallow, albeit only partially significantly. Soil pore volume was hardly affected by the cover crops, however, penetration resistance in the topsoil and the plough pan was lowered and aggregate stability in the upper 10 cm was increased by the cover crops to varying degrees. The extent of the benefits of the different cover crop might be connected to the respective accumulated root biomass, with largest effects found for radish and rye. Early sugar beet growth by May was increased for all cover crops compared to fallow independent of N fertilization, although significantly only for oil radish. As revealed by a regression analysis, aggregate stability and penetration resistance in the plough pan were identified as major influences on early sugar beet growth. Overall, sugar beet can benefit from soil structural improvements following a one-year cultivation of cover crops. This effect, however, is modified by cover crop properties, especially regarding cover crop roots.
Crop rotational position affects root health, soil water content, light interception and yield in wheat

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Yield decline of wheat in self rotation is often attributed to root senescence caused by infection with Gaeumannomyces graminis var. tritici (take all). Recent findings, however, indicate that a broader shift of the rhizosphere microbiome may be involved in the decline. The “RhizoWheat” project aims to elucidate and quantify key rhizosphere processes governing yield decline of multiple cropped wheat and to establish a model framework enabling the prediction of yield decline as a function of initial soil inoculum and environmental factors. We use rainout shelter experiments and long-term crop rotation experiments to measure the effects of crop rotational position, nitrogen fertilizer and drought stress on crop development, root health and yield. The experiments are located at Kiel university’s experiment station “Hohenschulen” in Northern Germany.

The rainout shelter experiment allows us to compare the performance of wheat grown after wheat and grown after fava bean under drought stress and optimal water supply. The long-term experiment was established in autumn 2015 and consists of four crop rotations and five fertilization levels. We use a crop rotation where wheat was grown for four consecutive times after canola.

Data were collected throughout the growing season via UAV-based multispectral imaging, destructively by harvesting biomass samples and three growth stages, visually by root health evaluation, with hand harvest for determination of yield components and combine harvest for grain yield. Soil water content was measured regularly by using a Sentek Diviner-2000 FDR sensor system.

Data collected in 2021 showed the expected increase in biomass development, light interception and yield at optimum water and nitrogen fertilizer supply compared to suboptimal conditions. Root health was positively affected by drought, probably due to poor conditions for pathogens. Crop rotational position affected root health, canopy development and light interception as well as yield. Wheat in self-rotation led to poorer root health in both experiments. However, optimum nitrogen fertilization reduced disease incidence. Under drought stress both, the first and the second wheat after faba bean had healthy roots, while irrigation led to severe take-all incidence in the second wheat. Soil water content was consistently higher in plots with wheat in self-rotation than in wheat after break crop. This indicated a reduced extent of the root system with less capacity in water uptake. The uptake of PAR throughout the season was higher in first than in a second or third wheat under sufficient water supply and in treatments with nitrogen fertilization. Under drought or nitrogen deficient conditions the pre-crop had no significant effect. Grain yield was reduced by self-rotation under reduced nitrogen availability. With increasing fertilization this effect
became smaller. However, wheat in self-rotation requires higher fertilizer levels to reach the economic optimum and results in lower yields.

The data obtained in these field trials in combination with root data analyzed by our project partners from IfZ Göttingen are used to integrate pre-crop effects into an existing soil-plant model for winter wheat.
Assessment of climate change impact on mid-century wheat production in Germany using multi-model-ensembles

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Keywords: crop model; climate change; wheat production

Process-based crop simulation models can provide valuable information on potential crop production under future climate conditions. They further allow the development and evaluation of suitable adaptation strategies in crop management to address future risk factors like increased temperature and altered precipitation patterns. The use of a multi-model-ensemble approach in crop modelling can increase simulation robustness compared to single model outputs. Therefore, this study aims to assess mid-century mean yield development and yield stability of winter wheat (Triticum aestivum) under different climate scenarios of RCP 2.6, RCP 4.5 and RCP 8.5 for important wheat production regions in Germany.

We use the three wheat crop models CERES, CROPSIM and NWHEAT embedded in the Decision Support System for Agrotechnology Transfer (DSSAT). This enables depiction of the model-specific uncertainties in addition to the climate-related uncertainties allowing a more robust evaluation of potential future wheat yields. In the first step, we conduct a cultivar specific calibration and evaluation of the three models building on a vast experimental data set of around 100 site-years, with 75 % of the data being used for model calibration and 25 % for model evaluation. Model calibration is executed in a similar extend for all models adjusting comparable types and number of coefficients to fitting observed and simulated phenology, growth and yield parameters. We then use the calibrated models to simulate yields in 2031-2060 and the reference period 1971-2000 using daily weather data of the 17 climate scenarios of the core ensemble of the German weather service (Deutscher Wetter Dienst; DWD). In addition, the simulations for 2031-2060 are performed with constant mean CO2-level of 1971-2000 in order to quantify and evaluate the CO2 fertilization effect on future yield development. These virtual experiments are executed for a range of representative wheat production sites that cover the multitude of soil types and climate conditions present in Germany. Furthermore, the selection of wheat production sites examined in this study also aimed to cover the most important crop production regions for wheat in the country. All selected sites are test sites of the Federal Plant Variety Office (Bundessortenamt; BSA). Cultivar-specific experimental data available for these sites had been used for previous model calibration and evaluation.

We find significant differences in yield development between climate scenarios and between the three crop models. While for some scenarios all models show comparative yield trends,
for some scenarios results differ between models and wheat production sites. We see that for all sites and climate scenarios the multi-model-ensemble predicts higher yields in the future than in the past, with a mean yield increase of around 11% for RCP 2.6 and RCP 4.5 up to 14% for RCP 8.5. Yield level of climate scenarios under RCP 8.5 are highest, while those of RCP 2.6 and 4.5 do not differ significantly. Furthermore, the results show that most of the predicted yield increase is driven by the increasing atmospheric CO2 concentrations, which are highest under RCP 8.5 and lowest under RCP 2.6. The simulation results show that the yield advances due to the CO2 fertilization effect are likely going to decrease in future. This indicates that other, non CO2-related climatic changes (i.e., temperature, precipitation) are going to excerpt an increasingly negative impact on future yield formation of winter wheat. The study demonstrates the potential and necessity of using multi-model-ensembles both, with regard to climate change scenarios and crop models, especially when intended for policy advice.
Exploring yield limitations and management variation in order to recognize future development potential of organic farming

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Keywords: organic farming, yield, management practices, path analysis

Finding sustainable agricultural systems is key for fostering the sustainable transition of food systems, and organic farming is a potential way. However, its sustainability has been questioned due to limited crop yields compared with conventional farming. To be able to promote higher yields in organic farming, we need to improve our understanding of the diversity of management practices among organic farms and the yield determining factors, especially in similar production areas.

By investigating on-farm agronomic and ecological indicators, we provide an example of the broad variation of organic farming practices in two main agricultural regions of Sweden. In our study, we chose to focus on highly productive agricultural plains where organic farming is poorly represented. Observational data from 52 commercial spring barley fields was complemented with semi-structured interviews with the farmers to understand their management strategies. We explored the relative effects of management and farming conditions on barley yield in a mechanistic way, by measuring yield-affecting agro-ecological indicators in the fields (plant nitrogen status, weed pressure, prevalence of plant disease and soil nutrient concentrations).

We show that some organic farming management strategies are relatively similar across farms, for example sowing rate and row spacing. In contrast, other strategies strongly vary, in particular fertilization rate, source of fertilizer, frequency of weed control, preceding crop and soil cultivation methods. These results suggest that farmers use different management strategies and adapt to local conditions. Overall, yields were mostly influenced by weed pressure and fertilization levels. Weed levels were controlled by more frequent weeding. However at this stage, we have not found a correlation between fertilization levels and plant nitrogen status. Moreover, we show that longer established organic fields are less susceptible to disease pressure, albeit observed diseases did not have a negative impact on yields in our present study.

We conclude that management strategies in organic farms are more heterogeneous than often presented, which is crucial to recognize for its future development. By understanding factors limiting yields, such as weed and nutrient management, in organic farms across contrasting farm conditions we can evaluate the potential to increase yields in line with sustainable agro-ecological principles.
The response of biomass yield in a wet grassland site to groundwater level change

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Introduction: A significant proportion of 40% of the world’s terrestrial biomes are covered by grasslands (White et al., 2000). The grasslands are highly diverse and the type of plant species and diversity is regulated based on many factors, water availability is one of the important factors (Reyer et al., 2013). Grasslands on groundwater level close to the surface where the vegetation is regularly consuming capillary water are called wet grassland (Dietrich et al., 2021). Their biomass production should linearly respond to water availability in the capillary fringe of the soils. However, wet grassland’s plant species are very sensitive to water availability (Toogood & Joyce, 2009). In periods with low water availability, species composition in wet grasslands changes rapidly and species that favour dry conditions emerge (Cebrián-Piqueras, 2017). As different species produce different biomass, the biomass yield is constantly altering alongside species composition change (White et al., 2000). Consequently, we hypothesized that the effect of groundwater level change on grassland biomass yield is masked by the shift in the species composition. We tested this hypothesis using the measured biomass data from an experimental station in Spreewald with a wet grassland site and constantly changing groundwater level recorded on a daily basis.

Material and method: We used the data from an extensively agriculturally used wet grassland in Germany, Spreewald (SPW, 51°52’ N, 14°02’ E, 50.5 m above sea level) (Dietrich & Kaiser, 2017). There are four lysimeters in the station with different water levels; two of them have relatively deeper groundwater levels than the other two lysimeters. The former lysimeters we categorized as dry conditions, and the latter group of lysimeters with closer groundwater levels to the surface, are classified as wet conditions so we have two different conditions of groundwater level change from 2010 to 2020. To elucidate how biomass yield values change with changing groundwater levels, we plotted the groundwater level change against the biomass yield values. A Pearson correlation analysis was also conducted between groundwater level deviation and aboveground biomass data.

Results and discussion: The groundwater level fluctuation did not show a clear relationship
with the grassland biomass yield in any of the lysimeters. The results of correlation analyses for all wet and dry cases were less than 0.18, which is negligible. Concisely, there seems to be strong evidence that wet grassland biomass yield is not directly related to hydrological boundary conditions. Rather, wet grassland biomass yield highly relies on plant community structure, that is, increases with wetness index. Hence, the results also indicated that if we consider the effect of wetness index on species composition and remove the trend that arises from it the correlation relationship of groundwater level with biomass yield would enhance.

Key words: Wet Grassland, Groundwater Level, Species Composition, Lysimeter.

Reference:


Valorization of cereals: Impact of year and fertilization on beta-glucan content in wheat and barley

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Keywords: beta-glucan, nitrogen fertilization, cropping system, organic

Beta-glucan is one of the most important dietary fibers in cereal grains, which has a big impact on human health and food quality. Wheat and barley as strategic crops are important sources of this valuable compound. The content of beta-glucan in grains of plants is affected greatly by agricultural management. To exploit and extract beta-glucan, the knowledge of effective factors increasing the amount of this component is needed. We hypothesized that nitrogen fertilization, cropping system, and climate conditions affect the beta-glucan amount in wheat and barley. For this purpose, an experiment was set up in a systematic block design with four replicates of each treatment in the experimental fields of the Estonian University of Life Sciences (58o 22´ N, 26o40´E). The experiment included conventional and organic cropping systems. In conventional systems, there were four different treatments, N0 as control with no fertilizer, N1, N2, and N3, which received 40-50, 80-100, and 120-150kg.ha-1 of mineral N, for barley and wheat, accordingly. The organic system included Org0 as control, Org1 with cover crops, and Org2 with cover crops and composted cattle manure (since in Org 1 the cover crops did not contain legumes that fixed nitrogen, thus added N amount considered 0 kg ha-1; in Org 2, 44–54 kg ha–1 of N applied with manure). The highest amount of beta-glucan, 0.61g 100g-1, in wheat was observed in treatment N1, where the lowest amount of mineral nitrogen was applied. By increasing the amount of fertilizer nitrogen, all three studied years showed a decreasing tendency in beta-glucan content. Among organic treatments, the highest beta-glucan content was in Org 2, where both cover crop and cattle manure were used. There were no significant differences in beta-glucan content between the studied years. Beta-glucan content in barley was at least eight times more compared to wheat, being the highest in treatments N2 and Org 0. In conclusion, treatments with lower nitrogen amounts were favorable to plants to increase beta-glucan content in grains and the growth year had minimal effect.
Hugo-Growth Stimulator technology as a new approach for boosting plant health and productivity in sustainable crop production system

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The development of modern technologies increasing global food production is being observed in the 21st century, in response to challenges rising from the need to feed the growing world population, which according to the FAO will reach about nine billion in the year 2050. This is all taking place in the context of climate change, with adverse effects on both water resource management and food production (Klimek-Kopyra 2021). To reduce the negative effects of climate change and simultaneously effectively support crop production, innovative agrotechnical solutions are sought. Currently used methods for enhancing plant productivity and crop protection are ineffective, since are strongly related to agronomic inputs e.g. dose of mineral fertilization, frequency of pesticides application.

The innovative Hugo Growth Stimulator technology is designed to intensify the most important physiological and biochemical processes of plants in order to effectively extract available water and nutrients from soil and to enhance crop self-protection. Hugo Growth Stimulator technology as a integrated approach may stimulate seeds (Growth stymulator) before sowing or/and seedlings in field conditions (Agricultural HUGO Robot) to rapid plants growth and development. HUGO technology uses integrated data of plants healths, and based on it information conduct biostimulation in field condition. Early detection of plant damage and immediate biostimulation may effectively suport IPM (integrated pest managemnt). Under experimental conditions, laser biostymulation by irradiation of soybean seeds or seedlings resulted in a signific ant increase the soybean yield, compared to the control (Klimek-Kopyra et al. 2020; Dłużniewska et al. 2021). HUGO technology is a response to two main challenges; boosting plants productivity in sub-optimal conditions and enhancing plants health.

Reference:


Does sugar beet need close row spacing for maximum yield?

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In Europe, sugar beet is grown with a row spacing of 45-50 cm, while in North America and Asia up to 75 cm are in use. Due to its slow early growth, late canopy closure and thus, incomplete initial light interception, it was hypothesized that closer rows such as 30 cm may enhance light use and yield higher since plant distribution is more regular at common plant populations of 80,000-100,000 plants ha⁻¹. Moreover, wider row spacings of 60 up to 90 cm were expected to substantially decrease yield. Nevertheless, they might be favorable for mechanical weed control because the portion of land reachable by e.g. hoeing implements is higher.

Several field trials were conducted from 2016-2021 to quantify (i) the yield gain/loss due to closer respectively wider rows in relation to the 45 cm standard under current central European production conditions, and (ii) differences in light interception among row distance treatments. Unexpectedly, yield did not increase with 30 cm compared to 45 cm rows, and yield loss with 60, 75 and 90 cm row spacing was only about 2.5, 5, and 10 %, respectively. Canopy light use data will be presented to elucidate to which extent yield reduction was caused by source limitation or if sink limitation might play a role.
Saving fertilizer N in Central European sugar beet cultivation through cover cropping

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Cover crops are grown on 70% of Germany’s sugar beet fields. Despite being practiced since decades, it is not yet clear what quantity of N can be accounted for sugar beet N supply from cover crops differing in biomass amount and composition (e.g. C:N ratio). For clarification, four biennial field trials were conducted at 2 sites in Germany (Hohenheim, Göttingen), two of which were offset by one year. The trials consisted of 4 cover crop types (oil radish, saia oat, spring vetch, winter rye) followed by sugar beet as the first and winter wheat as the second succeeding crop. In sugar beet, 4 different N fertilizer doses were applied to determine the N delivery from cover crops and the potential for saving fertilizer N. Moreover, the study focused on N2O emissions and nitrate leaching during and after the cover crop period. Results will be presented, focusing on cover crop properties, soil mineral content in spring, net-N-mineralization during the growing season, and finally, sugar beet yield response as affected by cover crop species and mineral N fertilization. All in all, we could not identify a clear beneficial effect of cover crops on N supply for succeeding sugar beets.
The impact of bio-products on soil, CO2 emissions and energy consumption in wheat and rapeseed cultivation

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Agricultural management, innovative technologies, chemical, organic and bio-based substances applied, as well as meteorological factors, have a significant impact on the soil properties, soil organic carbon (SOC), CO2 emissions and energy consumption. The aim of this study was to analyze the effect of several bio-products on the changes of soil properties, CO2 emissions and winter wheat and winter rapeseed yields by assessing the energy consumption efficiency. The field experiments were carried out in 2017-2020 in three treatments, in two of which were used either a molasses and magnesium sulphate based-bio-product (T1) or a bacteria-based bio-product (T2), while treatment T3 was applied as a control where no bio-products were used. The dynamics of SOC content and soil properties were analyzed at two depths: 0–10 and 10–20 cm. For the analysis of energy efficiency indicators and environmental impacts, the greenhouse gas (GHG) and energy consumption conversion equivalents were used. A summary of the results showed that both types of bio-products had a positive effect on the changes of SOC content, which was especially evident in the deeper layers at 10–20 cm depth, where, irrespective of the crop type, a more significant increase of the SOC content was observed every year of the experiment compared to the control. Correlation-regression analysis of the results during 2018–2020 period showed, that CO2 emissions depended on soil humidity, temperature, and electrical conductivity by 61.36 % (P < 0.01). Every percent of humidity decreased CO2 emissions by 0.24 (μmol m2 s-1), every degree of temperature increased emission by 0.213 (μmol m2 s-1) and every S·m-1 of electrical conductivity increased – by 0.013 (μmol m2 s-1). It can be concluded, that CO2 emissions strongly depends on soil humidity, temperature, and electrical conductivity by 61.36–91.92 % (P < 0.05). Temperature increases CO2 emissions, but influence of humidity and soil electrical conductivity may vary depending on other environmental factors. Bio-products had a significant positive effect on the winter wheat and rapeseed yield. The best energy efficiency ratio was observed in winter wheat (4.84) and winter oilseed rape (5.11) in treatment T1. The results of the environmental impact assessment showed that the lowest GHG emissions were recorded in the winter wheat production in treatment T1 at 108.7–149.1 kg CO2eq Mg–1, while the highest were observed in oilseed rape production in the control treatment T3 at 343.4 kg CO2eq Mg–1.
Changes in climatic water balance (CWB) during plant vegetation in the period 1981-2020 in Poland and its impact on plant production

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The study analyzed changes in relative climatic water balance (relative precipitation evaporation index) - RCWB during plant vegetation in the period 1981-2020 for long-term plant production.

The changes in relative climatic water balance were determined in a relative form comparing to the reference period 1981-1990 for data from 40 meteorological stations of the Institute of Meteorology and Water Management (IMGW).

RCWB values were determined on the basis of standardized climatic water balance (CWB) values for which potential evaporation was calculated by the Penman-Monteith method. Standardized values of CWB enabled comparison of different regions of the country and approximation by one curve illustrating changes in the rainfall-thermal relation. Average yields of arable crops (cereals, root crops and industrial plants) since 1990, i.e. from the economic changes in Poland, were collected from the Bulletin of Public Information of the Statistics Poland.

It was found that the average RCWB values show a decreasing tendency, in particular in the last decade of years (2011-2020). The RCWB changes were the result of an increase in the moisture deficit and a greater frequency of moderately dry, very dry and extremely dry periods. This is especially true in the south of the country with historically higher rainfall. The response to plant yielding was different and varies depending on the species analyzed. Adaptation measures for climate change can also were noticed, expressed in the regionalization of crops, the selection of varieties and changes in agrotechnics.

Reference:


Impact of cover crop termination time on N mineralisation dynamics and direct N2O emissions

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Cover crops are known for their manifold beneficial effects like reduced nitrate leaching, erosion control or increased agro-biodiversity. In contrast, direct N2O-Emissions from cover crops and subsequent cash crops might be higher compared to spring sown cash crops after a bare fallow. Within the joint research project “THG ZwiFru” effects of different termination dates of winter cover crops on N2O emissions and nitrogen (N) mineralisation dynamics were observed. Therefore, field trials with unfertilised non hardy winter cover crops were established in 3 consecutive years (2019-2021) on the experimental farm “Versuchsgut Hohenschulen” of Kiel University. Early termination (December) of cover crop stands was compared to late termination (April) and a bare fallow without cover crops as control. Greenhouse gas emissions were measured weekly with closed-chambers, soil mineral nitrogen (SMN) samples were weekly taken in 0-30cm and monthly up to 90cm. Furthermore, total plant biomass as well as N and carbon content were determined. SMN dynamics differed between the observed treatments: in autumn and early winter fallow plots showed higher contents than those with catch crops. After early termination in December, SMN increased during the first 6 weeks compared to later termination. In spring, both cover crop treatments showed higher SMN (26-49 and 25-52 kg/ha N in 0-30cm for early and late termination, respectively) than bare fallow (18-36 kg/ha N). Cumulative N2O emissions were significantly lower on bare fallow (0.24-0.32 kg/ha N2O-N) compared to cover crop treatments but did not differ significantly between the termination dates (0.93-1.44 and 0.99-1.98 kg/ha N2O-N for early and late termination, respectively). The ongoing trial will also include observations of N mineralisation dynamics and fertiliser response of the subsequent cash crop silage maize to enable a comprehensive evaluation of site-specific optimised cover crop management.
Comparison the value of rapeseed and maize evapotranspiration in vegetation period

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Keywords: active surface energy balance components

This paper presents the methodology of taking measurements of active surface energy balance components using the Bowen method. It discusses the applied measurement system, an important part of which are HMD 50U/50Y measurement sensors from Vaisala, adapted to work in the field. Their operation is a source of data for determining vertical profiles of temperature and water vapour pressure. These data are used to determine the turbulence components of the energy balance, i.e., sensible and latent heat. Measurements taken during the vegetative season on rape field showed that intensive evaporation occurred in the period until the end of June and that its decrease coincided with the decrease in the value of the degree of plant development determined on the basis of LAI records. In spring, during the period of intensive plant development, the decade sums of evaporation reached 30 mm, after which their quantities fell to the range of 10–15 mm. They became higher only in the periods of precipitation, when the water from the interception was available. Maize is characterized by a much lower evaporation variability, the 10-day values of which ranged from 25-35 mm during the growing season. This is a natural consequence of the fact that, in contrast to rape, live evaporating plants were present in the field almost throughout the entire measurement period. From the beginning of May, a gradual increase in the decade evaporation values can be seen as the plants grow and the LAI value increases. In the further course of plant development and the measured values of evapotranspiration, it should be noted that despite low rainfall in June and July, its value did not decrease in those months. This effect is the result of a well-developed root system of plants that can obtain the necessary water even from deeper soil layers.
Shoot-to-root ratio and root biomass of winter wheat under nutrient deficiency

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Even though nitrogen (N), phosphorus (P), potassium (K), and liming (Ca) are key for high yields and soil fertility in agriculture, there is a lack of studies investigating the shoot-to-root responses to deficiencies of these nutrients under field conditions. Understanding adaptation strategies of crops to poor-nutrient soils will help increase the resilience and resource efficiency of cropping systems, especially in low-input agriculture. Our study investigated shoot and root responses of winter wheat (Triticum aestivum L. cv. 'Boss') cultivated in 2019/20 at the long-term experiment Dikopshof, Germany, established in 1904 on fertile loess soil. Seven fertilization treatments are continuously assessed: no fertilization, two fully fertilized treatments (one with mineral fertilizer and liming "NPKCa" and one with additional farmyard manure "NPKCa+FYM"). In four additional treatments, either N, P, K, or liming ("Ca") was individually omitted from the mineral fertilizer treatment. The data presented include the biomass of shoot and root observed at tillering and flowering and grain yield at harvest. After root coring using a core auger (9 cm diameter, 100cm depth, split into 10 cm layers), ten samples per core (4 replicates) were washed, sorted, scanned, and dried to determine root biomass. Total carbon (C) and N were later analyzed. At tillering, the shoot-to-root ratio was higher in NPKCa+FYM treatment (0.53) as compared to the other treatments and lowest in the N omission (0.29) and the unfertilized (0.26) treatments. The root biomass was highest for the N omission treatment (0.6 t ha⁻¹) and lowest for unfertilized treatment (0.3 t ha⁻¹). At flowering, the shoot-to-root ratio declined from N omission (6.84), lime omission (5.81), K omission (4.96), NPKCa (4.73), NPKCa+FYM (4.42), P omission (4.31), and unfertilized treatment (3.21). The root biomass was highest for P omission and NPKCa+FYM treatment (both ~1.2 t ha⁻¹) and lowest for the N omission treatment (0.5 t ha⁻¹). NPKCa+FYM, P, and K omission fostered deep subsoil root biomass growth (70-100cm) at flowering. The enhanced root growth observed at tillering in the N omission treatment declined by 9% at flowering. In contrast, the relatively low root biomasses in the P and K omission treatments at tillering increased by 148% and 115% at flowering, resulting in greater biomass than the other treatments. At tillering, the total root carbon was the highest in the N omission (0.21 t ha⁻¹) treatment and lowest in the P and K omission (both 0.15 t ha⁻¹) and unfertilized (0.13 t ha⁻¹) treatment. At flowering, the lowest total root C was determined in the N omission (0.21 t ha⁻¹), while P omission and NPKCa+FYM (both 0.4 t ha⁻¹) showed the highest root C. Thus, root-based C input (without consideration of root exudates) and root-based N input into the soil highly depended on the nutrient availability not only of N but also of P. The grain yield was significantly higher for the NPKCa+FYM treatment and significantly lower for the N omission and the unfertilized treatments compared to the other treatments. Grain yield and root
biomass at flowering were positively correlated to some extent (R²=0.4). N omission and no fertilization most negatively impacted the root biomass and grain yield. N omission fostered the root biomass early in the vegetative stage but did not retain it at flowering, where it was the lowest. Otherwise, P omission resulted in a foraging response with more root biomass later (at flowering) that was even greater than the one in the fully fertilized treatment. In conclusion, shoot and root growths show different resilient strategies depending on the limiting nutrient.
Testing an inexpensive method for determining oil content in olive fruits

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The rate of oil accumulation in olive fruits and ripening duration are substantially affected by an ensemble of endogenous and exogenous factors including fruit load, cultivar characteristics and environmental conditions. This fact challenges the definition of rational criteria for deciding the best timing for harvest, even if it has strong effects on the quality and quantity of the olive oil produced. In the best case, fruit samples can be collected and carried to labs where oil concentration is determined, using this value as a criterion to decide whether harvest should start or not, but this comes at an unaffordable cost for most farmers. Recently, a conceptual model for predicting fruit oil content (Of) from inexpensive measurements of fruit dry weight (wf) have been published (López-Bernal et al., 2021). The aim of this work is to describe the main features of such a model and to contribute to further test its validity with new experimental data collected in 2021. In short, the model presents two physiologically relevant parameters, the fruit dry weight at the onset of the oil accumulation phase (wf0) and the ratio of accumulated oil per unit of fruit dry weight increase (β), the latter assumed invariable during oil accumulation. A compilation of new and already reported data on wf and Of dynamics suggests that β is fairly independent of crop load or watering regime and, to some extent, genetically controlled. On the other hand, wf0 is clearly affected by both the cultivar and the availability of assimilates for fruit growth in early summer, which makes it year- and orchard-specific. Hence, once cultivar-specific β values are available, wf0 could be easily calibrated by either a single determination of of or wf at any time during the oil accumulation phase (Approach A) or by directly measuring wf0 if the date for the onset of oil accumulation can be estimated (Approach B). The strengths and weaknesses of these two calibration approaches in terms of predictive power and ease of implementation are highlighted.

Keywords: fruit growth and development, oil accumulation, Olea europaea L.

Reference:

The determination of Nitrogen Use Efficiency for the German agricultural sector

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Crop needs-targeted and efficient nitrogen (N) fertilization is necessary for optimal nutritional plant supply and at the same time to reduce effects on the environment. Losses of reactive N compounds threaten biodiversity, climate, and human health (Sutton & Bleeker 2013). The utilization of N as an essential macronutrient must become more efficient in order to ensure food security and food sovereignty, mitigate the negative externalities of food production and to achieve the ambitious (inter-)national environmental, climate and sustainability goals simultaneously. The Nitrogen Use Efficiency (NUE) in an appropriate indicator for assessing N utilization in farm systems. The present work is addressing open aspects of methodological design, quantifying the level of NUE for different farm types in Germany and identifying determinants of on-farm N performance.

We use data of the German Farm Accountancy Data Network (FADN), covering around 10,000 farms with comprehensive annual information on farm structure and yields, and representing the German agricultural sector. For calculating NUE on farm-level for six farm types according to EU farm typology, the relevant input and output parameters as three-years mean are considered based on Löw et al. (2021) and pursuant national legislation. Further, an explanatory model is developed to identify linkages between NUE and regional (e.g., natural yield capacity and large geographic regions), farm structural (e.g., production system, farm size, fertilization intensity) and socio-economic (e.g., age, education level) characteristics. Thus, the MM-estimator, a robust regression technique to consider the existence of outliers, is utilized (Finger, 2010).

First results show a sectoral NUE of 58%, with significant differences among and within farm types. An increasing trend of NUE from dairy, over pig and poultry, towards arable farms can be observed, as well as a large variance within each farm type. However, limitations regarding organic fertilizer imports need to be considered. The explanatory model shows significant results for various independent variables, such as soil conditions, farm size, or education level. In order to achieve the targeted NUE of the national Sustainable Development Goals by 2030, further efforts are needed. However, an improving development can be observed lately. In order to maintain this trend, efficiency reserves of all farm types must be identified and mobilized henceforth. The determination of N performance shall contribute to a better understanding of the complexity of these linkages and support policy makers when designing agri-environmental policies to improve N management. In this context, the NUE serves as a robust and informative performance indicator whose relevance will further enhance due to the addressing and focusing on resource efficiency in current political and societal visions.
Literature


Integrating crop growth simulation models and data driven approach

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Yield prediction models can be divided between data-driven and process-based models (crop growth models). The first category contains models with parameters learned from the data themselves and where domain knowledge is only used to select the predictors. In the second category, models are based upon biophysical principles, whose structure and parameters are derived primarily from domain knowledge. Here we propose a novel approach based on the use of metamodels and transfer learning to combine the best of these two worlds.

Meta models reproduce the output of a more complex models using all or a subset of the input of the original model. Metamodels are typically data-driven models (e.g., a random forests) fit on a large synthetic dataset. Transfer learning consists in exploiting what has been learned from one domain (the source domain) into another, affine, domain. A typical example of transfer learning is the transfer of a model trained to classify the sentiment (good, bad) of food textual reviews to classify the sentiment of reviews on a different type of products, for example cars.

The approach we are proposing consists in developing a metamodel of a crop growth model by producing a large synthetic dataset and applying the principle of transfer learning on a smaller set of observed data. The advantage of this approach is that we can use both prior agronomic knowledge encoded in crop models (retained in the metamodel) and the data patterns that can emerge from the observations only. To verify our approach, we are testing the following hypothesis: the fitness to observed data of a model based on the metamodel plus transfer learning approach is better than a data-driven model and a crop growth model.

To test our hypothesis, we collected a set of data from 35 potato experiments conducted on Dutch sandy soils by Wageningen University and Research between 1994 and 2003. Each experiment consisted on average of 8 treatments for experiment, for a total of 285 yield observations. In these experiments the varied factors were Cultivar, Nitrogen fertilization rates and timings, irrigation rates and timings, sowing date, planting density.

Data recorded included crop management information like nitrogen fertilization and irrigation events, sowing date and distance. We will present data on model fitness (measured using the leave-one-out approach validation) of the three different types of models, Tipstar, a potato growth model (Jansen, 2008), a neural network model having as input management, soil, and weather and the metamodel + transfer learning approach.

The neural network used for both the transfer learning and the metamodel approach was a convolutional neural network composed of two convolutional layers to reduce the dimensionality of the time-series data (weather: air temperature, rainfall, radiation) and 4
fully connected layers to explore the effect of interaction between the non-time series input (soil type, base and side dress fertilization amount and date, sowing date), for a total of 3k parameters. For the transfer learning step part, the last layer of the metamodel neural network has been substituted and replaced with 3 additional fully connected layers that were trained on the observed data.

Preliminary results of model fitness indicate that purely data-driven (RMSE 10 fresh ton/ha) performs slightly better than the crop growth model (RMSE 12.8 fresh ton/ha) and similarly to models using the metamodel approach (RMSE 10.4 fresh ton/ha). During the presentation we will present an update on the status of the research.

Reference:

Nitrogen cycle regulation and associated ecosystem services in agroforestry systems. A methodology linking field, lab and modeling experimentations in the context of climate change in Brittany (France)

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Keywords: hedgerows, alley cropping agroforestry, multiscale assessment, nitrogen

Excess of reactive nitrogen threatens our ecosystems by altering soil, air, water quality and biodiversity. Especially, nitrogen losses to water streams are of great concern for territories that are specialized in livestock farming. In the near future, it is expected that such losses will increase under extreme events as a consequence of climate change. Agroforestry- whereby trees are integrated on a plot with crops and/or livestock- is considered as a lever to increase the resilience of agroecosystems facing climate change by intensifying ecosystems services and supporting productivity. In livestock areas, tree-crop associations should prevent nitrogen losses through the impact of trees on microbial driven processes, nitrogen acquisition and water drainage. However, the integration of agroforestry with livestock production is limited in temperate regions, and there is an urgent need to provide an assessment of its potential benefits on nitrogen cycle regulation.

This study aims to explore the potential benefits of agroforestry systems to improve nitrogen cycle regulation and associated ecosystem services within dairy farming systems in Northwestern France. To do so we wish to fit a nitrogen cycle model to the impact of extreme precipitation that are expected to occur in the near future in Brittany. As nitrification is a key process driving the production of reactive forms of nitrogen, we will take focus at understanding the impact of agroforestry on the nitrification stability -i.e. the biological response (resistance and resilience) of nitrifying microbial communities to a disturbance - within grasslands. We hypothesize that, by impacting the nitrification stability, the presence of trees or hedgerows limits nitrogen losses to the environment when experiencing heavy rainfall regimes.

Nitrification is a microbial driven process and its stability varies according to different environmental filters. Review of the literature enabled us to identify three environmental filters that explain nitrifying stability the most: (i) soil microclimate; (ii) soil porosity, and (iii) soil nitrogen content. In agroforestry systems, these factors are impacted by trees characteristics and practices. Studying the impact of trees and practices on nitrification stability calls for the use of structural equations modeling (SEM), a statistical analysis that aim at depicting causal relationships between various variable. After a review of the scientific literature, we designed a causal conceptual model to link measured variables on trees, soils characteristics, practices and nitrification with latent variables considering the three identified
environmental filters and nitrification stability. To inform the SEM, measurements on trees, soil and practices characteristics will be collected in spring 2022 in agroforestry plots and at three distances from the tree row. Similarly, lab measurements on nitrification stability will be done after applying a water saturation stress on soil cores collected at same distances from the tree row. Then, the results will help us to fit a nitrogen cycle model to evaluate nitrogen losses at the plots scale in the context of climate change.

Later on, the model will contribute to the multicriteria assessment of ecosystem services associated to nitrogen cycle delivered by agroforestry systems under climate change. Lastly, we wish to question the development of agroforestry at the territory scale regarding the regulation of the nitrogen cycle and associated ecosystem services by using a participatory design of agroforestry development scenarios. Testing these last two hypotheses calls for the interconnection of results obtained at plot, farm and territory scale using field, lab and modeling experimentations.

The novelty of the hereby presented methodology is (i) to combine field, lab and statistical modeling to assess the nitrogen cycle regulation and (ii) to consider its operational potential for building bridges between research, territorial development and field work.
CERES-Barley calibration for spring barley under German growth conditions

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Keywords. Crop model, DSSAT, CERES-Barley, Spring barley

Process-based crop simulation models (CSM) allow performing experiments in silico, investigating crop growth, development, and yield formation, for different genotypes under various management and environmental conditions, including future climatic conditions. Increasingly adverse weather conditions due to the ongoing climate change excerpt negative impacts on crop production and related food security. Predictive tools such as CSM can help to develop adaptation strategies considering the genotype (G) x environment (E) x management (M) interactions. Before applying a CSM for various research questions, it is important to calibrate it for the specific target genotypes and environment and evaluate its performance to be able to generate robust predictions. In this study, we calibrate and evaluate the crop model CERES-Barley embedded in DSSAT. We prepare the experimental input files based on a large dataset of federal and state variety trials from 1995 to 2019. We select four genotypes, namely Barke, Quench, Avalon, and RGT Planet, which were first tested in variety trials in 1993, 2003, 2009, and 2011, respectively, and hence represent breeding progress in spring barley in Germany over the past decades. The location x year-specific crop management data and the genotype-specific data on phenology, yield, and yield components are available for 45, 67, 89, and 114 site-years for Quench, Barke, Avalon, and RGT Planet, respectively. We use the time series estimator tool (TSE) for DSSAT to calibrate cultivar-specific coefficients. TSE estimates cultivar coefficients by minimizing the normalized root mean square error (nRMSE) between simulated and observed data. In addition to the empirical data from variety trials, we ran a field experiment at the Julius Kuehn Institute in Berlin for two consecutive years using the same four genotypes, growing them under good agricultural practice. We collected detailed growth data to complement the calibration dataset, including the development of leaf area index, biomass, leaf-stem-ratio, flag-leaf area, soil moisture, and others. After calibration and evaluation, the CSM CERES-Barley shows satisfactory model performance with regard to phenological development, growth parameters, and yield. The calibrated and evaluated model is available to conduct various CSM-based analyses, including the identification of optimal cultivar choice and crop management decisions for different target environments as well as climate change impact assessment. Being calibrated for four distinct spring barley genotypes commonly grown in Germany over the past three decades, we can comparatively analyze crop growth and yield formation of these genotypes for various growing regions over the past decades to help disentangle the effects of genetic and climatic changes on spring barley productivity.
Resilience is a dynamic process that comprises the attainment of positive adaptation to adverse events. In crop and pasture systems, resilience can be achieved by understanding the relationship between plant genotype (G), the environment (E) and their interaction (I). At an agronomic level, such insights can improve farming management to optimise the use of different species within a farm system. A systematic analysis and quantification of phenological- and seed-responses of subterranean clover (Trifolium subterraneum) to G, E and their interaction (I) have not been yet performed to inform breeding programmes and improve predictive models. Field and controlled environment experiments in New Zealand were used to identify GxE interactions for subterranean clover cultivars originated in Europe (‘Antas’, ‘Denmark’, ‘Monti’, ‘Leura’) (Pecetti et al. 2020) and cultivars bred in Australia (‘Narrikup’ and ‘Woogenellup’) (Enkbaht et al. 2021) during vegetative (e.g. appearance of first and fourth trifoliate leaves) and reproductive (flowering and self-pollination) phenophases, and for hardseededness (HSmax). ‘Monti’ and ‘Narrikup’ were consistently early flowering whereas ‘Leura’ and ‘Denmark’ the late flowering cultivars (Guo et al 2022; Nichols et al. 2013). The relative importance of G, E and I on these five variables, expressed as percentage, were estimated by the share of sum of squares for each factor in relation to the total sum of squares in ANOVAS for each variable. Overall, E was the most prominent driver of phenological and hardseededness responses. For phenological stages, E explained 75 to 90% of total variability. The large effect of environment was due to the wide range of sowing dates used to create differences in exposure to seasonal differences in temperature and photoperiod. For the HSmax the effect of G was greater than for crop development and ranged from 38% to 41%. This implies that cultivars performed differently when exposed to the same E and highlights the strong independence between G and E effects on crop development. These are important aspects to be considered for subterranean clover management as farmers have alternatives to, strategically, influence (E) at certain extent (e.g. by choosing the sowing date or terrain) and (G) by selecting cultivars to maximise subterranean clover as a forage. An understanding from this interplay GxE is relevant to inform model development and breeding programs.

Keywords: Trifolium subterraneum, re-analysis, phenological plasticity, agronomy.
A systematic review of methods for assessing the performance of conservation agriculture and its ability to cope with climate change in temperate zones

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Cropping systems in temperate zones are suffering from climate change, which is expected to cause even more damage in the future. Beyond the changes in mean conditions of temperature and rainfall, the increased intensity and frequency of extreme weather events (e.g. droughts, heat waves, heavy rainfall or windy episodes) are expected to increase. Historical intensive farming practices, including deep inversion tillage and monoculture, are known to increase vulnerability of cropping systems to such climate hazards, for example by increasing soil erosion or hydric stress. Conservation Agriculture (CA), based on three crop management principles (minimum mechanical soil disturbance, soil cover, and crop diversification), has received strong attention as an alternative for addressing the negative impacts of climate change on cropping systems. The effects of CA on the performance of cropping systems have been discussed in an increasing number of studies and some meta-analysis has evaluated its potential on crop productivity or soil protection. But no recent synthesis provides a description of the research activity on CA’s ability to cope with climate hazards.

This systematic literature review (SLR) aims to gather studies assessing the effectiveness of CA in the face of climate change in temperate zones and synthesize information related to a diversity of contexts (type of soil, geographic location), study design, set of practices, and evaluated performance.

Our SLR approach was guided by Cochrane and Prisma protocols. We first conducted a bibliographic search in the Web of Science to retrieve peer-reviewed English articles on the topic. After screening their titles and abstracts, we excluded off-topic papers and selected the ones that meet five eligibility criteria: (i) study has been conducted in a temperate zone; (ii) it involved one of the nine crops of interest (maize, wheat, barley, sorghum, sunflower, soybean, canola, triticale, pea); (iii) it included at least one CA practice; (iv) it was performed at the plot or farm scale, and (v) it assessed the effectiveness of CA to limit the negative impacts of climate change on cropping systems. A final subset of 162 articles was analyzed and we present here a synthesis of the information we extracted.

Preliminary results showed that most of the selected studies rely on experimental data collected at the plot level over short periods of time (< 5 years) in past and current climatic conditions. Model-based approaches in future conditions are still scarce. With regards to the choice of CA practices to be evaluated, few studies combined simultaneously the three principles of CA. A very large number of studies have evaluated the effects of tillage reduction, often in combination with increased organic soil cover, while very few studies have tested...
crop sequences with at least three crops. In terms of performance, we found a broad range of indicators. However, most studies focused on crop productivity and/or soil physical performance. Yet, few studies used an integrated assessment of the farming systems including social and economic attributes such as income, work time, or farmer satisfaction. Thanks to this synthesis of methods, contexts, and indicators used to assess CA performance in the face of climate change, we were able to identify advances and gaps, as well as new priorities for CA research. The SLR revealed a need for both (i) a system approach to better understand the combined effects of the three different CA practices and their dynamics over time, and (ii) an integrated assessment of CA multi-performance. An interdisciplinary approach could help to address these two points, and would provide more comprehensive information for agricultural advising and public policies.
Greenhouse gas balances of annual and perennial cropping systems

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Growing perennial crops can be a solution to meet the growing challenges of food security, sufficient biomass for biorefineries and mitigation of climate change since perennial crops are preserving the soil C stock. However, the long-term biomass yield production, soil C stock, and ecosystem CO2 flux are rarely simultaneously evaluated in the same study site, limiting the understanding of C flows in different cropping systems. In this study we compare the yield, five-year changes in soil C stock and two years of ecosystem greenhouse gas fluxes (CO2, CH4 and N2O fluxes) of an annual grain crop triticale (Triticosecale) grown every year since 2012 with the productive perennial grass festulolium (Festulolium braunii) both established in 2012 and festulolium renewed in 2018. All research is conducted at the research farm Foulumgård, Denmark and the greenhouse gas measurements are conducted with fully automatic state-of-the-art chambers that measure both in light and dark conditions.

The first five-year field observations (2012-2017) showed that festulolium produced 76% more biomass as compared to triticale (grain and straw). Meanwhile, there was an increasing trend of soil C stock in festulolium but a declining trend of soil C stock in triticale across the first five years, however, both changes were statistically non-significant. By having measurements of the complete carbon balance for 2020 and 2021, we can investigate the greenhouse gas balance of a cereal crop and a perennial grass crop. These results improve our knowledge of how we can optimize the management practices, the production of biomass, yield and the stability and potential growth of carbon stocks.
AKILIMO: customised advice on planting and harvest schedules and fertilizer use for smallholder cassava growers

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Smallholder cassava growers in Nigeria and Tanzania must make decisions on investments in their crops to produce food and income for their households. Due to climate change, however, rainfall is becoming increasingly erratic, generating risk and uncertainty. Especially decisions on planting and harvest time and returns on investments in fertiliser use are strongly dependent on rainfall during crop growth. We developed AKILIMO, an agronomic advisory service to provide smallholders with customised recommendations on all crop management operations from land preparation to harvest. Recommendations on planting and harvest schedules are based on crop simulations with DSSAT and LINTUL using historical rainfall data, allowing smallholders to consider cost implications, and how to maximise their revenue based on expected yield and commodity prices at harvest. Fertiliser recommendations are developed using a coupled modelling approach, using LINTUL and DSSAT to model attainable yields based on the planting and harvest schedule, QUEFTS to model crop response to added fertiliser, machine learning to predict indigenous nutrient supply using digital soil data and farmer-reported historical yields, and an economic optimisation algorithm to maximise returns on investment within a farmer-specified budget. The recommendation was cross-validated using data from over 600 on-farm researcher-managed field experiments. Next, over 5,000 farmers participated in validation exercises comparing the AKILIMO recommendations against their common practice. Over 80% of participants observed yield increases, resulting in net revenue increases of 100 – 800 US$ ha⁻¹, and 59% observed increases in net revenue due to modified planting and harvest schedules, with revenue increases of 120 – 460 US$ ha⁻¹. We developed a range of tools to offer advice to cassava growers. These include printable extension materials with decision trees, lookup tables and maps, and worksheets to perform a cost-benefit analysis. Further, we made recommendations available through digital channels, including an SMS chatbot, an interactive voice response service, and a smartphone app. Complementary training and promotion materials were developed to enable extension workers to demonstrate to cassava growers how to use these tools correctly, and how to implement the recommendations in their cassava farm. Today, over 310,000 farmers are registered on AKILIMO, and over 80 scaling partners from private and public sector have integrated AKILIMO advice into their services to smallholders. We continuously improve the service by gathering feedback through telephone interviews and investigate drivers and bottlenecks for use and uptake. AKILIMO’s model to deliver customised agronomic advice has been tested on other crops, including maize and potato, and we aim to further scale, both horizontally and vertically in future. All data and models are openly available and shared to stimulate interaction and collaboration within the digital agronomy community.
Breeding progress reduces carbon footprints of wheat and rye in Germany

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Key words: climate change; breeding progress; LCA; mixed models

Global agricultural production is increasingly faced with the challenge of producing more and at the same time causing fewer GHG emissions. However, little is known about the climate change mitigation potential of using modern crop varieties. Hence, this study aimed at evaluating the contribution of breeding progress in winter wheat and winter rye to climate change mitigation in Germany building on official variety trial data during 1983/1985 and 2019. This trial data comprised data of approved wheat (n=359) and rye (n=94) varieties, which were tested at multiple locations throughout Germany. All varieties were tested at two input intensities (I), with fungicides (I1) vs. without fungicides and reduced growth regulator intensity (I2). Additionally, breeding type (T), i.e., hybrid variety vs. population variety, was considered for rye. In total 55,306 and 21,319 genotype × environment (i.e., year × trial × site) × management (G×E×M) combinations were available for wheat and rye, respectively.

We computed GHG emissions and CFPs for every single G×E×M combination by conducting a partial life cycle assessment (from cradle to farm gate). Therefore, we considered all material and energy flows throughout the wheat and rye production in the variety trials. Additionally, we included fuel emissions for three farm sizes (F) (i.e., 100 ha, 500 ha and 1500 ha) per trial site to better reflect a realistic picture of agricultural practice. We statistically evaluated the results of the LCA using mixed models. In that regard, we controlled for a genetic and a non-genetic trend as fixed effects and genotype, location, harvesting year, input intensity, year of testing and their interactions as random effects. We derived the adjusted means of yield, GHG emissions and CFPs using post-hoc tests.

We identified N fertilisation as the primary contributor to GHG emissions. Nitrous oxide (N2O) emissions (~50%) and emissions caused by manufacture of N fertiliser (~30%) together account for over 80% of total wheat and rye GHG emissions. Diesel emissions account for the third-largest share (8-10%) of total agricultural emissions. Seed production emissions rank at fourth and are about twice as high for wheat (4-5%) than for rye (2-3%). The emissions for pesticide and machinery production are marginal.

Rye production revealed about 20% lower GHG emissions and 8% lower CFPs compared to wheat production. Regarding plant protection intensity, we observed 6% (wheat) and 10% (rye) higher GHG emissions with full fungicide and growth regulator application (I2). However, yields in I2 were also 14% (wheat) and 16% (rye) higher compared to yields in I1. Consequently, CFPs were 8-9% lower in I2 than in I1 for both crops. We furthermore observed decreasing CFP and GHG emissions with increasing farm size. Moreover, we detected that higher yield of
hybrid varieties (+13%) also overcompensated the resulting higher GHG emissions (+4%), leading to lower CFPs (−9%).

Looking at breeding progress, we found that annual yield increases led to concomitant higher yearly GHG emissions per land unit (+0.1% - +0.3%), largely due to increased N2O emission due to higher crop residues. However, despite increasing GHG emissions per unit land, CFPs decreased by −0.36% to −0.62% (wheat) and −0.25 to −0.48% (rye) per year. Hence breeding progress significantly reduced CFPs of wheat by −20 to −30% and rye by −10 to −20% over the past 37 years. Against the background of the rising global demand for food and the limited global crop land resources, the significant contribution of breeding progress to reducing the emissions per unit harvest product, i.e., CFP, of wheat and rye in Germany can be considered a valuable contribution to climate change mitigation.
Effects of heat and drought stress on oilseed rape (Brassica napus L.)

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Oilseed rape (Brassica napus L.) is a major global oil crop grown mainly under temperate climatic conditions. With increasing global edible oil demand and improving genetic yield, its production further expands to warmer climatic zones such as Mediterranean growth conditions. Moreover, global climate change leads to increasing heat and drought stress, which are critical limiting factors to plant growth and yield formation in oilseed rape, impeding its agronomic and economic performance.

While there are several studies investigating the separate effect of heat and drought stress, there is a lack of knowledge regarding their combined effect. Hence, a pot experiment was conducted investigating the single and combined effects of heat and drought stress on crop morphology, physiology, and yield formation under consideration of timing and intensity of stress. Four factors were tested in combination: heat stress at five levels (24°C, 30°C, 34°C & 38°C), drought stress (yes: plant available water capacity (PAWC) < 20% vs. no: PAWC > 60%), treatment timing (flowering vs. seed filling), and treatment duration (6 days vs. 12 days).

We find that all experiment factors excerpted significant effects on plant height, number of branches, number of siliques, and number of seeds, as well as seed oil content, protein content, and grain yield. Increasing heat and drought stress, as well as longer duration, lead to lower yields. During both flowering and seed filling, 6 days of drought stress without heat stress had no yield effect, but 12 days had. Similarly, for both periods, without drought stress, heat stress for 6 days had no yield effect, but 12 days had, but only at severe heat stress (38°C). After 12 days of drought stress, no additional heat stress effect was detected, i.e., no difference between 24, 30, 34 & 38°C. Assessing the performance on the branch level, i.e., separately for the main branch, 1st side branch, 2nd side branch, and rest of side branches, we first find that heat stress during flowering mainly acts on the main branch and 1st side branch by damaging flowers and reducing the number of buds and siliques. The available growth resources for reproductive development are then diverted in the formation of additional flowers on the rest of the branches. Accordingly, comparatively more siliques are established on the rest of the branches, and oilseed rape is capable of partially (12 days at 38°C) or fully (all other treatments) compensating for heat stress (without drought stress) during flowering. Heat stress without drought stress during seed filling acts significantly negative on the top branches only after 12 days but not after 6 days. We see that OSR can compensate for heat stress but not drought stress during flowering. Analysis of seed size distribution and fatty acid composition provide deeper insights into the effects and mechanisms of combined heat and drought stress.
Effect of irrigation and nitrogen management on wheat yields and N-leaching at three distinct locations in Germany in 1991-2020 – a simulation study using Nwheat and CERES-wheat

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Germany as the world's ninth-largest wheat producer grows wheat on more than three million hectares, which is more than a quarter of its total cropland. Climatic conditions for wheat production are favorable and mean national wheat yields of more than eight tons per hectare rank among the highest national yield records worldwide. Nevertheless, there is a continuous demand to improve wheat production systems. First, nitrogen (N) surplus, related N-leaching and respective negative environmental impact require improved nitrogen fertilizer management. Second, with accelerating climatic changes and increase in frequency and intensity of dry spells, drought stress induced yield losses are likely to further increase. While drought stress excerpts potentially negative effects on nitrogen use efficiency (NUE), optimal nitrogen supply can also help alleviate drought stress effects. Excess nitrogen and water, on the other hand, can amplify N leaching. Therefore, this study aims to analyze the effect of supplementary irrigation in the hitherto rainfed winter wheat production in Germany in combination with different N fertilization regimes. To be able to consider model specific uncertainty we employ two wheat models of the Decision Support System for Agrotechnology Transfer (DSSAT), namely the Nwheat and the CERES-wheat model. We purposefully selected three distinct sites in Germany, which differ regarding their soil quality and annual precipitation. Thyrow in Brandenburg has a very poor soil and low precipitation, Bernburg in Saxony-Anhalt has a good soil and low annual rainfall, and Feldkirchen in Bavaria has a good soil and high precipitation. At all sites, we test five nitrogen levels (0, 60, 120, 160, 200 kg N ha-1) under rainfed vs. irrigated conditions for thirty growing seasons (1991-2020). Irrigation is set automatically. If plant available water capacity (PAWC) in the top 30cm of soil falls below 70%, the topsoil is refilled to 100% PAWC. We find that both models reveal similar tendencies, i.e., increasing yields with increasing nitrogen, higher yields for irrigated vs. rainfed production and lowest irrigation effects for Feldkirchen. The statistical analysis regarding significant differences using a mixed model in R reveals that irrigation has no significant yield effect in Feldkirchen (both crop models) and Thyrow (only CERES), as well as under low, i.e., N < 160 kg ha 1 in Bernburg (only CERES) over the 30 years period. We further find that N-uptake is higher under irrigation vs. rainfed, especially in Bernburg, and N-uptake is higher at higher N-rates at all sites. Accumulated N-leaching out of the rooting zone during the growing period was generally low (< 60 kg ha 1 maximum), and lowest for Bernburg, followed by Feldkirchen and Thyrow with negligible effects of N-regime and irrigation management. Nevertheless, surplus N at harvest was highest under high N and rainfed conditions. We conclude that supplementary irrigation may help to increase yields and NUE at sites with low precipitation and high N doses of 120 kg ha-1 and more did not lead to significantly higher yields compared to 60 kg ha-1.

Keywords: DSSAT, nitrogen, wheat, irrigation
Does ppd-h1 modify yield sensitivity to heat in barley?

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Climate change in the Mediterranean environments is projected to increase the risk of heat waves. This is expected to have a profound impact on Mediterranean cereal productivity, particularly because the heat stress would take place during the reproductive development of the spikes. In barley the difference in time to flowering under long days is mainly controlled by the allelic form of the PPD-H1 gene, allowing adaptation, and in turn maximizing yield, depending on the region and sowing date. Under long days, the dominant Ppd-H1 allele confers sensitivity and advance flowering while the recessive ppd-H1 allele confers insensitivity (actually reduces the sensitivity) flowering later than Ppd-H1. As far as we are aware, no studies have analyzed the impact that the PPD-H1 alleles may have in the response of barley reproductive output to a heat wave immediately before flowering under field conditions. We aimed to determine whether these alleles affect the magnitude of the response to a heat wave, beyond their effect on time to flowering (as a true pleiotropic effect). For that purpose, we grew two near isogenic lines (NILs) of spring barley (produced by CSIRO, Australia) to study the performance of plants carrying dominant or recessive alleles of PPD-H1 in response to a heat wave occurring immediately before flowering. To impose the pre-anthesis heat stress, the crop area was enclosed using portable tents with transparent polyethylene films (mounted on wood structures, with the bottom of each structure left open to facilitate gas exchange) for approximately 10 days starting at the flag leaf stage. As heat waves were imposed at the same crop stage for each particular plot, any “escape” mechanism related to earliness would not be relevant here. Furthermore, to better analyze whether responses of sensitive or insensitive NILs are independently of the effects of these alleles on time to flowering, we tested the resilience to heat waves under four contrasting background conditions expected to modify substantially the differences in flowering time between NILs. They were (i) a fall sowing under natural (relatively short) photoperiod in Lleida (ii) a fall sowing under natural photoperiod in Bell-Lloc, (iii) a fall sowing with plots subjected to 24 h photoperiod (artificially extending daylength with low-intensity lamps over the plots) in Lleida, and (iv) a spring sowing. Background conditions in (i), (ii) and (iii) were field grown plots, and those of (iv) were plants grown in rows in large containers outdoors forming “micro-crops”. Developmental and crop-physiological traits related to spike fertility were analyzed. In general (in all experimental background conditions and in both NILs), heat slightly advanced flowering and clearly decreased yield (-3.1±0.3 days and -1044±326 kg ha-1, respectively; averaging across background conditions and NILs). The yield penalty was almost exclusively driven by changes in grain number (R2=0.99, P < 0.001). Although the yield of both NILs was penalized by the heat wave treatment, the NIL with the ppd-H1 allele was more responsive (-1164±495 kg ha-1; representing a yield loss of c. 19.1±4% respect to its unheated control) and that carrying the Ppd-H1 allele more resilient (-633±372 kg ha-1; representing a yield loss of only c. 8±5% respect to its unheated control). This may be relevant to take into account in breeding
for yield and yield resilience, as we may take advantage of the insensitive PPD-H1 allele when aiming to increase yield potential through improved spike fertility while, on the other hand, when heat waves are likely to occur we may consider exploiting the sensitive PPD-H1 allele to increase resilience through a reduced sensitivity to heat waves.
Plasticity of spike number and grains per spike in response to availability of resources in wheat

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Grain number per m² (GN), which is a main component of grain yield of wheat, is composed basically by the number of spikes m⁻² (SN) and grains spike⁻¹ (GS). Hypothetically, SN is a coarse regulator (mediating large responses of the crop) while GS is a component more relevant for fine-tuning smaller responses. However, meta-analyses of the literature failed in demonstrating this difference between components. Identifying physiological traits responsible for different levels of plasticity is desirable when adjusting crop-management and breeding strategies. We investigated the responses of GN and its components, as well as possible trade-offs between them, to increases or reductions in the availability of resources. Treatments consisted of two genotypes (Ascott and Sy Moisson, two current French cultivars with contrasting plasticity of SN and GS in previous studies), subjected to either a thinning of the plot (removing 50 and 75% of the plants at the onset of stem elongation) or shading (covering the experimental plots with a shading cloth intercepting 25 and 50% of the incoming solar radiation). Grain yield in the unmanipulated controls was similar between genotypes (c. 8 Mg/ha), and strongly responded to the treatments. These responses were highly correlated to those of GN. The treatment with least availability of resources (shading 50%) had lower GS than the intermediate treatment (shading 25%) which in turn was lower than control. The intermediate increase in resources resulted in higher GS, however no further noticeably response was observed from doubling (thinning 50%) to quadrupling (thinning 75%) the resources for both genotypes. On the other hand, SN showed a higher plasticity than GS. The responses of SN and GS were more related to the survival than to the generation of tillers and florets. Ascott showed more plasticity than Sy Moisson for SN, while the difference in plasticity for GS was smaller. This implies that Ascott would be more responsive than Sy Moisson to improvements in growing conditions (and more sensitive to stress) due to the consistent higher sensitivity of tiller survival to availability of resources during pre-anthesis.
The impact of soil properties on spatial variability of nitrogen balance and nitrate leaching on heterogeneous arable fields in southern Germany

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In this study, the spatial variability of nitrogen (N) balances and potential nitrate leaching were determined in two heterogeneous arable fields (size: 6.9 and 5.5 hectares) at one location in southern Germany using digital methods (tractor-mounted multispectral sensor and satellite data for modelling spatial N uptake with calculated vegetation indices and algorithms) and measurements of nitrate stocks in deeper zones (1-2.5 m soil depth) with deep drilling. The aim of this study was to achieve precise localisation of N losses at high spatial resolution (sub field level; 10 x10 m grid). The spatial variability of plant parameters (crop yield, N uptake) within uniformly fertilised (winter wheat: Field A: 212 kg total nitrogen ha⁻¹, field B: 251 kg total nitrogen ha⁻¹) fields was determined for the calculation of the N balances. The spatial variability of soil properties (e.g. soil organic carbon content, soil total nitrogen content) were determined to identify the causes of high or low N surpluses and nitrate leaching in sub-fields. The different data sources (N uptake winter wheat by tractor mounted sensor (2020); yield satellite: silage maize, soybean, winter wheat (2018-2020), measured nitrate stocks by deep drilling, SOC from top soil) were transferred into a 10 x 10 m grid using kriging. The plant parameters determined by digital methods and the ground truth measurements were compared using correlation analyses. N surplus determined using different digital methods and measured nitrate stocks showed similar spatial patterns.

Site-specific N balancing identified zones with high N loss potential (N surplus up to 86 kg ha⁻¹). Deep drilling showed zones with high nitrate loss (nitrate N up to 94 kg ha⁻¹). N surplus and nitrate loss correlated with r = 0.49. This relationship could be impacted by many other soil and management factors.

Soil properties showed considerable spatial variation within the fields. SOC and soil total nitrogen (TN) content were closely correlated in all fields (up to r = 0.96) and were most closely positively correlated with crop yield and N uptake (up to r = 0.74) and negatively correlated with N surplus (up to r = −0.73). The sensor data and satellite data (crop yield, N uptake, N surplus) showed similar distribution patterns. Based on these results, digital technologies are suitable for the calculation of site-specific N surplus and estimation of nitrate leaching risk. Satellite or sensor based site-specific and yield-oriented fertilization is one approach to reduce N surplus on sub fields with low yield potential and high nitrate leaching risk.
Adapting the CERES model to simulate growth and production of cereal rye

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Rye (Secale cereale L.) is primarily grown as an annual winter crop throughout the temperate zones of the northern hemisphere. Due to its high resource use efficiency, rather low input requirements and high resistance to frost and drought, it has good potential to support more sustainable crop production in the face of future climate change and rising food demand. Process-based dynamic crop simulation models (CSM) simulate crop growth, development, and yield under various soil, climate, and management conditions, making them essential tools in current agronomic research. A thoroughly developed and tested CSM to simulate rye growth, development and yield formation can help to assess the feasibility of rye production under various agro-climatic conditions. Only few rye simulation models have been developed to date, with limited applications and/or accessibility. We choose to adapt the widely applied CSM CERES-wheat as a starting point for the rye model development, as rye is similar to wheat in terms of its morphological and physiological properties. Furthermore, CERES-wheat is available in the Decision Support System for Agrotechnology Transfer (DSSAT), which is freely available and widely used in the crop modeling community.

We first calibrate the CERES-wheat model and building on that adapt the CERES-rye model. Therefore, we have established a large agronomic trial datasets of cultivar-specific data (rye cv. Palazzo and wheat cv. Winnetou) building on value for cultivation and use (VCU) trial data from the Federal Plant Variety Office and additional state variety trials of Saxony-Anhalt (SVT). The dataset covers all relevant wheat and rye-growing regions in Germany, allowing us to upscale the model calibration for those cultivars to the national scale. We supplemented VCU and SVT data with two additional in-season data sets, one from an N-regime trial conducted in Kiel, Northern Germany, from 2008 to 2010, and the other from the Julius Kuehn Institute in Braunschweig, Central Germany, from 2009 to 2010. Weather data for each experimental site were retrieved from the German weather service's climate data center (DWD), and soil data were derived from the European Soil Database (ESDB) v2.0, both data in 1km² grid scale.

For model adaptation and calibration, we randomly selected 75% of the trial dataset as calibration data and the rest 25% as validation dataset. We performed the model calibration using the time series estimator (TSE) tool for time-series calibration.

The calibration of the CSM CERES-wheat showed accuracy in simulating BBCH with an RMSE of 7 days, 2007.7 kg ha⁻¹ for above-ground biomass, 0.92 for leaf area index (LAI), 138.7 for tiller m⁻², 6769.4 for grain m⁻², 5.6 mg for unit seed weight, and 1611.7 kg ha⁻¹ for grain yield. The CERES-rye model also showed satisfactory simulation accuracy regarding phenology, LAI, above-ground biomass, and tiller m⁻² at harvest, unit grain weight, grain m⁻² at harvest, and grain yield. Simulation-observation comparisons resulted in an RMSE of 3.3 days for
emergence, 7.2 days for anthesis, and 7.3 days for harvest maturity date for the calibration dataset from the phenology part. From the growth and yield simulation, RMSE of 1.61 for LAI, 2468.7 kg ha\(^{-1}\) for biomass, 169.6 for tiller m\(^{-2}\), 7708.0 for grain m\(^{-2}\), 3.6 mg for unit grain weight, and 2182.7 kg ha\(^{-1}\) for grain yield.

CERES-rye is available to conduct various CSM-based analysis including the evaluation of crop management strategies, consideration in analyzing crop rotations in DSSAT, and assessing rye’s suitability for cultivation in different growing environments.
Influence of mineral nitrogen plus sulphur fertilization and seeding rate on yield, quality and asparagine concentration in Italian's old varieties of Triticum aestivum, L.

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Abundant studies have underscored positive effects on health from ‘old’ wheat (Triticum aestivum, L.) varieties. Thus, old wheat varieties show poor rheological properties, and there is also inadequate information on asparagine (ASN) concentration. The objective of this study was determining the effects of nitrogen (N) and sulphur (S) fertilization, as well as seeding rate (SD) on grain yield (GY), rheological characteristics, as well as ASN concentration in 14 ‘old’ common wheat varieties. However, two SD (200 and 300 seed m2), three N levels (35, 80, and 135 kg ha\(^{-1}\)) and two level of SL (0 and 6.4 kg ha\(^{-1}\)) were considered for each variety. N fertilization significantly improved the PC without increasing GY; while the GY significantly increased by S and SD without improving protein content (PC). S and N application significantly increased the dough strength (W) but was significantly reduced by SD. ASN content was substantially reduced by 85.1% with the S application. In contrast, ASN was considerably increased by 111.1% with N rate from 35 to 135 kg ha\(^{-1}\). The findings of this experiment showed that N fertilization combined with S can significantly improve the dough properties, as well as retaining the ASN content as low as possible.
An ecological approach to unravel the mechanisms behind yield benefits in wheat variety mixtures

Dr. Laura Stefan; Silvan Strebel; Dr. Lilia Levy

Agroscope

Utilizing biodiversity–ecosystem functioning relationships is a promising way to improve agricultural sustainability. It is indeed widely acknowledged that increasing diversity in plant communities benefits ecosystem functioning. These ecological concepts are well studied in natural ecosystems; however, applying them to an agricultural setting such as variety mixing has rarely been done. Here, we present data of a variety mixture experiment with eight different wheat varieties, where we first used a functional trait approach to quantify changes in niche differentiation between mixture plots and pure stands. We expected an increase in niche differentiation in mixture plots composed of several varieties compared to pure stand plots. We further expected that these increases in the space of functional traits would lead to higher yield benefits in mixtures. To investigate yield benefits, we used genetic sequencing to determine the proportion of each variety in the harvested mixtures and compared this to the initial seed weight sowing ratios, which was 1 divided by the number of varieties. This allowed us to determine the relative expression of each variety and also to quantify changes in complementarity and selection effects sensu Hector & Loreau in mixture plots. To test these hypotheses, we established experimental communities of pure stands and mixtures of two, four and eight wheat varieties, in which we regularly measured leaf area index using a ceptometer and chlorophyll content using a SPAD device. We used a selection of different plant and seed functional traits, including specific leaf area, leaf dry matter content, plant height and mass per seed, and we linked these traits to resource uses, namely light and nitrogen. Functional traits have been shown to be a helpful proxy to assess interactions between plants for resources, but they have rarely been used in an agronomical context. Understanding the relationship between functional diversity and the different components of yield benefits would help determining crop ideotypes for mixtures and to find optimal combination of varieties.
Amino acids composition in ancient wheat species (Triticum sphaerococcum and T. persicum) and common wheat (T. aestivum) grown organically under plowing and shallow tillage

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Keywords: exogenous amino acids, nutritional value, soil cultivation method

The need for foods with high nutritional value has led to the rediscovery of ancient wheat species as raw materials with valuable consumption properties (Skrajda-Brdak et al. 2020). One of the basic nutrients of cereal grains is protein, and its quality is verified by the amino acid composition and quantitative proportions between individual amino acids (Poutanen et al. 2021). The quality of cereal grain protein depends on the genotype of species and varieties, habitat factors and agrotechnical management (Siddiqi et al. 2020). The aim of the study was to compare the amino acid composition of the grain protein of the ancient wheat species Indian dwarf wheat (Triticum sphaerococcum) and Persian wheat (T. persicum) with common wheat (T. aestivum), grown under plowing and reduced tillage system, limited to shallow (10-12 cm) surface cultivation using a cultivator or a disc harrow. The wheat grain came from three strict field experiments conducted in 2019, in three certified organic farms, located in the province of Kuyavian-Pomeranian (53 ° 37′N; 19° 12 ′ E), Greater Poland (52º 11 ′ N; 18º 80 ′ E) and Pomeranian (53 ° 93′N; 18 ° 31 ′ E), Poland.

The amino acids content in the grain protein of the studied wheat species was determined using the AAA-400 amino acid analyzer, after prior hydrolysis with 6 M HCl at 110oC. In addition, sulfur amino acids were subjected to hydrolysis with 6 M HCl after oxidation with a mixture of formic acid and hydrogen peroxide in the ratio of 9:1.

The studies showed that, on average for soil tillage methods, the sum of essential amino acids in the grain protein of Persian wheat and Indian dwarf wheat was higher than in the protein of common wheat, and in this respect, plow tillage was more beneficial for Persian wheat, and shallow tillage for Indian wheat. The nutritional value of cereal protein expressed in the essential amino acids index (EAAI) was higher in Indian dwarf wheat compared to common wheat. Moreover, significant differences in the content of individual amino acids in the grain protein of the tested wheat, depending on the species, were demonstrated. Persian wheat was characterized by a greater content of Met, Ser, Pro and Tyr, and Indian dwarf wheat by a greater concentration of Arg, Asp, Prol and Gly in the grain protein compared to the concentration of these amino acids in common wheat. The obtained results indicate that the Persian wheat and Indian dwarf wheat are promising in the production of food with increased nutritional value.


Effects of biostimulant and hydrogel on potato plant productivity and agronomic value of the yield

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Keywords: potato, biostimulant, hydrogel, irrigation

The field experiment was carried out during two growing seasons (2020 and 2021) in Plant Breeding and Acclimatization Institute – NRI, Division Jadwisin. The experiment was conducted on two potato cultivars Denar and Gardena with irrigation applied. The experiment included two objects: the non-irrigated (NI) with the natural weather conditions prevailing in the growing season and irrigated object (I) included the natural weather conditions prevailing in the vegetation season and supplemented by sprinkler irrigation. Irrigation doses were determined according to the balance method and soil moisture measurements with the TDR moisture sensor. In the growing season 2020 two irrigation treatments with a total amount of 13.3 mm were applied, in 2021 one irrigation treatment was applied with an amount of 35.7 mm. On each object the following combinations were applied: (B) with biostimulator treatment (with foliar application of Bio-algeen S90 - 3 treatments in BBCH scale: 30, 59 and 70 at a dose of 1.5 l·ha⁻¹), (H) with hydrogel treatment (hydrogel preparation - soil supersorbent application at a dose of 360 kg·ha⁻¹ during planting), (C) control - without the use of biostimulator and hydrogel. During the growing season, the following plant productivity indices were assessed: plant height, stem number, stem mass, leaves mass, leaves assimilation area, SPAD index and root mass. After the end of vegetation season, the tuber yield, the yield structure (share of tubers below 35 mm, 35-50 mm, 50-60 mm and over 60 mm in diameter) and the share of tuber defects were determined.

In both seasons, the amount and distribution of rainfall was favourable for the development of potatoes, which was reflected in the growth and development of plants. The use of a biostimulator and a hydrogel accelerated the development of plants. Higher LAI indices were observed on combinations where a biostimulator or a hydrogel was applied. In the 2020 season, the use of a hydrogel and a biostimulator did not increase the yield. However, under the influence of the use of hydrogel, a significant increase in the proportion of tuber fractions with a diameter of more than 60 mm was observed in the non-irrigated object in both tested cultivars. In an irrigated object only for Denar cultivar it was observed.

In the year 2021, this effect was very high, especially in combination without irrigation. In the combination without irrigation, the increase in yield after using the hydrogel was 13.3% on average for the cultivars, and 14% under the influence of the biostimulator. In combination with irrigation, the increase was lower and amounted to 5.2% due to the use of a hydrogel and 8% due to the use of the biostimulator.
Spatially simulating lucerne (Medicago sativa) yields with gridded models - some methodological considerations

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Lucerne (Medicago sativa) is the most widely cultivated forage legume globally. It is able to produce high biomass and protein yields as direct or supplementary feed to livestock. The crop fixes atmospheric N through symbiosis and can access water at deeper soil layers than most grass options, due to its deep taproot. These imply in less dependence on synthetic N-fertilisers and provision of ecosystem services such as deep soil profile drying and nitrate uptake. However, assessments of land suitability and productive potential for lucerne crops using process-based gridded models are uncommon. This is partially due to the challenges involved in quantitatively representing the physiology and management of this perennial legume within biophysical models, particularly regarding seasonally of production. Within seasons, there are periods of biomass remobilisation from and partitioning to perennial organs (crown and taproot) that differ with genotype. For instance the share of biomass partitioned to perennial organs is relatively greater from mid-summer to winter, reaching up to ~50% of assimilates. The amount and composition of such reserves, particularly nitrogen, then influence canopy expansion during the following season’s flush of early-spring regrowth through remobilisation to shoots. This implies that the radiation use efficiency (RUE) for above-ground biomass, a constant parameter in many annual crop models, seasonally differs in lucerne models. At multi-year time scales, the productive capacity of lucerne stands depend on the rate of plant population decline, which is influenced both by plant competition within the stand (e.g. self-thinning) and by external drivers such frequency and intensity of defoliations and biotic stresses. Yields in lucerne stands start to be compromised if plant populations decline below critical thresholds when other yield components (e.g. shoots per plant and shoot weight) cannot compensate. These are examples of complex plant- and crop-scale dynamics which are relevant to lucerne modelling applications in which spatial and temporal variability are important to be captured. Based on multiple years of field data in New Zealand, we highlight these and other key considerations that are important to simulate lucerne stands with gridded models. We use these to describe the results from a spatial yield assessment at 5 km resolution with the APSIM-Next Generation model prototype for lucerne, that shows potential yields ranging from 10 to 28 t dry matter/ha per year across the country. Such insights from our study are relevant to inform future development of gridded modelling assessments for lucerne and other perennial forage legumes.

Keywords: Alfalfa, APSIM, GIS, Modelling
Capturing cultivar differences in water-limited yield potential of potato in the Netherlands via experimentation and modelling

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Climate change leads to more frequent droughts. In recent years, potato production in the Netherlands suffered, particularly on sandy soils. Farmers need decision-support for crop management and adaptation to climate change and variability, but currently crop models do not capture cultivar differences and are therefore not suited for on-farm decision support. Recently, new WOFOST parameter sets for potential yield of potato in the Netherlands were calibrated (ten Den et al., in review). These parameter sets allow for cultivar-specific estimation of potential yields; of the seven parameters five are correlated with cultivar earliness. With the old parameter set (derived in the 1993) the potential yield in 2019 was 12.6 t DM ha⁻¹ while with the new parameter sets the potential yields ranged from 16.3 to 18.5 t DM ha⁻¹ (66 to 83 t ha⁻¹ in FM). In a next step we will calibrate water-limited potential yields of modern potato cultivars using WOFOST, in combination with SWAP.

Two experimental fields were set up, one on a sandy soil near Vredepeel and one on a clayey soil near Lelystad. Throughout the season data was collected on crop phenology and growth, e.g. leaf biomass, stem biomass, and tuber biomass as well as on soil conditions such as groundwater level, soil moisture content (pF), and soil temperatures. Two irrigation treatments were used to allow for assessment of both a potential and water-limited production situation. The optimally irrigated plants were irrigated to maintain a target pF value of 2.4 while the drought stressed plants had a pF target of 3. The experiment was repeated over two years: the 2020 data were used for calibration and the 2019 data for model validation. The difference in water supply between the two irrigation treatments for Lelystad was 121 mm (2019) and 73 mm (2020). In Vredepeel the difference was 148 mm (2019) and 139 mm (2020). Five different commercial potato cultivars were used, with for Lelystad the cultivars Innovator, Fontane, and Markies and for Vredepeel Premiere, Fontane, and Festien. Drought stress in 2020 was more severe in Vredepeel than in Lelystad with an average 21% yield reduction in Vredepeel and 6.9% in Lelystad. There was no noticeable yield reduction due to drought in 2019 in Lelystad and a reduction of 13% in Vredepeel. There was large variation between the three replications of the trial which made that only the yield reduction for the early cultivar Premiere in Vredepeel in 2020 was significant. There was also a large within treatment variation in measured LAI and leaf biomass. For Lelystad there were few differences in LAI and leaf biomass between the irrigation treatments. In Vredepeel the strongest effect was for Premiere in which the drought stressed plants had a lower LAI from July onwards for both the 2019 and 2020 seasons. Drought stress had little to no effect on stem biomass, plant height, or light interception.

For modelling water-limited production the models WOFOST and SWAP-WOFOST are used.
The WOFOST model uses a relatively simple soil module to calculate soil water balances while SWAP-WOFOST uses WOFOST for crop growth and the more extensive SWAP model for the soil water balance considering soil hydraulic properties for each different layer in the soil. As both models use WOFOST for the crop aspects of the simulations, both simulate the same potential yields as described at the start of the abstract. We will focus on the insights derived from using two different soil modules to understand water-limited production of potato cultivars on different soils. The resulting updated model should generate valuable insights in explaining the large between field variations of potato yields in the Netherlands.
Foliar silicon treatment can increase barley yield and quality

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Farmers are faced with many challenges, as they have to stand for food security, while adapting with climate change and several crises simultaneously. It has been proposed that silicon amendment can help against abiotic and biotic plant stress.

Field experiments with spring barley cv. Fantex have been conducted in 2020 and 2021 in testing fields in Agricultural Research Center in Viljandi and in production fields in Valgamaa (Estonia). The treatments included different nutrient regimes (control, mineral fertilizers with the rate of N100P80K140 and organic fertilizers) and different foliar treatments (control, Si, Se, combined). Three different silicon products were used (Lebosol silizium, Optysil and Nanosil). In all cases, the above ground biomass, resistance to abiotic and biotic stresses and yield were determined. Barley yield varied from 4,6 - 5,5 t/ha. First results indicated that even though silicon does not increase above ground biomass, it can increase barley yield by 360 kg/ha. However, not all silicon products had the same effect. There was also positive impact on quality, as silicon treatments increased protein percent in dry matter by 0,5 in control and 0,5 - 0,9 in mineral fertilized treatment. The results will provide valuable information for farmers on how to increase the stress resistance of crops and produce biofortified crops on marginal soils.
As the intensity of dry period’s increases, so does the need for climate-resilient field forage legume mixtures, which are particularly relevant in organic farming due to the limited nitrogen fertilizer options. Ribwort (Plantago lanceolata L.) is a multi-cuttable dicotyledonous plant that also develops valuable properties in ruminant feeding. To test the climatic resilience of ribwort plantain, in comparison with ryegrass (Lolium multiflorum var. westerwoldicum L.), two-year field trials were conducted at two sites in Germany with sandy-loamy and silty-clay soils, respectively. Appropriate pure and mixed seedings of red clover (Trifolium pratense L.) were tested in a systematic replacement series. The study’s results showed, that ribwort plantain already developed a maximum rooting depth of 170 cm after 12 months of growth and was thus able to realize higher cuttings yields in pure and mixed seeding with red clover during dry periods in summer than ryegrass. Ribwort plantain was shown to make better use of water reserves in the subsoil than grass during drought conditions. The project results illustrate, that in terms of annual cut yield performance, the optimum seeding ratio for the maximum relative yield total max (RYT) of red clover mixtures with ryegrass or ribwort, are in a similar range (30 to 40% relative seeding rate of the non-leguminous mixture partner), but the mixtures with ryegrass were always higher yielding at the first cutting date than those with grass. Therefore, it can be concluded from the studies that mixtures of all three species are likely to have the highest yield performance due to mixed resource complementarity. The secondary plant constituent "Aucubin", contained in ribwort plantain, causes a nitrification inhibition, as laboratory tests could show. This effect was also demonstrated in the field before and after incorporation of ribwort plantain into pure and mixtures with red clover: Pure seed and mixtures with ribwort plantain led to significantly lower nitrate levels in soils, before and after turning over the stands in the fall under winter wheat, compared to corresponding stands with ryegrass, so that nitrate shifting and presumably also leaching by ribwort plantain can be reduced.
Multi-year evolution of soil structural stability in three cropping systems trials in Belgium

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Soils are at the heart of agro-ecosystems. In various parts of Europe, soils, their structure and function are under pressure from intensive farming practices and global changes. In field cropping systems, the soil is increasingly affected by extreme climatic events, especially intense rainfall. These events can lead to erosion of soils with low structural stability. This can have direct consequence on farmers through loss of natural resources and loss of agricultural production.

Farming practices is expected having an important role in the structural stability of agricultural soils. This has been previously studied in agronomic factorial trials in Gembloux (Centre wallon de Recherches agronomiques) and on-farm experiments (various Walloon farmers network). In the present communication, soil structural stability was assessed with the QuantiSlakeTest (QST) approach (Vanwindekens et. al., 2020) on three cropping systems trials in Gembloux, a loamy region in Belgium.

The QST was developed as a low-tech approach to assess the structural stability of soils. It is based on the principle of a continuous quantitative measurement of the disintegration of a soil sample immersed under water (slaking). To compare the modalities of the different treatments, the curves are normalized and a series of synthetic indicators are calculated based on the analysis of the curves (e.g. relative weights at stabilization, time to reach the maximum relative weight after immersion, different slopes, area under the curve).

The three cropping systems trials were settled in 2019: (a) a Conventional field crop experimentation (approx. 15 ha), (b) an Organic field crop experimentation (approx. 6 ha) and (c) an Organic market gardening experiments (approx. 5 ha). The application of the QuantiSlakeTest on samples taken from different modalities in these systems shows significant differences between the cultivation practices.

The analyses of the first results shows that the most important differences are linked to main soil management practices. Regarding tillage, the results revealed that only plots that were tilled had a negative effect on soil structural stability. That confirms previous observation in field factorial trials and farmer’s network. We now want to look further into the analyses, using time series observations (intra-year and inter-years) for highlighting the role of other practices (cover crop management, rotation) that can modulate the structural stability evolution and bring resilience to farming systems to cope with extreme climatic events.
Optimization of complex fertilizers with FertiliCalc 4

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Fertilizer management is a critical activity in farms. For nitrogen, deficit rates limit yields while excessive applications cause pollution of surface and subterranean water resources. The limited mobility of P and K and the buffer capacity of soils allows a longer term perspective for nutrient management in order to maintain fertility levels in the long run. Despite the importance of fertilizer management, the actual adoption of computer tools to help in decision making is still scarce.

Using mixtures of straight fertilizers in the farm results in poor uniformity and may be a challenging task for many farmers. This is solved by using complex fertilizers with the right composition for the crop/soil case. The objective of this work was to develop a methodology for optimization of rate and composition complex fertilizers.

FertiliCalc (Villalobos et al., 2020. Int J Plant Prod. 14) is a decision support system for fertilizer management that is used for management and for teaching/learning fertilizer management? The calculations are based on chapters by Delgado et al. (2016) and Quemada et al. (2016) (in Villalobos and Fereres, Principles of Agronomy for Sustainable Agriculture. Springer). It takes into account the crop rotation, agronomic and soil data and provides first a recommendation of total requirements of N, P and K. Then, the user selects fertilizers and gets the total rates to be applied. The current version for Windows (FertiliCalc 3.4) is available for download (https://www.uco.es/fitotecnia/fertilicalc.html). The outputs also include estimates of N losses by volatilization, denitrification and leaching. Soil acidification, expressed as the rate of pure lime required to neutralize it, is also given. For most crops an approximate balance for other nutrients (Mg, Ca, and S) is provided as it may change substantially depending on the selected fertilizers.

An important advance has been incorporated into FertiliCalc for smartphones (https://www.fertilicalc.com) as the user may select explicitly which fertilizers to use before and after planting. In addition to that we incorporated the calculation of the leaching Index as a function of rainfall.

In version 4 for Windows (under testing) we provide a novel procedure to order all possible complex fertilizers according to their suitability to the actual needs of the crop. The idea is to match the requirements of P, K and basal N, leaving the remainder N for post-planting applications. For this matching we equate the derivative of the sum of the relative deviations for P and K to zero, leaving basal N to fluctuate between 0 and 40% of the total N required.
Climate trends and limitations driving the performance of winter wheat varieties during the last 30 years in Switzerland

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Wheat (Triticum aestivum L.) is a crop of importance as it is the second most produced food crop worldwide with 761 x 10^6 t produced in 2020, just after maize (116 x 10^7 t) (FAOSTAT 2022). Wheat productivity is significantly influenced by genotype by environment interactions (G×E). A better characterization of these interactions would allow optimizing wheat productivity by taking full advantage of the potential of each site. We used a large historical dataset from multi-environment trials conducted during 30 years in Switzerland to identify the main environmental constraints and climatic trends affecting the yield of winter wheat varieties in Switzerland. During the 30 years of trials, weather data were collected from MeteoSwiss (Federal Office of Meteorology and Climatology MeteoSwiss, Switzerland).

A mixed model was used to quantify the amount of variability explained by variety, location, year and their interactions on the grain yield of winter wheat. Variety, as a single factor, explained 14% of the variability in grain yield, while year and location as single factors explained 14% and 17% of the variability on the same trait. These results will help to better anticipate the impact of climate change on wheat productivity and to optimize genotype selection in the future according to the environment.
Statistical models for crop yield prediction in winter wheat

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Crop yield mainly results from the soil, genotype, climate, and crop management interactions. The presented experiments target the question: What can be expected from statistical models to predict yield if comprehensive data on field level are available? The used data set comprised more than 22,000 records of yields of wheat from 81 locations all over Germany which originate from plot trials from the years 2005 – 2019. The data represent, to the author’s knowledge, one of the most comprehensive data sets currently in use.

The suitability of different statistical models for simulating wheat yields was investigated in this study. Monthly accumulated weather data, soil- and agronomic information served as features. Different linear models, Ridge, Lasso, and ordinary-least-square regression - and non-linear models, Random Forest (RF) and Multilayer-Perceptrons (MLP), were tested. A mean estimator (ME) was introduced as a benchmark model that consistently predicts the long-term average.

K-fold cross-validation (CV) was applied and the leave-one-year-out method was practiced. The years 2012 and 2018 served as the final test set and were not included in the training and validation process. The latter instantiating as a year of historical drought in Germany and was chosen to evaluate how well statistical models would predict on years with climatic extremes. The 2012 year could be considered as a “normal” climatic season.

Throughout the modeling process, it became clear that some basic assumptions of machine learning were being compromised. Individual years in the validation data set showed a significant distribution shift. This negatively impacts statistical models as they are in based on the assumption that training and test data origin from the same distribution. Using kernel-mean-matching and a distribution-classifier it was explored if weighting training samples higher that are closer to the test data distribution improves the results. This hypothesis cannot be confirmed, at least not the way that it was tested.

Based on these insights all training data were used. Two different architectures of the MLP were tested - a 3-Layer-MLP and an 8-Layer-MLP, whereas the deeper network tended to perform better. The results of the validation process showed that the non-linear models, first the 8-Layer-MLP followed by the 3-Layer-MLP and the RF, are more suitable to capture the non-linear interactions in its predictions. They performed in more than 10 out of 12 years better than the benchmark model. The years where the ME was not outperformed could be classified as “normal” from a climatic perspective. The RMSE for the best model varied across the CV from 1.02 t/ha to 1.86 t/ha with a mean of 1.36 t/ha at an average yield of 9 t/ha. On the test data, an ensemble model consisting of the 8-Layer-MLP, and the RF was applied, as it
was found that these yield estimators captured different dynamics in their predictions. The ensemble reduced the RMS error by 2%-12% and did lead to an RMSE of 1.3 t/ha (2012) and 1.56 t/ha (2018).

In conclusion, non-linear statistical models were well suited to forecast yields on the available data set and outperformed a simple benchmark model as well as linear approaches. In years with climatic hazards the models showed the largest improvement compared to the benchmark model. Generating subsets from the training set, did not lead to any improvements and considering all training data still seems to include more valuable information. There is more research needed to evaluate the model’s robustness and to lower the prediction error, e.g., by intense model optimization and uncertainty quantification. Potential for improvements might also have the introduction of in-season captured features that reference the crop status e.g., satellite images or the expansion of the data set.
Agronomic managements that stimulate canopy development improve yield stability in winter wheat

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Achieving stable and high yield over a wide range of environmental scenarios is essential topic under climate change. Yield stability on farm can be achieved by using stable cultivars or optimal agronomic managements. However, due to the complex interactions between managements, cultivars and environments, the mechanisms that improve yield stability are still unclear. Here we hypothesize that agronomic managements stimulating canopy development improve yield stability. Three-year (2018-2021) field experiments using eight elite cultivars of winter wheat (Triticum aestivum L.) were carried out in Hannover under split-split-split plot design with three replicates. In each experiment, eight agronomic managements were conducted by combining 1) two total nitrogen levels, 220 and 176 kg N/ha, representing optimal and sub-optimal nitrogen supply, respectively; 2) two early nitrogen availability, split and combined, with application of 20+20 and 0+40 kg N/ha, respectively, at sowing and at ear emergence and 3) two sowing dates, early and late, that create differences in phenological developments and canopy size in spring. During the growing season, biomass and chemical contents (soluble carbohydrate and nitrogen) of different organs (straw and ear) were measured at six developmental stages (tiller, stem elongation, booting, heading, flowering, and mature). Canopy traits including leaf area index, light interception, tiller number and green canopy duration were measured weekly. Yield components including spike number, grain number, and thousand kernel weight were quantified at the harvest. To compare the stability of each measured trait between agronomic managements, a stability index (superiority measure; Pm) were used. Interestingly, we found interacting effects of different managements on Pm. Under optimum nitrogen level, early sowing date is a more effective management than early nitrogen availability to achieve stable yield. In contrast, early nitrogen availability is more important than sowing date to achieve stable yield under suboptimal nitrogen level. Our data further suggest that agronomic managements affect yield stability by their effects on canopy development. This study highlights the mechanistic interactions between nutrient management, canopy development and yield stability.
Economic effects of variable irrigation on yield and quality parameters of high-amylopectin potatoes

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Global freshwater availability, increasing world population and food demand require profound solutions to secure world nutrition with less water use, while maintaining each crop’s productivity. For potatoes (Solanum tuberosum L.), water management is a key factor for securing yields, increased tuber quality and for reducing pest susceptibility. New varieties were cultivated during the last decades, which only consist of amylopectin compounds. We suspect that these high-amylopectin potatoes react differently to variable irrigation levels in terms of yield and tuber quality compared to food potatoes and that deficit irrigation levels might be sufficient for high-amylopectin potato production.

The aim of this study as part of the “AgriSens DEMMIN 4.0” experimental site in Mecklenburg-Western Pomerania, Germany, was to compare different sprinkler irrigation levels in terms of yield in a three-grade tuber size distribution (< 35 mm, 35-55 mm, > 55 mm), tuber quality (dry matter content, starch content and yield, internal and external tuber deformations) and economic responses (total production value, irrigation water productivity, benefit to cost ratio) of the high-amylopectin potato variety “Waxy/Eliane”.

Four irrigation levels were applied in a field experiment (27 ha) inside one sprinkler irrigation lane during the 2021 growing season on a loamy sand in Mecklenburg-Western Pomerania, Germany. In addition to the farmer’s common irrigation (100%), two deficit (80% and 90%) and one abundant (120%) irrigation levels were applied. The 100% irrigation corresponds to a total irrigation level of 119.39 mm, supplied during five irrigation events, each scheduled according to monitored root-zone moisture and weather forecast.

Irrigation led to significantly increasing total yield, which was highest in the 90% irrigation (561 dt ha⁻¹), leading to highest total production value and irrigation water productivity in this irrigation level. It was found that final starch content and total starch yield significantly increases with increasing irrigation level. Quality deficiencies (e.g., scab infestation or tuber greening), indicating severe reactions to short-time drought stress, led to decreased monetary revenues in all irrigation levels. Total precipitation during the 2021 growing season was 255.1 mm, but early growth stages were exposed to short-time drought stress with an overall precipitation amount of 40.5 mm during leaf development and early tuber formation. In-situ measured soil moisture dynamics in each experimental plot indicated optimal conditions between 40-50% plant available water content and field capacity for “Waxy/Eliane”, corresponding to the 90% irrigation. Lower irrigation levels (i.e. partial root-zone drying...
techniques, corresponding to the 80% irrigation level) lead to significant yield and starch yield losses and reduced tuber quality.

Furthermore, yield, tuber quality and economic responses under different irrigation levels were assessed using second and third grade polynomial functions. The statistically derived optimum irrigation level was 107.52 mm (corresponding to the 90% irrigation) for the meteorological conditions of the 2021 growing season (cumulative water supply: 362.62 mm). Yield and starch yield losses of 354.11 dt ha\(^{-1}\) and 31.05 dt ha\(^{-1}\), respectively, were derived for the lowest profitable irrigation level.

With a total area of 400 ha of high-amylopectin potato production on the local farm, and assuming similar soil conditions and variety properties, a potential of 15,040 m\(^3\) of water could have been saved by a farm-level 90% irrigation level during the 2021 growing season, with similar total yield and starch yield. Yield and starch yield of medium-size tubers would be increased by 98.42 t (109.55\%) and starch yield by 18.3 t (109.86\%), when compared to a farm-level 100% irrigation.

Forthcoming, further field experiments are carried out to investigate how these findings are transferable to other meteorological conditions, soil types, and high-amylopectin potato varieties to enable a farm-scale irrigation management with accurate yield, quality, and economical prediction of high-amylopectin potato cultivation.
Session 2

Posters

Towards Pesticide-Free Agriculture
With weeds against insect decline? Promoting in-field weed diversity increases absolute arthropod density and biomass in cereal cultures

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Since about the 1950s there is growing evidence for worldwide dramatic loss of biodiversity. The IPBES Report predicts that in the coming decades about a million species are facing extinction, half of which being insects. As widely accepted, land-use, with agriculture in particular, is considered one of the main drivers for loss of insect biodiversity. Agricultural intensification lead to habitat loss and degradation. Furthermore wide spread use of agrochemicals such as herbicides or insecticides are also known for having direct negative effects on insects in agricultural landscapes. In contrast, the indirect effects of herbicides on insects caused by the loss of in-field weed diversity have received clearly less scientific attention. Mostly seen as pests, weeds are an important as food resource for birds and pollinators or provide shelter for arthropod predators, that provide beneficial ecosystem services such as e.g. natural pest control. However, it is yet poorly studied how in-field weed diversity affects arthropod densities or biomass. To study the effects of species richness of weed communities on absolute arthropod densities and absolute arthropod biomass, we conducted a field trial in 2020 in oat, barley and maize cultures under organic farming in the region „Vogtland“(Saxony, Germany). To create a wide gradient of weed diversity, we applied three different treatments: monoculture (weeds manually removed), seedbank (no additional treatment) and weeds of the seedbank with an additional undersowing of twelve different weed species. In each crop species, we created 8 blocks consisting of one study plots (4m²) per treatment. We assessed arthropod communities at two occasions using enclosures and suction sampling conducted with a modified garden vacuumer. A total of 32,154 arthropods were sampled, with thrips and beetles being most the most abundant taxa. The overall variation of mean floristic richness was low among crops but high among the different treatments (Monocultures: 8 weed species, seedbanks 14 and plots with additional undersowing 18). We used GLMM to model the relationship between weed species richness and absolute arthropod biomass, absolute arthropod densities and absolute densities of juvenile insects of selected taxa. Despite our small scale approach, weed species-richness showed clearly signficant correlations with the measures mentioned. Floristic species-richness had very high positive effects on arthropod fauna. On plots with fewer than 10 weed species, mean absolute arthropod biomass was as low as 1,25 ± 0,22 kg/ha. In comparison, on plots with more than 20 weed species, we found the mean insect biomass to be about 4,6-fold higher (5,80 ± 0,22 kg/ha). Effect sizes were similar for absolute densities of all ("< 9" species: 85 ± 8 individuals/m² vs. "> 20" species: 351 ± 46 individuals/m²) and juvenile densities. For densities of juvenile insects, we further found significant differences among crops, with maize showing much lower mean densities. The findings of our study suggest that increasing weed diversity in crops may be an effective way for promoting arthropod fauna in agriculture,
without pronounced yield losses or even yield increases. Further studies should concentrate on the relation of weed diversity and arthropod diversity.
Influence of biodiversity of the segetal flora on yield of spring barley (Hordeum vulgare L.), spring oats (Avena sativa L.) and forage maize (Zea mays L.) in organic agroecosystems of Germany

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Intensive farming, as widely accepted, is one of the main drivers of biodiversity loss, in particular of the severe decline of pollinators that are, essential for global food safety. Thus, one of the biggest global challenges is the conflict between high-yield agriculture- and biodiversity protection. The enrichment of cereal monocultures with species-rich undersowing of selected weeds is an integrative approach of biodiversity protection in agriculture.

Recent studies provide growing evidence that highly productive agroecosystems and high biodiversity in field are not necessarily opposing aims. Decreasing yield losses or even increasing yield have been reported in agroecosystems with more diverse weed communities, due to species complementarity and the associated reduction in competition between crops and weeds. One possible explanatory model for this phenomenon is the Resource Pool Diversity Hypothesis (RPDH), which states that, based on the assumption of niche differentiation, functional different species are able to acquire resources from different pools (e.g. different rooting depth).

This study aimed at disentangling the influence of weed diversity on dry matter crop yield of spring barley, spring oats and forage maize. In particular, the research examined whether manipulated weed diversity affects crop yield and whether crops respond differently to weed diversity. For this purpose, 72 plots à 4 m² were established on the site Eichigt in 2020 (24 per crop species) under organic farming conditions, creating three different treatments:

- Monoculture (weeds manually removed), seedbank (no additional treatment) and weeds of the seedbank with an additional undersowing of twelve different weed species. The results revealed that field weed diversity was changed by the different treatments. Diversity of weeds (based on weed species biomass as abundance measure) proved to significantly influence yield parameters in crops, with pronounced difference in the studies crop species. In spring barley, increasing weed diversity caused complementarity effects that led to a mitigation of weed competition effects. At high biodiversity levels, moderate yield reductions in spring barley (7 %) were observed. In spring oats stands, no significant impact of weed diversity on crop yield was detected, but we found even a slight increase in spring oats’ yield (5 %) within diverse weed communities. In contrast, severe dry matter yield losses (more than 70 %) were observed in forage maize crops, which can be attributed to a high competition ability of weed...
vegetation during the critical development phase of maize. We conclude, that promoting a healthy and diverse segetal flora does not necessarily lead to severe crop yield losses and may even increase crop productivity. We hence demonstrate that both high-yield agriculture and protection of biodiversity may be successfully combined.
Comparison of sequential herbicides applications in sugar beet in Belgium based on active substances analysis

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In Belgian conditions, sugar beet is one of the crops demanding the highest use of plant protection products (PPP). The use of herbicides is particularly crucial to avoid any competition with weeds regarding the plant needs (nutrient, water, light...). Usually, in order to reduce the use of herbicides, agronomic practices must be adapted to allow a substitution of the active substances by mechanical weed control combined with adequate reduced use of herbicides. The low dose chemical weed control system used in Belgium for sugar beet was developed in the 80's and has become a reference. The principle consists in a sequential application of low doses of the herbicide's active substances. Most of the applications are a mix of the three main active substances: phenmedipham, ethofumesate and metamitron. The phenmedipham is the main contact foliar herbicide, and is applied with ethofumesate that enlarge the treatment against weeds communities. The metamitron is a root systemic herbicide also used to complete efficacy spectrum and brings remanence to the system. Nowadays many restrictions on the use of other key active substances such as desmedipham and chloridazon have been implemented from European level leading farmers to review their phytosanitary practices which can cause complications for the control of certain weeds. In order to be able to monitor PPP applications at farm level, several indicators have been used such as applied pesticide quantities (kg.ha-1) obtained from farmers surveys or after recording in a database and also the French widespread indicator TFI (Treatment Frequency Index). Nevertheless it was demonstrated that this index implies a systematic bias in the evaluation of active substances used because it takes into account the number of national recommended doses of commercial products applied to each unit of cropped area and averaged across the crop sequence. Therefore, to quantify and compare farming practices related to weed control through herbicides use in sugar beet, a derived unbiased index called ISAC based on active substances per crop has been developed1 and is now applied to compare several weed control strategies. This index links the quantity of active substances applied (g.ha-1) and the maximal authorized doses that can be sprayed per hectare, which is defined at national level. We analyzed some datasets from surveys in Wallonia about usual sequential herbicide treatments. In conclusion the use of the ISAC index allows relevant comparisons between different strategies which can in fine help to propose alternatives for reducing herbicides use in sugar beet. Obviously, it is necessary to investigate how to manage weeds with less or no herbicides in arable farming while maintaining the productivity and therefore take into account agronomic performance such as yield and crop net profit.

The effect of different weed communities on growth and yield of tender wheat

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Keywords: Weed ecology, weed community, sustainability

The effect of different weed communities on growth and yield of tender wheat

In agroecosystems, different biotic threats can decrease crop yield, such as insects, weeds, fungi, viruses, and bacteria. Among all, weeds are known to be the most impacting. The annual global economic loss caused by weeds has been estimated to be more than $100 billion U.S. dollars (Oerke, 2006).

Moreover, weed management is mainly done using herbicides that have a high environmental footprint with a detrimental impact on habitats and biodiversity. The current weed management raises economic and environmental problems, calling for new sustainable ways to reduce herbicide use. In 2020-2021, we performed an experiment on tender wheat at the Department of Agricultural Science of the University of Naples Federico II (Portici, IT), in which we imposed two treatments: weed-free vs. weedy plots. Weed-free plots were obtained spraying a post-emergence herbicide for wheat. During the growth cycle, we evaluated i) weed species composition (number and biomass) and ii) wheat growth and productive parameters (eight plots per treatment, 2 m2 each). This approach allowed us to evaluate weed species composition per plot, showing that the field was infested by two main weed communities (WC1 and WC2), differing by the high presence of Medicago polymorpha in WC2 (25% on total weeds number), which was almost absent in WC1 (less than 3% on total weeds number). When correlating biometrics and productivity with the two weed communities, we found that where M. polymorpha was absent (WC1), wheat growth and yield were not reduced by weed presence compared to weed-free plots. Conversely, wheat grown under WC2, where M. polymorpha was one of the dominant species, wheat biomass and yield were severely reduced compared to weed-free plots (-57% and -74%, respectively). Our results are in line with previous studies in which the authors identified neutral weed communities for wheat productivity (Adeux et al., 2019). These considerations have important implications for the future of weed management, especially when with the principles of precision agriculture. Indeed, thanks to machine learning and robotics, it will be possible to train robots to remove only the detrimental species from the field (in our case only M. polymorpha), with an important reduction of the use of herbicides. This approach has positive implications on the biodiversity of the agro-environment, which is obviously maximized compared to weed-free plots, with important benefits linked with the ecological services that wild plants can provide to the ecosystem (Foley et al. 2005). We are currently working on the automatic identification of weeds via machine learning to implement this approach in real agricultural contexts. Indeed, the models identified by the machine learning approach will enable us to rapidly...
evaluate weed density and composition to be handled through selective robotic systems. Moreover, the automatic evaluation of weed density and composition represents an important tool to correctly calculate the specific thresholds for the herbicide treatments, that are currently assessed on random areas of the entire field.

Reference:


Are no-till herbicide-free systems possible? A simulation study

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INRAE

Conservation agriculture (CA) allows farmers to reduce costs and enhance soil health, but tends to increase either weed infestation and associated crop yield loss, and/or herbicide use. We aimed to investigate how much tillage contributes to reducing weed infestation and yield loss, and which systems and weed species are the most affected if tillage is deleted. We collected farming practices on 395 arable cropping systems from Spain and France, and simulated them over 30 years and with 10 weather repetitions, using FLORSYS. This process-based model (Colbach et al., 2021, Field Crops Res 261:108006) simulates daily multi-species weed floras and crop canopies from cropping systems and pedoclimates over the years. Three series were simulated, (1) using the recorded cropping systems, (2) eliminating tillage without otherwise changing management practices, (3) eliminating all herbicides without any other changes. Each series was run twice, once starting with a regional weed-flora pool to simulate weed dynamics and their impact on crop production and biodiversity, and once without weeds to predict potential crop yield. Among the recorded systems, herbicide treatment frequency index (HTFI) averaged over rotation increased when tillage frequency decreased. No recorded no-till system was herbicide-free. The untilled crops with the lowest HTFI (0.16) were unusual crops, i.e., relay grass crops or multi-annual crops.

Simulations of the recorded systems showed no correlation between tillage-frequency and weed biomass or yield loss. When tillage was deleted without any other change, yield loss almost doubled. Tillage deletion similarly increased most of the other weed impacts, i.e. harvest pollution, harvesting difficulty or weed-based carabid-food offer. Weed offer for birds and pollinators increased approximately twice as much whereas species richness, field infestation and potential yield (in the absence of any weeds) varied little on average. We then identified (1) which weed species and traits (e.g., spring/summer annuals) increased after tillage suppression and in which cropping systems (e.g., species with persistent, thick-coated seeds in rotations with frequent winter crops), (2) which recorded systems were robust to tillage suppression in terms of weed-caused yield loss (e.g., with cover crops, summer crops), (3) which no-till systems (recorded or obtained after deleting tillage) limited yield loss (usually those with frequent and/or efficient herbicides), (4) which management techniques were associated with a reduction in tillage, in herbicides, and in yield loss (e.g., long and diverse rotations, cover crops). No tested system achieved all three objectives simultaneously. The simulations indicated that two CA pillars (diverse crop rotations, cover cropping) were essential to manage weeds in systems with reduced tillage and reduced herbicide use. More no-till cropping systems must be investigated to determine whether sustainable no-till herbicide-free systems are possible.

Funding: INRAE and the Ecophyto COPRAA project.
How hedgerow characteristics alter Pseudocercospora fijiensis dispersal?

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Keywords: Musa spp., Black leaf streak disease, barrier effect, Martinique

Diversification of agrosystems is often presented as an important lever for pest management. However, there is very little knowledge about the effect of this diversification on disease dynamics. Because of their size, trees and hedgerows have the potential to alter the dispersal of aerial diseases. Black Leaf Steak Disease (BLSD) caused by Pseudocercospora fijiensis is the main disease of bananas and leads to significant crop losses and environmental concerns due to fungicide applications. In this work, we have experimentaly evaluated how hedgerows influence the dispersal of two types of spores involved in short (conidia) and long-distance (ascospore) dispersion of BLSD. Our aim was to determine how hedgerow characteristics interfere with spore dispersion. We set-up 21 experiments on 7 contrasted hedgerows, with no sources of BLSD in the 400 m radius around. Each experiment consisted in i) placing an artificial source of one type of spores on one side of the hedgerow, and ii) on both side a set of 25 banana trap plants (i.e. 50 cm high vitr-o-plant) in line of 5 at equal distances to the source of spores until 50 meters. Banana plants were exposed during 10 days (corresponding to the time of emergence of one leaf). After exposure in the field, each banana plant was settled in an individual greenhouse in order to favour disease expression in a humid environment during 2-times the incubation period. Then the density of BLSD lesions was measured on the leaf that emerged during exposure. Using linear models, we analysed the density of BLSD lesions on each banana tree including four factors: i) the wind (frequency of wind directed between the source of spores toward each given plant), ii) the distance between the banana plant and the source of BLS, iii) the side of the hedgerow (i.e. on the side of the source or not), and iv) the characteristics of the hedgerow (including their height, width, porosity, that were summarized in a capacity of interception variable). For ascospore dispersal, there was no massive difference between sides control and test (respectively, without and with hedgerow). However, there was a strong effect of the characteristic of the hedgerows on the BLSD lesion. As expected, the lesion density decreased with the distance to the source. There was a maximal dispersion of spores for medium winds, while it was lower for lowest or strongest winds. Our results is the first quantification of the effect of hedgerows on BLSD dynamics. Interestingly, there was a strong effect of the hedgerow presence characteristics (capacity of spore interception) on the dispersion of the disease, i.e. the higher the capacity of interception the lower the dispersion. There was up to 50% decrease of lesion density between small and large capacity of interception hedgerows. Our results also provide a quantification of the dispersal capacity of the two types of spores and the influence of the wind. This study gives key information to better include hedgerows in agroecological control against BLSD and fungal diseases in general.
Multicriteria assessment of alternative solutions for potato protection

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Arvalis

Potato is one of the cash crops that consumes the most phytopharmaceutical inputs (Agreste, 2019). Therefore, the challenge is to reduce the use of synthetic pesticides to improve environmental and societal impacts for all potatoes’ production steps. The objective of the project COM-POT was to reduce the use and dependence on pesticides. It aimed to develop and evaluate solutions for the regulation of pests (blight, wireworm, weeds) and for haulm destruction of potatoes. A multicriteria assessment was performed to evaluate the technical, economic, and environmental performances of each solution.

Different solutions were tested, they can be levers or combinations of levers. Four alternative levers for blight protection were considered: use of the Decision Support System, varietal resistance, use of biocontrol products and combination of these three levers. For weeds management, three levers were studied: pre-emergent treatment, combination of pre- and post-emergent treatments and combination of pre-emergent treatment with post-emergent mechanical weeding. Four levers were evaluated for haulm destruction: crushing and defoliating treatment, haulm pulling, thermal haulm destruction and plant electrocution. At first, the technical efficiency of each solution was evaluated in field trials set up in three locations in the North of France (Gaucher et al., 2022).

The multicriteria assessment was then performed on the most promising solutions for efficiency using the tool SYSTERRE® and a reference farm. SYSTERRE® is a calculator that assesses the sustainability of cropping systems and crops at farm scale. After describing entry data, SYSTERRE® calculates a range of technical, economic, and environmental indicators to provide an overall view of performances (Berrodier et Jouy, 2018). The reference farm is a model of realistic farm, which represents the structure, the practices and the performances of the farms in an area.

The reference farm for Hauts-de-France area was used for COM-POT. A common technical management route was defined thanks to the expertise of potato specialists. Then they contributed to integrate the promising solutions to this management route. Cultural operations, pesticides and machines used, and costs were adapted to suit farms constraints. Performances of each solution were analysed. Then, solutions were compared to highlight their positive and negative impacts. The analysis focused on technical criteria (workload, active ingredient quantity...) on economic criteria (inputs costs, mechanisation costs...) and on environmental criteria (Green House Gaz emissions, energy consumption).
Most of the solutions tested on field led to a reduction of pesticides use, which comes with the decrease of pesticides pressure. They finally lead to the reduction of inputs costs. Depending on the solution studied, the work time and mechanisation cost evolve differently: They increased when the mechanisation was intensified (chemical techniques replace by mechanisation) or they decreased when pesticides application was more accurate (defoliant application at the top of the hills...).

The multicriteria assessment performed in COM-POT provided a range of indicators reflecting the advantages or disadvantages of each lever and lever combination. It allows the decision-maker to choose the best option according to his priorities or constraints. However, these results were acquired for a single soil-climate context and with trial data of three unusual, dried crop years. To provide more representative results, data should be collected on all potato producing regions over a longer period.


Impact of plant protection strategy and soil tillage on the carbon footprint of crop production - evidence of a long-term field experiment in 2008-2019

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Keywords: climate change mitigation, greenhouse gas emissions, life-cycle-assessment, crop rotation

There is an increasing societal and political wish to reduce the use of chemical-synthetic plant protection products (csPP). While csPP help to avoid biotic stress induced yield losses they are seen critical with regard to their environmental impact. At the same time, there is an increasing global demand for agricultural products, and the greenhouse gas (GHG) emissions from agricultural production should further decrease in the future. To provide evidence to these pressing questions of producing more food with less environmental and climate change impact a long-term experiment with six components was analysed using a life-cycle-assessment approach. The experiment is conducted at the Dahnsdorf experimental station in Brandenburg, Germany. Three experimental factors were tested: i) soil tillage, i.e., with plough vs. without plough, ii) with fungicides / insecticides vs. without fungicides / insecticides, and iii) plant protection strategy, i.e., good agricultural practice vs. integrated plant protection. Production data from 2008 to 2019 were considered. We find significantly higher yields when using fungicides and insecticides for most crops, i.e., wheat, rye, triticale, barley, oilseed rape, maize/sorghum, and peas. With regard to the plant protection strategy and soil tillage no distinct yield advantages are found. Looking at the carbon footprint of crop production we find that foregoing the use of csPP leads to higher carbon footprints of crop production for all crops except peas. With regard to tillage the use of plough did not result in significantly higher carbon footprints for most crops. Integrating the results at the level of the crop rotation using grain units we determine higher overall productivity and lower carbon footprints when using fungicides and insecticides. The year-wise analysis reveals strong differences in results and potential conclusions depending on the specific years and period that one looks at. This highlights the demand for and specific value of long-term experiments.
Reducing pesticide use through crop diversification

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Managing pests while reducing pesticide use is a major challenge to improve cropping systems' sustainability. Crop diversification appears as a promising tool to promote ecosystem services such as pest control (Tamburini et al., 2020; Beillouin et al., 2021). Lechenet et al. (2016) identified crop sequence and crop diversity, among other management practices, as important factors to reduce pesticide use in most French production situations. Crop diversification could allow the reduction of pesticide use at the cropping system level through: i) the introduction of crops with low intrinsic pesticide use (i.e. grassland, sunflower,...) and ii) the disruption of biological cycles of pests and diseases in time and space. Nevertheless, the reduction of pesticide use allowed by crop diversification has never been quantified nor the stability of its effect highlighted across diverse production situations. We addressed this issue by using the Dephy network dataset, a national network of 3000 farms initiated as part of the French national plan Ecophyto, which aims to reduce pesticide use by half across the French territory. We considered 1614 non-organic cropping systems described annually over a period of one to thirteen years. Cropping systems displayed a wide diversity of management strategies (i.e. in the crop rotation and in the specific management of each crop) within and across various pedoclimatic conditions. For each cropping system and year, the number of crops and the return delay in the rotation of nine main crops (i.e. wheat, barley, oilseed rape, maize, potatoes, sugar beet, sunflower, pea and soybean) were computed. Pesticide use at the crop level was quantified with the Treatment Frequency Index (TFI). At the cropping system level, TFI was expressed as the weighted average of each crop’s TFI according to its proportion in the sequence. The relationship between the number of crops in the cropping system and TFI at the cropping system level was modelled as a second order polynomial, using a linear quantile mixed model. The effect of return delay of nine crops on pesticide use was quantified at the crop and cropping system level and modelled in interaction with climatic region, using generalized linear mixed models. Increasing the number of crops from one to five tended to increase cropping system TFI, because crops with low pesticide use (i.e. maize and meadow) tended to be replaced by crops with higher pesticide use. However, when the number of crops in the rotation was higher than five, cropping system TFI decreased, especially for the 25% cropping systems with the highest TFI. For five crops out of nine (i.e. wheat, oilseed rape, maize, sugar beet, and barley) increasing the return delay from one to five years reduced crop TFI from 0.3 (i.e. barley) to 1.2 points (i.e. wheat). In most cases, increasing the return delay of crops also scaled up to a reduction of TFI at the cropping system level, which could either reflect either a selection effect (substitution of crops strongly relying on pesticides i.e potatoes) with crops with low intrinsic pesticide use) or a regulating effect of diversified crop rotations on pest pressure in a given crop. Conversely, for maize in the oceanic degraded climatic region and for sunflower in all climatic regions (i.e. two crops with
low intrinsic pesticide use) increasing the return delay from one to five years induced a small increase of cropping system TFI (i.e. +0.6 and +0.2 point, respectively). Hence, increasing their return delay may lead to the introduction of crops with higher pesticide use. To go further, a more detailed characterization of crop sequences associated to low pesticide use is needed.
Is phytochemical defence transferred between plant species?

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Benzoxazinoids (BXs) are secondary plant metabolites, which are widespread in wild and cultivated species in the Poaceae family, such as maize (Zea mays), wheat (Triticum spp.), and rye (Secale cereale). [1, 2] BXs are important for defence against insects, parasitic nematodes and pathogens, and root exuded BXs are considered to have allelopathic effect on neighbouring plants. [3] We hypothesized that plants which do not synthesize BXs are able to take up BXs exuded from neighbouring plants and exploit them in their defence against pests and pathogens. Metabolomic studies on BX root uptake and transformation in the neighbouring/receiving plants are very limited. Therefore, we aimed to elucidate the profile of BXs after uptake by white clover (Trifolium repens L.), and to determine whether clover uptake of BXs enhances clover defence against plant parasitic root-knot nematodes. We grew clover plants in Phytatray II boxes, which contained a regeneration media (0.22% murashige and skoog basal salt mixture, 0.5% sucrose, 0.3% phytagel, adjusted pH to 5.8) and 100 µM individual BXs (BOA, DIBOA, HBOA, and MBOA) for 3 weeks. Subsequently, the plants were translocated to soil and inoculated with root-knot nematodes (Meloidogyne incognita), when they were 5, 7.5 and 10 weeks old. Seven days after nematode inoculation, we sampled roots and shoots and analysed BX concentrations by LC-MS/MS and quantified nematode infections.

All BXs were taken up by clover roots, although the BXs have different solubility and structure. The individual BX concentrations ranged from 1 to 469, and 0.3 to 170 µg/g dw in the roots and shoots, respectively. Upon uptake of DIBOA and HBOA, the parent compounds and a range of transformation products were seen in the roots and shoots. In BOA and MBOA exposure studies, only the parent compounds were detected. In all cases, pre-exposure to individual BXs reduced root-knot nematode infections of clover plants harvested at 6 and 8.5 weeks.

We thus show that white clover uptake and transformation of bioactive phytochemicals synthesized by other plants species enhances clover defense against an important plant pest. These findings suggest that co-cropping of plant species with complementary defence metabolites can enhance pest resistance of diversified cropping systems and reduce the need for pesticides.

Reference:


Mixed cropping with wildflower strip at margin for multiple pest regulation and agroecosystem productivity

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Agroecology and Organic Farming Group, University of Bonn

Spatial diversification; Insects; Weeds; Yield

Spatial diversification at the field scale is one of the key steps toward productive pesticide-free agriculture. Among other practices, mixing plant species is expected to disrupt the colonization, development and spread of weeds, insect herbivores and diseases, while implementing wildflower strips at field margins is expected to recruit natural enemies of these pests. So far, research has generally considered either the effects of crop mixtures, or the effects of diversified field margins, on pest regulation. In addition, the focus has often been on either weeds, insects or diseases. The present research tests the strategic integration of these two diversification instruments, with a view on their multifunctional effects.

A trial was set up in autumn 2019 in a 1.5 ha field at the University of Bonn Teaching and Research Station for Organic Farming Wiesengut (Hennef, Germany). Four cropping treatments, with or without wildflower strip at one margin, were compared in a split-plot design (i.e., eight treatments repeated four times): sole cropping of winter wheat, sole cropping of winter fava bean, the intercropping of both in an intermediate design (100% of sole bean density + 50% of sole wheat density), and winter wheat with an under-sown mixture of white clover, black medic and red fescue. The wildflower mixture was composed of 12 annual, biannual and pluriannual forb species and one grass species. Weeds, insects, diseases and crop yield were monitored in each cropping plot at 10 m and 20 m distance from the managed margin in a 1 m²-permanent quadrat. In the present analysis, data collected at 10 m and 20 m were pooled. Yield was also measured in an additional 1 m²-quadrat placed in each cropping plot at 10 m from the margin where weeds were manually removed once a month.

Weed biomass at crop harvest was strongly reduced in intercropping compared to sole bean, and it was the lowest in sole wheat without wildflower strip. In the absence of wildflower strip, colonization rates of aphids and their predators (i.e., ladybird beetles, predatory hoverflies and lacewings) were significantly higher in sole bean compared to intercropped bean, while aphid colonization was significantly higher in intercropped wheat compared to sole wheat. No significant effect of cropping treatments on insects was observed in the presence of wildflower strip. Regarding disease severity, no effect of diversification was found on either wheat or bean. When considering each cropping treatment separately, the presence of wildflower strip had no effect on weed biomass, insect colonization and disease severity.

Wheat yield was significantly reduced in intercropping compared to sole cropping in the absence of wildflower strip (-12% on average, while it’s sown density was half of the sole crop).
In the presence of wildflower strip, this difference in wheat yield (-8%) was not significant. Bean yield was strongly reduced in intercropping compared to sole cropping, but relatively less in the presence of wildflower strip (-71% and -47%, respectively). Weeds had significant effects on grain yield neither on wheat nor on intercropped bean. Only sole crop bean suffered from weeds, with a yield reduction of 60% on average. Land-Equivalent Ratio (LER) of intercropping was significantly higher than 1 only in the presence of wildflower strip. Partial-LER (pLER) was always significantly higher than 0.5 for wheat, and significantly lower than 1 for bean, with the exception of bean pLER with wildflower strip at margin and without weed removal which was not significantly different than 1.

Hence, the present results show that the strategic integration of intercropping with wildflower strip at margin can enhance the overall productivity of the agroecosystem, although the effect on pest regulation was limited.
Early detection of Phytophthora infestans in potato plants using hyperspectral imaging, local comparison and a convolutional neural network

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An important primary inoculum source of Phytophthora infestans are latently infected seed potatoes. To remove those sources before symptom expression, it is necessary to detect those early. Often, when a human can detect it by eye, sporulation has occurred, moreover it is not feasible to check all potato plants by hand. It is possible to detect a P. infestans infection early, using hyperspectral imaging. However, models trained on the spectral information only, do not generalize, because the spectrum is very much dependent on the local conditions like soil humidity. A method is developed to detect phytophthora early by comparing spectra from infected plants with the spectra of healthy plants that have grown under similar conditions, i.e., in the same row, and creating an image that quantifies deviations. On those images in turn a convolutional neural network is trained, which is able to detect infections on plants grown in another field or a year later in a similar manner but under different conditions.
From movement experiments to dispersion predictions of a lupine pest: the case of Sitona gressorius

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Keywords: Agricultural pests; Diffusion; Hidden Markov Models

Little is known about movement and dispersal of many agricultural pest species, even though it is widely accepted that many of them will benefit from global warming, intensifying their potential damage. We have investigated how temperature and light conditions affect different movement metrics and the feeding rate of the large lupine beetle (Sitona gressorius) through video recordings. The movement of 384 beetles was digitally analysed under six different temperatures and light conditions in the laboratory. Bayesian linear mixed-effect models were used to analyse the data. Furthermore, the effects of temperature on the daily diffusion coefficient of beetles were estimated by using Hidden Markov Models and random walk simulations. Results of this work show that temperature, light conditions, and beetle weight were main factors affecting the flight probability, displacement, time being active and the speed of beetles. Significant individual variation was also observed in all evaluated metrics. On average, beetles exposed to light conditions and higher temperatures had higher mean speed and flight probability. However, beetles tended to stay in more active at higher temperatures and less active at intermediate temperatures, around 20 °C. Therefore, both the diffusion coefficient and displacement of beetles were lower at intermediate temperatures. These results represent a cornerstone in the prediction of when and where the large lupine beetle is likely to occur and how it disperses in a heterogeneous agricultural landscape. Such models will help to assess how landscape structure and use will affect beneficial and harmful insects, and to draw conclusions for the reduction potential of pesticide use.
Methodology and indices for the spatial evaluation of different planting patterns

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An optimized spatial planting pattern can help to minimize negative intraspecific competition for light, nutrients and water. Furthermore, the competitiveness against weeds can be increased and an improved microclimate may help reduce diseases. In addition to the conventional drill seeding technique, where the seeds are placed rather randomly within the row, there are now single grain seed drills, with more precise spacing within the row as well as precision sowing machines for low-density crops such as maize and cabbage, which enable an equidistant planting pattern. A planting pattern is equidistant, when both the inter- as well as the inner-row distance are equal.

So far, there are is a lack of methods and criteria to assess and evaluate the spatial pattern of different sowing techniques in the field. Therefore, we developed a standardized and reproducible approach and respective indices.

The aim of this study is (i) to present indices for an profound evaluation of spatial planting pattern on a two dimensional scale, (ii) to elucidate the methodical approach for the derivation of those indices in detail as well as (iii) to demonstrate this approach on two field experiments. One comparing an equidistant (EqS) with a conventional drill planting pattern (DrS) and the second comparing a single grain seeder (SGS) with a DrS.

As results, (i) our indices, one for each parameter, are first, the coefficient of variation (CV) for comparing the sizes of the polygons, second, the circle-polygon-ratio (CPR) to analyze the shape, e.g. if a polygon is rather compact or elongated and third, the eccentricity to determine the relative distance between a polygon’s centroid and the plant’s point of emergence. (ii) Applying our approach, we were able to create our indices by a low number of data sources. The step by step methods is part of the supplement. (iii) The experimental results show that the EqS exceeds in all indices comparing to DrS, whereas due to the increased row distance, the SGS was worse in the CPR compared to DrS with no differences in CV and Ec. Even though its good results, the equidistant seeding pattern is only available as a prototype for high-
density crops such as wheat, due to its needed high-level precision technique, it provides the most homogenous spatial distribution for the crops.

Caused by the time consuming method of tagging each plant by hand, an AI-based approach is already in the test stage.
PestiRed: an on farm project to reduce pesticide use while maintaining profitability

Sandie Masson PhD; Dr. Judith Wirth; Dr. Alexander Zorn; Solène Clémence

Agroscope

In Switzerland, the current Agricultural Law makes the granting of direct payments conditional on the fulfilment of ecological requirements. Crop diversification is thus promoted as well as a targeted use of plant protection products (PPP). However, the awareness of the various problems caused by the use of PPP, like pest resistance, contamination of ecosystems and health problems encouraged the development of new instruments for risk reduction and sustainable use of PPP in Switzerland. For this purpose, an action plan was implemented in 2017. One of the measures enacted is the "Development of alternatives to chemical plant protection". It is in this context that the project PestiRed was set up. Reduced quality and quantity of agricultural output, as well as increased costs, are risks associated with limiting use of PPP. Therefore, these criteria are taken into account in the project.

PestiRed brings together 68 farmers with the aim of reducing pesticide use by 75% in a 6-year crop rotation (2020 to 2025), with a maximum economic loss of 10%. Each farmer cultivates one innovative field with a combination of agroecological crop protection practices and one control field with the same crops grown conventionally. All cultivation operations are precisely documented technically and economically. At the end of each year, farmers assess the perceived effectiveness and profitability of the techniques implemented. Along entire crop rotations, effectiveness of alternative crop protection strategies on weeds, pests, diseases and beneficials are monitored and evaluated.

During the first two years of the project (2020 and 2021), 128 pairs of innovative and control fields were evaluated: wheat (26), rapeseed (20), maize (18), barley (17), cereal-legume mixtures (11), pea (10), spelt (7), sunflower (6), sugar beet (5), potatoes (4) and soya (4). The indicator used to evaluate the reduction of PPP is the treatment frequency index (TFI). For all crops, except sugar beets and potatoes, the TFI reduction between the innovative plot and the control plot was over 75% (between 75% and 100%). In potatoes, the reduction was only 30% (due to fungicides) and 50% in sugar beets (due to herbicides).

Economic results from the first season show that the profitability of wheat, rapeseed and sunflower could be maintained, while the profitability of barley, spelt, maize and potatoes decreased more than 10%. Reasons are that agronomic yields generally decreased as well as, to a lesser degree, yield quality. Simultaneously, costs rose with increased labour and machinery costs (for increased tillage and mechanical weeding). Higher direct payments and contributions from labels related to the new practices implemented did not always compensate for the higher costs and losses of yield quantity and quality.
A balance must be found, in the next 4 years of the project, to limit economic losses while maintaining limited pesticide use.
Alternatives to synthetic pesticide use are required to increase the sustainability of crop protection strategies. Identifying technical options based on the biological regulation of pests (pathogens, animal pests and weeds) is a promising and complex challenge. Among the options to be developed are ‘service plants’, also called ‘cover plants’, ‘companion plants’ or ‘biocontrol plants’. The principle is to sow these plants, either in association or in rotation with cash crops, to provide different ecosystem services, among which pest regulation. Past studies demonstrated the usefulness of service plants for regulating one category of pest, i.e. either pathogens, animal pests or weeds. However, few of them considered the role of these plants for multi-pest regulation. Yet, meeting the challenge of agroecological transition definitely requires an integrated view of the mechanisms leading to a pest regulation. To what extent can service plants provide a relevant option to promote multi-pest regulation, while limiting potential disservices of these plants, is still an open question? Given the diversity of the academic disciplines concerned and the scarcity of the scientific references, developing a conceptual framework appeared as a prerequisite to address this question. Such a framework allowed to synthesize the mechanisms and traits of the service plants potentially involved in the regulation of each category of pest. Both direct (i.e. directly targeting the pest) and indirect (i.e. targeting the pest through the mediation of natural enemies) mechanisms were considered, involving traits of service plants related to growth, morphology, phenology, biochemistry and immunity. Mechanisms and traits by which service plants can trigger unintended effects (e.g. by competing with cash crops for resources, promoting non-targeted pests, etc.) were also synthetized. This framework allowed to identify optimal ranges of trait values promoting the regulation of each category of pest and limiting negative impacts of service plants. It also highlighted different synergies and antagonisms between the different categories of pests, leading to a comprehensive view of the potential for multi-pest regulation. For most of the traits, we identified synergies. For example, tall service plants with a rapid growth rate can promote weed regulation (by competition for light) as well as aerial pathogens and phytophagous insects (by providing a physical barrier or increasing emission of volatile organic compounds affecting these pests). However, synergies and antagonisms need to be studied in more details for traits related to emission of chemical compounds. Indeed, a given molecule may promote the regulation of different types of pests but also may repel beneficial organisms such as natural enemies.
As a last step, synergies and antagonisms between overall pest regulation and disservices provided by the service plants were also considered.

This framework lays the foundations of a plant-trait-based approach that will be useful to prioritize research actions to identify efficient service plants and their way of use in agroecological contexts. Such framework, in combination with the development of databases, will be crucial to help farmers choose the most efficient and resilient service plant Species/varieties to combine in order to enhance multi-pest regulation.

Funding: Métaprogramme SuMCrop of INRAE.
Reducing pesticide use in arable fields through cropping system re-design: what impact on farm productivity and profitability?

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Due to their impacts on biodiversity and human health, reducing pesticide use is a key step for transitioning to sustainable farming systems (Matson et al, 1997; Storkey et al, 2012). Following the European SUD Directive, the Ecophyto plan set the objective of halving pesticide use in France, primarily by 2018, but thereafter postponed to 2025 (ECOPHYTO II+ Plan, Ministry of Ecological and Solidarity Transition, 2018).

The Ecophyto plan launched the DEPHY network, based on about 3,000 farms engaged in the demonstration that reducing pesticide use is possible without impairing farm profitability. Farms are coordinated in groups of 10-15 farms, and detailed practices data are collected and gathered into a national database (DEPHY FARM network, 2018).

Previous research based on this database has shown that in a majority of sites, low pesticide use was not conflicting with profitability nor productivity (Lechenet et al, 2017). Cropping systems with low pesticide use were associated with combinations of preventive measures that varied across production situations and across farms (Lechenet et al, 2016). These results, based on a synchronic comparison of farms, tend to demonstrate that using little amount of pesticide is possible in most cases, but research remains to address the transition from high to low pesticide use, based on a diachronic approach.

With a large range of data (more than 1,300 farms having joined the network since at least 3 years), we are performing detailed analysis of the evolution of pesticide use over time, and its relation to the evolution of farm practices implementation. We consider how the production context (soil type, climate, access to specific markets) influences both practices and pesticide use.

For each site, we computed a range of variables describing (i) the production situation, (ii) the cropping system and pesticide use at the enrolment in the network, and (iii) the changes in cropping system and pesticide use after a few years. The Treatment Frequency Index (a commonly used index for estimating the pesticide use dependency of a farm (Brunet et al, 2008)) is used as a metric of pesticide use. Variables describing cropping systems include descriptors of practices expected to have an effect on pest pressure, and therefore on pesticide use (e.g. among others: soil tillage strategy, crop sequence, sowing dates, Fertilization level, mechanical weeding, etc. (Davis et al, 2012; Lechenet et al, 2016). A CART (Classification And Regression Tree) method is used to analyse changes in pesticide use (DTFI = TFI final – TFI initial) as a function of all variables describing (i) changes in cropping systems and crop management, (ii) initial cropping systems and (iii) production situations. The methods allow to identify which evolution of (combinations of) practices are associated with...
a reduction or an increase in pesticide use, taking into account both specificities of production situations and initial cropping systems.

Analyses are currently in progress. At the date of the conference, we will present the results. We anticipate that major changes in practices allowing to reduce pesticide use will be in accordance with strategies with low reliance on pesticides identified by Lechenet et al. (2016), namely the diversity of the crop sequence, the soil tillage strategy, the moderation of fertilization, the use of resistant cultivars, the sowing date, the reduction of pesticide dose at each application, etc. We intend to complement this study by analyzing the consequences of these changes in cropping system and management on other sustainability indicators (productivity, profitability at the farm level, work load, environmental impacts).
Landrace cereal cultivation, weed management and other services – experiences of Swedish farmers

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The need for robust crops is increasing, both as a strategy for adaptation to climate change, and as organic farming is becoming more common. Landraces of cereals – varieties with a historical origin and characterised by a high genetic diversity – have been subject to an increased interest, and are pointed out as having traits that can be crucial in future sustainable farming systems (Wolfe et al., 2008). One trait associated to sustainability is the ability to compete well with weeds, which can enable a less intensive weed management (Lazzaro et al., 2019; Murphy, Dawson, & Jones, 2008).

Little is known about farmers’ experiences of using landraces to reduce weed management. In an interview study with 32 Swedish farmers cultivating landrace cereals, we found that they used the agronomic traits of the landraces to fulfil multiple functions in their farming systems, for example control weeds. In the farmers’ experience, the landraces competes well with weeds, a fact that was commonly attributed to the long straws and a strong early development. The farmers described that the length of the straw, although it meant a lower harvest index, also meant that they could reduce the intensity of weed management. According to the farmers, landraces shades the weeds more than modern varieties, and only the most persistent weeds survives. Such persistent weeds are for example perennials or climbing species that are able to build up a seed bank. The farmers sometimes used the landraces cereal as sanitary crops in the crop rotations, preparing ground for less competitive crops or used after ley because they competed well with surviving forage plants. The higher straw yield also meant other advantages according to the farmers, since straw could be used as bedding and feed for livestock, or could be sold at advantageous prices. The length of the straw was not regarded as a solely positive trait, but was also described as leading to an increased risk of lodging. Problems related to lodging could, in the farmers’ experiences, be reduced by lowering the nitrogen doses and by using special harvesting techniques.

In addition, the farmers described how landrace cereals could be a way to introduce more cash crops in more margin agricultural areas dominated by cereal and ley for feed production, thereby increasing crop diversity and food production in areas dominated by feed production. Consumer interest in landrace cereal products were described as increasing, which gave the farmers opportunities for selling grains for good prices. As a conclusion, the farmers in our study used landrace cereals to develop more multifunctional farming systems, providing not only grain yield but also other agronomical, ecological and economic functions. Although all farmers in our study used organic management, we believe that these results also show interesting opportunities for conventional crop improvement of cereals, thereby reducing agro-chemical weed management.
References:


A systematic review of methods for assessing the performance of conservation agriculture and its ability to cope with climate change in temperate zones

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Cropping systems in temperate zones are suffering from climate change, which is expected to cause even more damage in the future. Beyond the changes in mean conditions of temperature and rainfall, the increased intensity and frequency of extreme weather events (e.g. droughts, heat waves, heavy rainfall or windy episodes) are expected to increase. Historical intensive farming practices, including deep inversion tillage and monoculture, are known to increase vulnerability of cropping systems to such climate hazards, for example by increasing soil erosion or hydric stress. Conservation Agriculture (CA), based on three crop management principles (minimum mechanical soil disturbance, soil cover, and crop diversification), has received strong attention as an alternative for addressing the negative impacts of climate change on cropping systems. The effects of CA on the performance of cropping systems have been discussed in an increasing number of studies and some meta-analysis has evaluated its potential on crop productivity or soil protection. But no recent synthesis provides a description of the research activity on CA’s ability to cope with climate hazards.

This systematic literature review (SLR) aims to gather studies assessing the effectiveness of CA in the face of climate change in temperate zones and synthesize information related to a diversity of contexts (type of soil, geographic location), study design, set of practices, and evaluated performance.

Our SLR approach was guided by Cochrane and Prisma protocols. We first conducted a bibliographic search in the Web of Science to retrieve peer-reviewed English articles on the topic. After screening their titles and abstracts, we excluded off-topic papers and selected the ones that meet five eligibility criteria: (i) study has been conducted in a temperate zone; (ii) it involved one of the nine crops of interest (maize, wheat, barley, sorghum, sunflower, soybean, canola, triticale, pea); (iii) it included at least one CA practice; (iv) it was performed at the plot or farm scale, and (v) it assessed the effectiveness of CA to limit the negative impacts of climate change on cropping systems. A final subset of 162 articles was analyzed and we present here a synthesis of the information we extracted.

Preliminary results showed that most of the selected studies rely on experimental data collected at the plot level over short periods of time (< 5 years) in past and current climatic conditions. Model-based approaches in future conditions are still scarce. With regards to the choice of CA practices to be evaluated, few studies combined simultaneously the three Principles of CA. A very large number of studies have evaluated the effects of tillage reduction, often in combination with increased organic soil cover, while very few studies have tested
crop sequences with at least three crops. In terms of performance, we found a broad range of indicators. However, most studies focused on crop productivity and/or soil physical performance. Yet, few studies used an integrated assessment of the farming systems including social and economic attributes such as income, work time, or farmer satisfaction.

Thanks to this synthesis of methods, contexts, and indicators used to assess CA performance in the face of climate change, we were able to identify advances and gaps, as well as new priorities for CA research. The SLR revealed a need for both (i) a system approach to better understand the combined effects of the three different CA practices and their dynamics over time, and (ii) an integrated assessment of CA multi-performance. An interdisciplinary approach could help to address these two points, and would provide more comprehensive information for agricultural advising and public policies.
The influence of sowing date, row width and seed rate on organic winter triticale (*Triticosecale* Wittm. Ex A. Camus) development and weed growth in autumn in North-West Germany

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Key words: biodiversity, arable flora, crop-weed-interaction, sowing parameters

Weeds provide the basis of life for many other organisms, promote soil fertility and reduce erosion (Storkey and Neve, 2018). These effects motivate to enhance arable flora diversity on the entire field. However, competitive weeds can lead to lower crop yields and reduce biodiversity by suppressing rare weed species (Storkey and Neve, 2018). The aim of the experiment was to determine how weed biodiversity in organic winter triticale can be influenced by different sowing practices without losing yield because of crop-weed-competition.

In 2021 winter triticale cultivar 'Tulus' was sowed at the organic research station “Waldhof” of the Osnabrück University of Applied Sciences in Wallenhorst, Lower Saxony, Germany. Treatments were arranged in a three-factorial split plot design with four replications. Main plots consisted of two sowing dates, October 18th and November 1st. Middle plots were composed of two types of row width, 12.5 cm and 25 cm. Subplots consisted of two seed rates (278 seeds m⁻² and 370 seeds m⁻²). No weed control was carried out until spring. In December 2021 plots were investigated on triticale and weed growth by measuring the height of triticale and estimating ground coverage of crop and of weed. Weed species were determined and counted. In addition, the Shannon Diversity Index (SDI) and Shannon Evenness Index (SEI) were calculated. Statistical analysis was executed with R 4.1.2 (ANOVA) and Microsoft Excel (correlation analysis).

While investigation there was a threefold higher ground coverage by triticale in the first sown plots (p = 0.01) because of better development (GS (Growing Stage) 12 compared to GS 11). Ground coverage of weeds was significantly higher in the early-sown plots (1.8 %) compared to the late-sown ones (0.6 %). Number of species and number of weed individuals were significantly higher in the first sown plots (5.8 compared to 4.6 respectively 151.3 compared to 78.5) while SDI and SEI showed no difference. *Aphanes arvensis* and *Papaver rhoeas* appeared significantly more frequently in the early-sown plots, which could be caused by specific emergency times. Thus, an early sowing date could enhance biodiversity by the number of weed species while the crop develops well and enhance the occurrence of winter annual weeds, which get minimized by spring crops (Bachinger and Zander, 2007). The most abundant species, *Aphanes arvensis*, didn’t show a high correlation with the ground cover of weeds, but the summed-up individuals of *Papaver rhoeas* and *Veronica hederifolia* did ($R^2 = 0.68$). This can be explained mainly by the larger cotyledons. Therefore, it can be suggested that high occurrence of specific weeds don’t necessarily result in high
competitiveness against crops. Furthermore, the ground coverage increased with higher seed rate from 9.5 % to 11.4 % (p = 0.001). As assumed, crop density was highly affected by seed rate (p = 0.001). But due to not competitive triticale plants seed density and row width didn’t show any impact on weed in autumn. Differences may occur while investigation in spring and summer 2022. SDI and SEI were significantly higher in replication 1 than in 4, probably due to the spatial soil heterogeneity. In conclusion, biodiversity might be first affected by the seed bank. Additionally, the early sowing date resulted in higher weed ground cover, number of weed species and weed individuals.

Reference:


The effect of flowering „Beetle banks“ on arthropod predators and insect pests in winter wheat

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Beetle banks are promoted as a method to create overwintering habitats for arthropod predators in agricultural landscapes and thereby strengthen conservation biological control (e.g. Collins et al. 2002). These in-field elevated tussock grass strips are recently being enriched with flowering plant species in order to foster insect biodiversity. However, evidence of pest regulating effects in adjacent crops is scarce.

In two contrasting regions in north- and southeastern Germany, conventional, no-till winter wheat fields adjacent to a flowering beetle bank and a control field margin were studied on commercial farms in 2021. At three distances (5, 25, 45 m) from the bank or margin, activity density of ground-dwelling predators was assessed with pitfall traps. To demonstrate antagonist effects, exclusion barriers against ground-dwelling and flying predators (polythene walls, Collins et al. 2002, and wire cages with insect glue, Schmidt et al. 2003) and an uncaged area were installed at each assessment point. Standardized predation was measured with aphid prey cards (Boetzl et al. 2019), and natural pest densities without insecticidal treatments were monitored in 14-day intervals from begin of tillering to milk ripening.

The effect of beetle banks on activity densities depended on species groups. While ground beetles (Carabidae) showed higher activity adjacent to the control margins, rove beetles (Staphylinidae) were more active adjacent to the beetle banks. Staphylinid activity was particularly high in one site where springtails (Collemboala) were highly abundant in May. Spider (Aranae) activity density showed diverging trends over sites and time. Standardized predation differed greatly between the two sites and attained an average of 26% and 84 %, respectively. Preliminary analysis indicates increased predation by carabid and staphylinid beetles in the field area adjacent to the beetle banks.

Wheat pests infested the crops late and at low levels due to unfavorable weather conditions. Oulema beetle larvae infested especially the southeastern site (up to 0.12 larvae/tiller), and appeared to be reduced by ground-dwelling predators in the area adjacent to the beetle bank, as indicated by activity densities and predator exclusion. Cereal thrips (Thysanoptera) were abundant in the northeast (up to 0.62 thrips/tiller). They were more abundant adjacent to the beetle banks than to the control margin and appeared to be regulated by flying predators towards the milk ripening stage. Cereal aphids (Sitobion avenae, Metopolophium dirhodum, Rhapolosiphum padi) and Cnephasia moth larvae infested wheat at low levels (up to 0.11 aphids/tiller and 0.002 Cnephasia larvae/tiller). No clear control effect of predators and only diverging effects of beetle banks or control margins were found.

Beetle banks enhanced standardized pest predation by ground-dwelling predators, but had
differing effects on natural pest infestations depending on predator group and pest species. Oulema pest regulation by ground-dwelling predators appeared to be supported through beetle banks, whereas thrips regulation by flying predators seemed to be independent of the field margin structures. For tortrix moths and aphids, predator regulation was not apparent, possibly due to their low density. Results are thus highly context-dependent and assessments over several years as well as consideration of species assemblages are required for a conclusive evaluation. The combined consideration of predator activity density, standardized predation measures and exclusion barrier effects helps to improve the understanding of predation effects on natural pest infestation.


What are the biological determinants of regeneration of perennial weeds? Effect of fragment weight and bud number on the regrowth of five perennial weed species

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Tags: Perennial weeds regeneration, fragment size, number of buds, vegetative organs

Perennial weeds have become an increasing problem with the reduction of herbicide use and tillage. Because of their capacity to regenerate from vegetative organs, such as roots and rhizomes, they must be controlled with different management techniques than annuals. To date, few studies exist on this topic and farmers often lack solutions to control perennials in their cropping systems. Management strategies must focus on the depletion of the regenerative organ reserves to hamper the production of new shoots. However, there is a need for a better understanding of below-ground organs physiology and the determining factors of their regrowth capacities.

Our aim was to assess the number of shoots and their growth speed from one below-ground fragment according to 1) its weight, which is related to the amount of available reserves, and 2) the number of buds initially present (visible) on it. Five species were investigated: Cirsium arvense, Sonchus arvensis, Convolvulus arvensis, Elymus repens and Rumex crispus. They were chosen for their frequency and harmfulness in arable crops in temperate regions and for their difference in terms of multiplication strategy, which implies different vegetative organs. Two pot experiments were carried out in a greenhouse: fragments of roots and rhizomes with different weights or different visible bud numbers were buried into 6-L pots, and the number and length of the produced shoots were measured dynamically during the experiment. The effects of fragment nature (creeping root, rhizome, taproot), weight and the number of buds on (1) the probability that a fragment produce a shoot, (2) shoot growth rate, (3) shoot number and (4) maximum shoot length were analyzed. Also, shoot length was Quantified as a function of hydrothermal time since bud sprouting.

These results will be used to model regrowth of perennials from below-ground fragments after tillage in a cropping system simulation model (FLORSYS). This model simulates daily weed dynamics and crop production over the years from cropping system and pedoclimate. The ultimate goal will be to identify agroecological weed management strategies and to help farmers to redesign their cropping systems.
Use of meteorological characteristics for weed infestation prognosis

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Weed prediction can become an essential part of integrated weed control. The weather affects the weed seeds in the soil seed bank and their physiological processes (seed dormancy). Predicting weed germination based on weather would make mechanical and chemical weed control more efficient. Understanding the relationship between weather and weeds is required to create a weed prediction.

Long-term measurements of meteorological characteristics together with records of weeds in monitoring plots can be used to understand these interrelationships. From 2001 to 2018, weeds in a long-term monoculture of spring barley were evaluated at the experimental field station in Žabčice belonging to Mendel University in Brno. A total of 49 weed species were found throughout the monitoring period. The results show that certain climatic factors affect the weed infestation of spring barley. Nevertheless, the reactions of weeds to previous weather are very different and depend on the specific period (month) of each measured characteristic.

The results indicate that some weather factors influence the weed infestation of spring barley. However, the reactions are very different and depend on the time period (month) in which the characteristics operate. Based on the results obtained, it can be stated that higher temperatures in December, March and April and higher precipitation in October and January lead to lower weed infestation. On the contrary, higher precipitation in November, December and April, as well as a higher number of frost days, lead to higher weed infestation. The reactions of individual weed species to selected meteorological characteristics are very different, and the degree of explained variability is relatively low.

We can assess which characteristics are useful to create a weed prognosis based on the interactions between the average number of weed individuals and selected meteorological characteristics. The following meteorological characteristics have a statistically highly significant negative effect on weed infestation: average maximum temperature in December, average daily temperature in April, average maximum temperature in April, average daily temperature in December, average minimum temperature in December and average daily temperature in March. The average minimum temperature in April, the total precipitation in October and the total precipitation in January have a statistically significant negative effect. The following meteorological characteristics have a statistically highly significant positive effect on weed infestation: total precipitation in November, total precipitation in December, total precipitation in April and a statistically significant positive effect on the number of frost days.

The relationships found between weed species and meteorological characteristics are from only one locality. Therefore, it is necessary to verify the validity of these relationships in other
localities as well. These characteristics can be recommended as a basis for creating algorithms and weed prediction models for early sown field crops.
Potential of crop mixtures to reduce pesticide use in France. A data analysis

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Crop diversification - Plant protection products

Over the last 50 years, agricultural intensification has led to simplified agricultural systems highly dependent on fertilisers and pesticides, causing biodiversity loss, changes in the balance of nutrients, water and soil contamination. The total amount of pesticides applied each year in France makes it the main consumer of plant protection products in Europe, and arable crops are currently the most pesticide-consuming production systems. Reducing pesticide use in arable crops is thus a major challenge. There is now evidence that crop diversification in time, with more diversified rotations, and in space, through crop mixtures, can help restore ecosystem services and represent a potential key lever to reduce pesticide use (Lechenet et al., 2016). However, research has often analysed the effects of crop mixtures on pesticide use over small areas (e.g., single plots or fields), whereas these effects need to be evaluated over larger and more realistic spatial extents to fully assess their potential to reduce pesticide use. By focusing on species mixtures, we aim to (i) quantify the potential of crop mixtures for pesticide use reduction in France and (ii) identify the drivers of mixture use leading to its temporal and spatial dynamics observed at a national scale.

We combined data from a network of over 3000 farmers (DEPHY Farms) who voluntarily committed to reducing their use of pesticides, and the French Land Parcel Identification System (FLPIS). Data from the DEPHY network have been collected annually since 2010 and provide information on farm location, cultivated crops and yield, farming management, and the levels of pesticide use through the Treatment Frequency Index (TFI). The FLPIS is a French-wide database reporting information on the geographical coordinates of the fields, their area, cultivated crops, the type of management (organic or not) at field-scale. It is based on farmers’ declaration for the Common Agriculture Policy subsidies. In the FLPIS, each field is attached to its farm through a unique identification number. More than 80% of the French farms are represented in the database, and since 2015, farmers have reported the species mixtures. For this reason, we only used data starting from 2015 until 2020.

These databases provide information on the distribution of species mixtures cultivated in France and the related TFI levels. We compared the TFI levels of different species mixtures with those of corresponding pure crops. For example, grain species mixtures (e.g., wheat, barley, or triticale mixed with pea or faba bean) and annual fodder mixtures (e.g., triticale, oat, and pea) were compared with pure wheat, and rapeseed undersown with companion crops were compared with pure rapeseed. We assigned each farm of the FLPIS to a farming System (e.g., arable or livestock farming) based on the type of crops cultivated.
We found significantly lower TFI for crop mixtures when compared with those of pure crops, confirming that crop mixtures are an effective lever to reduce the use of pesticides. Results indicated that from 2015 to 2020, the French arable land area cultivated with crop mixtures increased, diffusing from hotspots. Organic agriculture is a strong driver for crop mixtures but is not the only one; in fact, livestock systems turn out to be strategic to foster crop diversification. Indeed, grassland and fodder mixtures, directly used to feed animals, are currently the most widespread species mixtures in France, thus explaining that in some French districts, more than 90% of crop mixture areas are cultivated in livestock systems. On the contrary, cereals and oilseeds, primarily used in transformation processes, appear harder to value as mixtures.

Session 3

Trade-Offs of Producing Protein from Crops and Livestock Systems
Elucidation of field variation in root-exuded flavonoids from Lupinus angustifolius L

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Aarhus University

Flavonoids are plant secondary metabolites with defence and plant growth functions. Many plant species synthesise flavonoids, including narrow-leafed lupin (Lupinus angustifolius L.). Exploration of the link between the presence of flavonoids in roots and soil will contribute to the understanding of the biological effect of flavonoids in the soil.

L. angustifolius and reference spring barley (Hordeum vulgare L.) plants were grown in a long-term crop rotation field experiment, and roots and rhizosphere soil were sampled. Flavonoids were identified and quantified in L. angustifolius and H. vulgare root and soil samples using high-performance liquid chromatography-tandem mass spectrometry. Flavonoids present in the soil represent root exudation of the given flavonoids [1].

L. angustifolius roots contained 14 of 27 flavonoids; genistein, genistin, and luteone being the most abundant. In L. angustifolius soil four flavonoids (apigenin, genistein, luteone and rutin) were detected, but none were detected in H. vulgare soil. Great variations in flavonoid concentration between the field plots were observed for both L. angustifolius and H. vulgare with variations as large as 4-fold and 100-fold for isovitexin in the roots of L. angustifolius and H. vulgare, respectively.

The presence of four flavonoids in L. angustifolius soil and roots, but not in H. vulgare soil, suggests that the flavonoids were exuded from the L. angustifolius roots. The observed field variations indicate different factors influencing the synthesis and exudation of flavonoids within a small field area, such as fungal infection, insects or water stress.

[1] Andersen, Ida K.L.; Laursen, B.B.; Rasmussen, Jim; Fomsgaard, Inge S. Optimised extraction and LC-MS/MS analysis of flavonoids reveal large field variation in exudation into Lupinus Angustifolius L. rhizosphere soil. Submitted
Europe lacks protein crops because of several reasons: the low cost of soybean imports, the reduction of mixed farms, more variable yet overall decreasing yields in traditional cultivated pulses and less economic interest compared to other crops (Voisin et al, 2013). On the opposite side, the interest in vegetal proteins has been increasing for the last two decades due to changes in eating behavior such as the rise of vegan or flexitarian diets (Kearney, 2010). Therefore, there is a growing interest about increasing pulses production in Europe for agronomic, environmental and social reasons (EC, 2018). The present research wanted to evaluate the climatic conditions necessary to grow several new minor pulses in order to determine the feasibility of their introduction in European crop rotations. 6 tropical pulses species, including chickpea as control, were cultivated in a greenhouse during the spring/summer of 2021. The sum of temperatures necessary to reach each main physiological stage were estimated along with measurements of yield components. Minimal growing temperature to allow germination was also evaluated in growth chambers. Cowpea, Adzuki and mung bean were field cultivated during the summer of 2021 in Belgium in order to establish the feasibility of growing and harvesting these crops along with initiating the calibration of the STICS model using these data. Among the 6 species, Rice bean had the highest number of pods per plant 10.0±2.6, followed by Adzuki 6.6 ±2.1, Cowpea 5.8 ±1.3, Mung bean 5.6 ±2.2 and Scarlett runner bean with only 3.0 ±0.8 pods per plant. The pod length was of 29.3 ±8.9cm for Scarlett runner bean with 7.6 normal grains/pod and a thousand kernel weight of 147g; Cowpea pods length was of 16.0 ±1.7cm with 5.6 grains/pod, 191 g/1000kernels; Ricebean 12.4 ±2.0cm with 4 grains/pod and 349 g/1000kernels; Mung bean 10.0cm and 2.7 grains/pod and 53 g/1000kernels and Adzuki only measured 9.0 cm for 5.7 grains/pod and 96 g/1000 seeds. Germination test showed that the minimal germination temperature was around 12°C for all the studied species. This temperature has been selected as base temperature to calculate the sum of temperature to reach each growth stage. The earlier emergence was reached by mungbean which required 90 GDD (Growing Degree Days), the latest was Scarlet runner bean with 115 GDD. Flowering was reached between 427 GDD and 707 GDD for ricebean and mungbean respectively. Ricebean (843 GDD) and Adzuki bean (946 GDD) were the earliest species to reach senescence and mung and Scarlett (1306 GDD) were the latest. In field conditions, after a late sowing on June 7th and a cold-humid summer only Adzuki and Mungbean reached senescence at the end of September 2021. STICS simulations showed encouraging results in predicting the growth and yield of these new crops in temperate climates. First results showed that some of the species studied could be cultivated in oceanic temperate climates, as the regions with this climate in 80% of the situations between April and first decade of October fit the crop requirements (Ayerdi Gotor & Marraccini, 2022). These results pave the way to diversifying the number of protein crops cultivated in those regions, but for this to become reality it will be necessary to find the most
appropriate varieties or breeds in order to reach a higher yield potential in these temperate oceanic summer conditions. Ayerdi Gotor, A. Marraccini E. 2022.


Agronomic fertilization strategies based on microbial biostimulant and organic matter application on Lupinus angustifolium L. growth

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The Lupinus genus includes approximately 300 annual and perennial species. The seed protein content ranges between 38% and 43%. As all legumes, this genus is characterized by a high symbiotic nitrogen fixation rate (Georgieva et al., 2018).

Introducing Fabaceae in crop systems improves soil physico-chemical characteristics and increases soil fertility. However, before introducing lupin in a crop system, it is necessary to know the soil pH because of the narrow range (4.5 - 6.0) in which L. angustifolius thrives. Jansen et al., (2010) reported that pH influences significantly L. angustifolius yield, protein content and secondary metabolites production.

Given the current knowledge, the aim of this study was to evaluate the effects of Biostimulant based on nitrogen fixing bacteria (Bradyrhizobium spp.) and organic matter fertilization on L. angustifolius bio-agronomic characteristics.

The study was conducted in pots located in an experimental field of Consiglio per la Ricerca in Agricoltura e l’Analisi dell’Economia Agraria (CREA) (Acireale, Sicily - Italy), in a typical Mediterranean area. The studied treatments were: control, biostimulant (BT), fertilization with organic matter (OM), combined effect of inoculum and organic matter (BT+OM). L. angustifolius L. cv Polo was sown in 1 m² pots in a sandy-loam soil (SISS classification). A randomized block design, four times replicated was applied. The rhizobium strains were composed by: B. japonicum AGF 542, B. lupini AGF 543, B. japonicum AGF 544 (Agrifutur srl) and was inoculated at sowing. For OM treatment, in pre-sowing, 20 g of organic matter per pot was distributed.

During the trial period (from 27/11/2020 to 01/04/2021) a minimum of 2.1 °C and a max of 23.3 °C air temperatures were registered, and total precipitations were 436 mm (SIAS data). The results obtained showed that L. angustifolius bio-morphological and agronomic traits were significantly influenced by the studied treatments. As compared to control, BT and BT+OM treatments positively affected lupin height while OM treatment did not. Biostimulant determined a height increase of +12% (“p < 0.01”) as compared to Control (48.1 cm). Plant biomass was positively influenced (“p < 0.05”) by BT (+ 33%) and OM (+56%) treatments as compared to Control (18.7 g). The same trend was observed on seed dry weight per plant. The application of microbial biostimulant with selected rhizobium strains and Organic fertilization were effective in determining significant improvement in plant growth and seed yield per plant of L. angustifolium.

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Perceptions of protein crop production on Finnish farms

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While all crops provide protein, some are grown especially for this purpose. For grain legumes, protein is the primary purpose of production and for oilseeds, the protein is a valuable side-stream. In both cases, as broad-leaved crops, they provide breaks in cereal-based cropping systems and the nitrogen-fixing symbiosis of legumes provides further ecosystem services. Nevertheless, their profitability is often low and European farmers are often reluctant to grow them. Hence, protein supplements for livestock feed are heavily dependent on imported soybeans and soybean meal, 70% in the EU as a whole and 85% in Finland.

Improving the local production of protein crops for food and feed, thus improving protein security, is receiving greater attention from agricultural scientists and policy makers in Europe. Knowledge about the perception and practice of Finnish farmers towards legumes is, however, lacking. As a result, we conducted a survey on the perception and practices of protein crop production in Finland. The link to the survey was sent to 14,000 farmers in 2018, of whom 503 replied. Data analysis, text interpretation and concept map formation were conducted using Stata 16 and Atlas.ti 8 software packages. The farms were equally split between arable and livestock systems and similarly between those producing protein crops and those not. Organic farms represented 8.7% of the total.

More than 80% of responding farmers believed that they had the relevant knowledge to produce legumes and oilseed crops, were aware of the importance of protein self-sufficiency and understood the use of legumes in crop rotations. Farmers considered that the available information on protein crops production was reliable and that they would need to receive more information on specific technical areas regarding cultivation and feeding grain legumes to animals. Livestock farmers wanted more information on the use of domestic protein crops as livestock feed, whereas arable farmers producing protein crops required information on the technical aspects of crop production, the physiology of protein crops and plant protection. The dearth of high yielding and appropriately early protein crop varieties, along with the low cost of imported plant protein sources, discouraged the involvement of farmers in local protein crop production. Interest towards growing protein crops was strongly associated with organic production systems, which was attributable to the relative importance in this sector of legumes as bio-fertilizers, as break-crops to break disease cycles, and on-farm production of feed. Arable farms produced protein crops for the benefits obtained from crop rotation (96%), pre-crop value and profit margins. Conducive agricultural policy (75%), subsidy and incentives (77%) given to the farms, and financial information support (75%) and pre-arranged contract agreement (55%) were also reported to affect the farmers’ willingness to produce protein crops. Generally, domestic protein crops in Finland were associated with high risk and high production costs. With proper agricultural policy and incentive system, development of
earlier varieties and winter-hardy cultivars might reduce the risk of production and reliability of cultivation. Developing national market network among protein-feed producers, processors and livestock farms may solve the problem of marketing, attract more farmers to protein crop production and ensure long-term plant protein self-sufficiency.

Keywords:
Grain legumes, oilseeds, feed protein, protein security
Influence of pea protein sowing density and nitrogen residues on spring wheat-pea intercrop performances

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Legume, intercropping, organic farming, nitrogen residues

In organic farming, legumes are key elements of cropping systems and protein crops are particularly interesting for their capacity to fix atmospheric nitrogen and to produce protein-rich seeds. However, yields variability due to their lack of tolerance to biotic stresses (competitiveness against weeds, resistance to pests or diseases) and abiotic stresses (resistance to climatic hazards) limits their extension in oceanic temperate climates. Intercropping (i.e. growing several species in a mixture) is an agronomic technique that can reduce the influence of these factors but can also lead to a complex control of the protein crop proportion in the mixture. In spring intercropping, the increase of nitrogen residues at sowing can favour cereals over protein crops and inversely.

This study objective is therefore to evaluate how spring nitrogen residues and pea protein density influence spring wheat-pea intercrop performances. A two-year trial (2019 and 2020) in four randomised blocks was set up. Pure crops of wheat and pea protein were sown respectively at 350 and 80 seeds/m² while intercrops were sown with wheat whose density is fixed at 50% of wheat pure crop density, with pea at variable densities of 75 and 100% of pea pure crop density. In addition, to simulate different levels of nitrogen residues, 3 levels of fertilisation (0 - 80 - 160 kgN/ha) based on blood powder (N=13%) were applied at sowing. Dry matter, energy and protein yields as well as cereals and protein crops proportions were quantified after harvest.

In 2020, the average yields (kg/ha at 15% H°) of the different treatments were higher than their counterpart harvested in 2019. For the Pea-100 intercrop, regardless of the level of fertilisation, yields were significantly higher in 2020 than in 2019: 0 (6101.2 vs. 1580.7; p < 0.01), 80 (4062.9 vs. 893.7; p = 0.01) and 160 (4230 vs. 984.2; p = 0.015). For the Pea-75 intercrop, yields are significantly higher in 2020 than in 2019 for fertilisation level 80 (4285.44 vs 1417.9; p = 0.02) and marginally significant for level 160 (3959.8 vs 1010.7; p = 0.547). In 2020, there was a significant interaction between pea density and nitrogen fertilisation level on pea protein yield in the mixture (p = 0.014). In this case, the average yield of Pea-100 intercrop shows a tendency to decrease when nitrogen fertilisation increases. This decrease, which is not observed in either the Pea-75 intercrop or in 2019, is associated with a reduction in pea protein yields while wheat yields are maintained. In 2020, all Land Equivalent Ratio (LER) are above 1.2, regardless of pea protein density and nitrogen fertilisation level. In 2019, pure crops performed well, only Pea-100 intercrop led to an LER above 1.

Although previous results highlight the impact of year, pea protein sowing density and nitrogen residues on intercrop performances, it is necessary to confirm these results with crop
Nutritional quality (energy and protein yields). These elements will also be presented at the conference.
Increasing soil organic carbon with temporary grasslands in the rotation

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Soil carbon sequestration in agroecosystems was identified as one of the most promising strategy to mitigate climate change and to adapt to extreme climatic events. Despite a strong interest by policymakers, the size of the C sink and the methods to accumulate soil organic carbon remain unclear. This is mainly due to the absence of reliable estimations of the current soil C-saturation level in croplands, the lack of information about subsoil storage potential and the response of deep soil layers to management practices. Here, we fill these gaps by quantifying the carbon storage potential in the topsoil and subsoil down to 50 cm depth in a typical cropland-grassland agroecosystems and by demonstrating the potential of increasing temporary grasslands in crop rotations to reach soil carbon saturation down to the subsoil. We used a soil monitoring network established in 1987 on 184 well-drained cropland (CR) and permanent grassland (PG) sites in western Switzerland to determine factors affecting long-term dynamics. In addition, we sampled a subset of CR and PG sites to determine current SOC stocks in the topsoil (0-20 cm) and subsoil (20-50) cm. Levels of mineral-associated C (MAC) and bulk SOC in grasslands were used as reference to estimate C-deficit in croplands. We found that i) MAC in CR were depleted by a third compared to PG, ii) accounting for the storage potential in the subsoil doubles the soil carbon storage potential of croplands, iii) the C sink is proportional to the increase of temporary grassland in the crop rotation and iv) the size of the C sink in the croplands of the study region is equivalent to one year of the total anthropogenic greenhouse gas emitted from the same region. The study highlights the importance of agricultural diversification to seek for a carbon-neutral agriculture and enhance agroecosystems resilience. It demonstrates the potential of temporary grasslands to favor SOC accumulation and its impact down to deep soil layers, revealing a substantial potential of subsoil to sequester C.
Multidimensional and Multiscale assessment of the agroecological transition of a village in Eastern Senegal

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Agroecology is seen as the most promising approach to overcome the daunting economic, environmental and social challenges that agriculture is currently facing. Yet, there is a lack of systemic, multiscale and multidimensional assessments of agroecological transitions (GTAE, 2018; Wiget et al., 2020). Research is also needed to gather evidence from and communicate about stories of success and failures to draw lessons on how to accelerate these transitions (Dendoncker et al. 2018). Assessing agroecological transitions presents many methodological challenges related to their complexity. The aim of this study was to develop and apply an innovative multiscale and multidimensional assessment method that overcomes the methodological challenges of the assessment of agroecological transitions. This innovative method builds on a systematic review of existing assessment methods, through which we identified 14 methods. Using the characteristics of these 14 methods, our method articulates different steps, encompassing various scales: 1) a contextualisation step depicting the socio-economic and environmental context and analysing the level of agroecological transition and its development conditions, 2) a multicriteria assessment of the multidimensional impacts at the field, individual, household, farm and landscape levels, and 3) a multistakeholder multicriteria assessment of the impacts at the territory scale. A total of 61 indicators were calculated for the multicriteria assessment: 53 at the field, farm and landscape levels that enabled to reveal technical performance, social aspects and environmental impacts and resilience, and 8 at the individual level that allowed to assess individual well-being. We applied the method in a case study in Eastern Senegal, in the village of Sare Boubou, located in the Tambacounda region. Supported by a Senegalese NGO, the village is going through an agroecological transition with the aim of improving households’ self-sufficiency. The application of the method provides a holistic assessment of the agroecological transition. Results show that the adoption of agroecological practices benefited from a good dissemination of agroecological knowledge among farmers and a long-standing support from the Senegalese NGO. Breaks to the broader adoption related to a lack of agricultural equipment, a difficult access to credit and to market, a declining soil fertility and irregular rainfall. At the village level, the agroecological transition is characterized by fairly high scores (65%) regarding ecological aspects (related to farm-livestock integration, the inclusion of rotations and crop combinations, the use of organic fertilizers and a good input self-sufficiency) and social aspects (high social capital), and low scores for economic aspects.
(related to marketing difficulties). The method allows to demonstrate the variability across farms in the village, regarding the level of agroecological transition and the multidimensional impacts. Levels of agroecological transitions between farms vary particularly for issues related to cultivated biodiversity and diversity of activities, the level of introduction of crop rotation, and level of supply of organic matter. The variability of multidimensional impacts between farms relate to economic aspects (such as self-consumption, specialisation rate and material well-being). This variability illustrates individual strategies. The assessment of individual well-being further highlights variability across individuals related to social cohesion and drudgery of work. The agroecological transition supported by the NGO therefore does not lead to the same impacts according to farm specificities. Mobilizing regional and local references enables to visualise strengths and weaknesses of the agricultural systems, as shown above. Such information could help to improve current support given to agroecological transitions.
“MilKey” and “DairyMix”: circular, GHG and N optimised crop-livestock systems for milk production in Europe

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Keywords: Mixed farming systems, crop-livestock integration, multicriteria assessment, circularity

The livestock sector is the world’s largest user of natural resources; 80% of agricultural land is used for animal grazing or feedstuff production and 8% of global water is primarily used for irrigation of feed crops. The global livestock sector, mainly ruminants, contributes approximately 18% of total anthropogenic GHG emissions. Dairy production systems (DPS) are an essential part of European agriculture. Nevertheless, these systems face many challenges across the three pillars (3P) of sustainability (environment, economy, society). DPS produce high quality protein, converting fibrous feed resources that could not be utilized by humans or monogastric animals. However, this desirable level of circularity is currently met only to a very limited extent, with most dairy systems heavily relying on external input (e.g. concentrate feeds, mineral fertilizers). Dairy production is the sector in agriculture where region-specific concepts are most prominently required and where the opportunity to install circular mixed crop-livestock systems is evident, though not sufficiently researched, exploited and implemented. It is essential that holistic concepts are developed to ensure sustainability of the sector, and to assist farmers and stakeholders in making knowledge-based decisions. The “MilKey” and the “DairyMix” projects aim to develop flexible concepts for sustainable milk production, including farming systems for dairy production into circular economy, closing nutrient cycles and mitigating GHG and N emissions by defining region-specific concepts for sustainable mixed crop-livestock systems in key European areas.

To this end, farm typologies for integration of crop and livestock production across Europe are currently being assessed, and data on mixed crop-dairy systems are being collected from selected case study farms, looking at the inflows and outflows of C and nutrients. The detailed understanding at process level will be fed into sustainability assessment and modelling approaches (e.g. LCA, ARMOSA, FarmDyn), aiming to identify mitigation options and to provide a toolbox for innovative, region-specific and flexible solutions that combine the demands of farmers, consumers and the environment.

Multi-criteria assessment, including the quantification of trade-offs and synergies, will be
conducted under a systems thinking approach, evaluating the possible linkages of increased circularity and nutrient use efficiency in the dairy and crop subsystems with the immediate and long-term economic performance as well as with the social sustainability dimensions. Monitoring emissions is a crucial step for the design and implementation of mitigation measures to enhance animal welfare and environmental sustainability of the sector. To this end, an online tool for monitoring indoor barn climate, animal stress and emission levels of GHG and air pollutants (OTICE) is currently being tested in the MilKey project and will be further developed in the DairyMix project.

The results will be fed into the easy to use and long-living online MilKey/DairyMix platform that is currently being created within the EraNet project “MilKey” (www.milkey-project.eu). The platform aims to enable stakeholders, farmers and politicians to make knowledge-based decisions for circular, integrated crop-livestock systems in their regions.

Acknowledgements
These projects are funded by the German Federal Ministry of Food and Agriculture (BMEL), through the Federal Office for Agriculture and Food (BLE), under the Joint Call 2018 ERA-GAS, SusAn and ICT-AGRI on “Novel technologies, solutions and systems to reduce the greenhouse gas emissions in animal production systems” (MilKey, grant number 2819ERA08A) and the Joint Call 2021 ERA-GAS, ICT-AGRI-FOOD, SusCrop and SusAn on “Circularity in mixed crop and livestock farming systems, with emphasis on greenhouse gas mitigation” (DairyMix, grant number 2822ERA15A).
Introduction
Brittany is the main dairy region in France, with a wide diversity of forage systems. Grass-based dairy farms have shown good performance in terms of sustainability but face questions regarding their capacity to cope with climate change. In particular, their dependence on grasslands raises the question of their greater vulnerability compared to more diversified farms.

A collaborative study between a farmers’ association (CEDAPA) and researchers from INRAE was set up to work on this issue. The present work details the construction of a method for assessing the resilience and sustainability of dairy farms and the first results obtained.

2. Materials and methods
A two-step approach was conceived to evaluate farm resilience to climate change. First, we looked for the link between technical and economic variables (vulnerability variables) and climatic and economic variables (exposure variables) to characterise the most and least vulnerable farms. The second step compared the different farms through a multi-criteria evaluation of resilience indicators. This two-step approach was tested on 29 dairy farms in Brittany.

Our multicriteria assessment of sustainability was based on life cycle analysis. We evaluated climate change, acidification, eutrophication and land use, and expressed those impacts per hectare. Other social and economic indicators were included in the analysis. It was tested on three dairy farms.

We finally combined the resilience and sustainability assessments using the DEXI software, in order to identify the possible compromises between those two characteristics.

3. Results and discussion
The results showed that 2015-2019 climate, although quite variable, had little effect on the selected vulnerability variables for all farms. However, the farms with the most grass-based systems experienced more inter-annual variations in milk production. Nevertheless, their strategies to minimise production costs and to maximize milk price (organic milk premium for most grazing systems) gave them better economic results than studied maize-based farms. These farms with less grass had a more diverse forage production and a more stable milk production, but lower and more variable economic results.

Animals were the main source of greenhouse gases in all farms. Feed production was the most impacting element for eutrophication and land use. For acidification, feed production was the main source for the two specialized dairy farms, but animals were the main source in the only farm having both dairy cows and poultry.
DEXI software looks promising for aggregating a large number of quantitative and qualitative indicators without losing the detailed results. However, we cannot elaborate more on these results as the work is still under way. Several limitations call for improvements. The main limit for resilience evaluation is the access to pluri-annual data. For some aspects (workload, feed storage), this would really improve the analysis, but would require that farmers or counsellors collect and store this information. Sustainability evaluation would be more interesting if we could add indicators related to biodiversity, carbon storage and workload.

4. Conclusion
We developed a method to evaluate the resilience and sustainability of dairy farms. This work showed that the studied dairy farmers are currently resilient to climatic hazards and relatively sustainable. Our method is still under development and various aspects can be improved, but it already seems an interesting tool to evaluate dairy farms and foster discussion with farmers.
Effects of winter wheat and legumes mixtures on grain yield and baking quality in organic farming

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In Europe, the area under organic farming has doubled from 6.8 million hectares to 15.6 million hectares between 2005 and 2018. Especially, the demand for organic wheat has increased in recent years. However, organic yields are often 20 – 30% lower, and the protein content 10 – 25% lower than in conventional farming. Efforts to boost wheat production and quality include breeding and selection but these take a long time and are costly. Designing novel farming practices could be a complementary strategy. Mixtures of wheat with legumes could help to mobilize nutrients from the soil, enhance wheat yields and quality (Konvalina et al., 2009; Lacko-Bartošová et al., 2021; Mie et al., 2017). The main goal of this study was to quantify the agronomic effects and baking quality characteristics of winter wheat variety and legumes mixtures as a factor influencing grain wheat quality.

In the vegetation season 2020 and 2021, trial variants of the winter wheat variety also known as Butterfly with various types of legumes mixtures were evaluated. The legume types used included field bean (Vicia faba L.), incarnate clover (Trifolium incarnatum L.), spring pea (Pisum sativum L.), and winter pea (Pisum sativum L.). The experiment was conducted in a small loamy soil plot of an organic certified field (48°58’26.4”N, 14°37’43.5”E) located in the south region of the Czech Republic, at an altitude of 460 meters. The agronomic traits and the grain yield without legume were measured. Baking quality such as protein, wet gluten, gluten index, sedimentation value (Zeleny test), and falling number was also evaluated. For the analysis of measured data, the STATISTICA program (version 13.2, StatSoft, Inc., California, and USA) was used.

A highly significant statistical difference for winter wheat on agronomic traits, grain yield, and baking quality between the two seasons was found. The differences in weather conditions during the two growth seasons affected their traits and also baking quality. Grain yield was higher in the first season by 5.85 t ha⁻¹ compared to the second season. On the other hand, the baking quality traits were also significantly different on wet gluten, gluten index, and sedimentation value in the second year by 2.25%, 7.99%, and 3.57 ml, respectively, compared to the first year. The falling number was lower by 54 seconds in the first season than in the second season. However, the comparison of single grown winter wheat with winter wheat mixed and legumes was not significantly different. The combination of winter wheat and legumes showed a grain yield increase of 4.3% compared to a monoculture of winter wheat. The baking quality of winter wheat ranged from 17.54 to 19.76%, 28.13 to 30.03 ml, and 273.83 to 286.79 seconds for wet gluten, Zeleny test, and falling number, respectively, for
single grown winter wheat compared to winter wheat mixed with legumes while the gluten Index varied from 88.54 to 79.96%.

Acknowledgment: This study was supported by the research project No. NAZV QK1910046 of the Ministry of Agriculture of the Czech Republic.

Reference:


Assessment of P efficiency in forage legumes by utilising fertilisers from recycling products

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Key words: P utilisation, P fertilisers, alfalfa, red clover

Alfalfa (Medicago sativa L.) and red clover (Trifolium pratense L.) are important forage crops cultivated around the world. As legumes they have a relatively high phosphorus (P) demand during their growth, which is caused by the energetically costly biological nitrogen fixation. Application of P containing recycling products can contribute significantly to replace commercial P fertilisers. However, in order to utilise them efficiently, an assessment of their P fertiliser effect in different crop species is necessary.

At the University of Rostock, North-Eastern Germany, a two-year field study based on a long-term field experiment since 1998 was conducted. Six treatments (no P, triple superphosphate (TSP), biomass ash, manure, biowaste compost and biowaste compost+TSP) were compared in a randomised split-plot design to test their agronomic effects in combination with eight accessions each of alfalfa and red clover. The trial was sown in 2020, plant biomass was harvested twice every year at the flowering stage, and soil samples were collected after the second harvest of both trial years. Shoot biomass, plant P content (Pcon), P uptake (product of shoot biomass and Pcon), P utilisation efficiency (ratio of shoot biomass to P uptake) as well as bio-available soil P (Pdl) were determined every year.

In 2020, the year of establishment, shoot biomass was considerably lower than in 2021, the second year of cultivation. Alfalfa produced less shoot biomass, Pcon and plant P uptake than red clover in 2020, while it was vice versa in 2021 (P < 0.05). Apart from the differences in shoot biomass, the P utilisation efficiency was found to be at a similar level in both years, with intraspecific differences between the accessions only being observed in red clover. The P recycling products increased the plant P uptake of both species as well as the Pdl in the soil (P < 0.05), which both followed the overall order biowaste compost > manure > biomass ash in both years. Compared with TSP, biowaste compost showed a higher ability to increase shoot biomass and P uptake in both species. The combined treatment biowaste compost+TSP did not increase P uptake in either species further than pure biowaste compost. Our results verified differences in the interspecific and intraspecific P efficiency of alfalfa and red clover, which also varied in dependence of the P source and time after establishment. The P recycling products were generally proven as a suitable P source for both species, with a more pronounced P fertilising effect of biowaste compost, which also exceeded the effect of TSP.
Agronomic and environmental impacts of sheep integration in cover crop management

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Keywords: nitrogen, sheep, cover crop, leaching

Crop residues valorisation through grazing, previously practised in Western Europe, was practically abandoned as a result of farms specialisation. The establishment of cover crops between two cash crops in order to reduce and avoid nitrate leaching, weeds development as well as soil erosion induces the production of an interesting biomass of adequate quality (0.9 UFL and 90g PDI/kg MS) (Sagot, 2017), potentially recoverable by livestock. This valorization, especially by sheep, can be part of a new form of partnership between breeder and cash crop producer. This partnership supports the development of the sheep sector in Wallonia, which covers only 16% of national sheep meat needs. However, this practice generates questions whether they are organizational, agronomic, environmental or socio-economic. The trials reported here explored the potential impact that cover crop grazing can have on nitrogen soil cycle and plant performance.

In order to answer these questions, 10 trials were performed over two years in Wallonia. Each of the trials included three treatments related to grazing intensity (non-grazing, partial grazing and total grazing), repeated three times, thus bringing together nine plots of 30mx48m. The previous crop was wheat (n=8), oats (n=1) or pea (n=1). In each trial, a cover crop was sown, between 15 July and 10 September, with the following composition (% of the seeds weight): Avena sativa L. (61%), Trifolium alexandrinum L. (12%), Vicia sativa L. (20%), Raphanus sativus var. longipinnatus L. H. Bailey (5%) and Phacelia tanacetifolia Benth. (2%). The grazing period extends from late October to mid-January. Sheep grazed 80% (partial grazing) to 93% (total grazing) of the available biomass.

The choice of this plants mix pursued several objectives: trapping nitrogen residuals, soil protection and covering feeding needs of sheep. Depending on the development of cover crops and the treatment applied, the animals remained on the plots for 1 to 2 days (6.6 LU per day) in the case of partial grazing at 2 to 4 days (10.9 LU per day) for total grazing. During the time spent on the plot, sheep recorded an average daily gain of 70g/d. to characterize the risks of nitrogen leaching, soil samples (0-30, 30-60, 60-90 cm) were taken at different periods: cover crop sowing, after grazing, middle of winter and end of winter. For each of these periods, a composite sample, including 10 sub-samples, was taken per plot.
On the entire trial, one spring crop was sown post-grazing (sugar beets, chicory, peas, beans, potatoes or corn). On each plot, the seedlings densities (beets and chicory) as well as the yields (all crops) were measured.

Soil analyses carried out at the implantation of cover crops show great variability in nitrogen residues. However, logically, at each site, the amount of mineral nitrogen present in the soil has decreased thanks to cover crop. Soil analyses indicate a significant increase (+15kg N/ha) in nitrogen content in the first 30 centimetres of soil following grazing, regardless of the intensity applied. Although the contents remain acceptable, this difference was no longer noticeable when the entire profile was considered (0-90 cm). Similarly, at the end of winter, there was no significant differences between the different treatments.

For the spring crop that followed, no significant differences were observed in either the emergences or the yields recorded for all crops.

This renewed interest in this practice offers several diversification opportunities within the farm but also at territorial scale. Cover crop grazing could also lead to a reduction in cropping interventions for the destruction of winter cover.

Bibliography
Sagot L., 2017. CET automne mes brebis pâturent les couverts végétaux, Institut de l’Élevage/CIIRPO.
Grain legumes and dryland cereals for enhancing carbon sequestration in semi-arid and sub-humid agro-ecologies of Africa and South Asia

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Subsistence agriculture is the main source of livelihood for millions of households in Africa and South Asia, where small farms (< 2 ha) account for about 30% of the food produced. The impact of climate change has put smallholders at risk and reinforced poverty and vulnerability. Intensification of the regions’ agriculture is among the efforts employed to increase agricultural production and incomes for smallholder farmers. It is vital that this intensification focuses on crops and cropping systems that enhance soil organic carbon (SOC). Cereals and legumes form an important component of crop production in Africa and South Asia, where they dominate the debate on sustainable intensification. Their role in food security and economic growth is of critical importance, although farm yields in smallholder systems fall below their potential. Low yields are generally attributed to low soil fertility and a host of factors that are aggravated by climate change.

Grain legumes (chickpea, common bean, cowpea, lentils, pigeon pea and soybean) dryland cereals (sorghum, pearl and finger millet), collectively referred to as GLDC under the CGIAR research program on Grain Legumes and Dryland Cereals, are commonly grown, eaten and traded by small holder farmers in Africa and South Asia. These crops contribute to food and nutritional security, environmental sustainability, and economic growth in the region. However, their possible contribution to carbon sequestration through biomass production and accumulation of soil organic carbon (SOC) is not known. To find out more about their contribution, and how to increase SOC, this study reviewed the evidence of carbon sequestration in farming systems that integrate GLDC in Africa and South Asia. A total of 437 publications reporting SOC and its proxies across 32 countries in Africa (N=250 studies) and South Asia (N=187) were identified as sources of evidence for carbon sequestration. Among these, 179 publications provided appropriate control groups for evaluating changes in aboveground carbon when GLDC were integrated under intercrop (n=38), crop rotation (n=8) or agroforestry (n=13), or when improved varieties of GLDC were compared with local varieties (n=14). A further 81 publications compared SOC content at the start and the end of the experiment while 43 publications compared SOC between farms growing GLDC and those which did not. Aboveground carbon of GLDC was found to be 1.51±0.05 Mg/ha in Africa and 2.29±0.10 Mg/ha in South Asia. Absolute SOC concentration in the topsoil (0-30 cm) was 0.96±0.06% in Africa and 0.58±0.04 in South Asia. It was observed that GLDC produced more aboveground carbon and significantly increased SOC when grown as intercrops and in crop
rotations. The increase, however, depended on the species and whether the crop was a legume or a cereal. The largest amount of aboveground carbon (>2 Mg/ha) was found in cereals (and pigeon pea) while the largest increase in SOC was found in farming systems that included legumes. Aboveground carbon of improved varieties of GLDC was lower compared to local varieties. Soils which had low initial (< 1%) SOC but high clay content (> 32%) showed the greatest potential for carbon sequestration when GLDC were grown. Among the GLDC crops, pigeon pea which is a perennial grain legume showed the highest biomass production and carbon sequestration in the soil when integrated into farming systems in Africa and South Asia.

Findings from this study underscore the importance of aboveground residues in regulating the addition of carbon to the soil, and the role of legumes in the enhancement of SOC.
A functional ecology approach to define a conceptual method for species mixing design: a case study on nitrogen management

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Key words: mixing crop, ecosystem services, functional ecology, plant trait, nitrogen recycling

Actual agroecosystems mainly rely for their productivity on external inputs, as the use of agrochemicals and fossil fuels that generate negative impact on the environment limiting their sustainability. A biodiversity-based agriculture, through i.e. crop mixtures, can promote ecosystem services by increasing biological interactions in agroecosystems to limit the dependency on external inputs (Duru et al., 2015). However, little is known about crop mixture design to promote these ecosystem services. We therefore aim to propose a generic method for designing crop mixtures based on a functional approach that takes into account the functioning of the mixtures in order to overcome the specificity of each species through a participatory approach with farmers, scientists and advisors.

To do so, we mobilized the trait-function-services functional ecology approach to identify in a generic way the plant traits as well as the functions that are important in a crop mixture to render ecosystem services, taking into account the pedoclimatic conditions. Indeed, the trait-function-services approach of functional ecology makes it possible to establish the links between functional traits and biological processes, which are themselves at the basis of ecosystem service production (Garnier & Navas, 2012; Damour et al., 2014; Mediène et al., 2016). The use of the trait-function-services model was done through participatory workshops for knowledge sharing between scientists, farmers and advisors (n=14). Participants were chosen according to their complementary expertise and experience in the functioning of crop mixtures. In our study, we focused this approach on the ecosystem service of managing nitrogen nutrition in species mixtures that allow the reduction of synthetic nitrogen use.

Our results identified functional processes, plant traits, and agronomic and environmental characteristics important in a crop mixture to reduce fertilizer use. The main functions important for N management in mixtures were (i) functions that reduce N losses in the system, (ii) functions that increase and diversify N inputs in the system, and (iii) functions that promote efficient N use by plants in the crop mixture. Traits such as root system, growth rate, nitrophile level of plant, height, biomass production capacity, cycle length, leaf area and orientation, and ramification rate were important for the realization of the above functions identified. On this basis, we were able to identify multifunctional traits, i.e. traits involved in the realization of several functions (e.g. root structure, height) and traits involved only in the realization of a single function (e.g. nitrophile level of plant, cycle length). We also showed that fertilization, initial nitrogen level and soil type mainly affected traits and functions related to nitrogen
losses, nitrogen increase and nitrogen use efficiency. The next step for our work will be to identify assembly rules of plant traits (functional convergence and divergence) in a crop mixture.

The conceptual method based on knowledge production through participatory workshops focused on the functional relationships of crop mixtures lays the foundation for the design of operational crop mixtures. For example, the identification of important functions and traits will allow us to assess the level of service provided by a crop mixture and to identify the crop mixtures most likely to reduce nitrogen use in a given agro-environmental context. Ongoing work takes into account other ecosystem services (weed, pest and diseases regulation).

Main reference
A systematic review of methods for assessing the performance of conservation agriculture and its ability to cope with climate change in temperate zones

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Cropping systems in temperate zones are suffering from climate change, which is expected to cause even more damage in the future. Beyond the changes in mean conditions of temperature and rainfall, the increased intensity and frequency of extreme weather events (e.g. droughts, heat waves, heavy rainfall or windy episodes) are expected to increase. Historical intensive farming practices, including deep inversion tillage and monoculture, are known to increase vulnerability of cropping systems to such climate hazards, for example by increasing soil erosion or hydric stress. Conservation Agriculture (CA), based on three crop management principles (minimum mechanical soil disturbance, soil cover, and crop diversification), has received strong attention as an alternative for addressing the negative impacts of climate change on cropping systems. The effects of CA on the performance of cropping systems have been discussed in an increasing number of studies and some meta-analysis has evaluated its potential on crop productivity or soil protection. But no recent synthesis provides a description of the research activity on CA’s ability to cope with climate hazards.

This systematic literature review (SLR) aims to gather studies assessing the effectiveness of CA in the face of climate change in temperate zones and synthesize information related to a diversity of contexts (type of soil, geographic location), study design, set of practices, and evaluated performance.

Our SLR approach was guided by Cochrane and Prisma protocols. We first conducted a bibliographic search in the Web of Science to retrieve peer-reviewed English articles on the topic. After screening their titles and abstracts, we excluded off-topic papers and selected the ones that meet five eligibility criteria: (i) study has been conducted in a temperate zone; (ii) it involved one of the nine crops of interest (maize, wheat, barley, sorghum, sunflower, soybean, canola, triticale, pea); (iii) it included at least one CA practice; (iv) it was performed at the plot or farm scale, and (v) it assessed the effectiveness of CA to limit the negative impacts of climate change on cropping systems. A final subset of 162 articles was analyzed and we present here a synthesis of the information we extracted.

Preliminary results showed that most of the selected studies rely on experimental data collected at the plot level over short periods of time (< 5 years) in past and current climatic conditions. Model-based approaches in future conditions are still scarce. With regards to the choice of CA practices to be evaluated, few studies combined simultaneously the three Principles of CA. A very large number of studies have evaluated the effects of tillage reduction, often in combination with increased organic soil cover, while very few studies have tested
crop sequences with at least three crops. In terms of performance, we found a broad range of indicators. However, most studies focused on crop productivity and/or soil physical performance. Yet, few studies used an integrated assessment of the farming systems including social and economic attributes such as income, work time, or farmer satisfaction.

Thanks to this synthesis of methods, contexts, and indicators used to assess CA performance in the face of climate change, we were able to identify advances and gaps, as well as new priorities for CA research. The SLR revealed a need for both (i) a system approach to better understand the combined effects of the three different CA practices and their dynamics over time, and (ii) an integrated assessment of CA multi-performance. An interdisciplinary approach could help to address these two points, and would provide more comprehensive information for agricultural advising and public policies.
Statistical modelling of water consumption of individual livestock type in the Czech Republic

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Statistical modelling of water consumption of individual livestock type in the Czech Republic
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This study has developed the livestock production scenarios for individual regions of the Czech Republic (CZ) with estimation on what categories of livestock have been bred during the last 20 years and will be bred in the following years and what will be their water consumption, both throughout the year and in particular seasons (spring, summer, autumn, winter). The numbers of farm animals (cattle, pigs, sheep, horses, goats, and poultry – hens, ducks, turkeys, geese) in the years 2002–2020 were evaluated, and their numbers were predicted for the following years until 2050. Then livestock water consumption (m³/year) per region was determined based on the number of livestock individuals. Changes in the amount of water consumed by livestock per year in individual regions in 2050 compared to 2005 are estimated. The Czech Republic can be divided into four areas according to livestock production development. By 2050, a substantial reduction in the breeding of pigs and poultry is expected in most regions of the CZ, and, conversely, a substantial increase in the number of sheep, horses, and goats is expected in most regions. Substantially higher livestock water consumption is expected in the Karlovy Vary Region, Liberec Region and Moravian-Silesian Region, similar or lower water consumption is expected in other regions. A substantial decrease in the amount of water consumed by livestock is expected in vulnerable areas in terms of water scarcity, such as South Moravia and the Central Bohemian Region. In the next part of the paper, the relationship between meteorological parameters (maximum temperature, minimum temperature, temperature humidity index) and the number of farm animals is studied, and the factors influencing livestock breeding are discussed. Results indicate potential risks of livestock breeding in individual parts of the Czech Republic.

Keywords: farm animals, cattle, pigs, sheep, horses, goats, poultry, water scarcity

Acknowledgement: This research was supported by the grant of Technology Agency of the Czech Republic (TAČR “Vodní systémy a vodní hospodářství v ČR v podmínkách změny klimatu” SS02030027).
Methods of yield stability analysis in long-term field experiments

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In the face of a changing climate, yield stability is becoming increasingly important for farmers and breeders. Long-term field experiments (LTEs) generate data sets that allow the quantification of stability for different agronomic treatments. However, there are no commonly accepted guidelines for assessing yield stability in LTEs. The large diversity of options impedes comparability of results and reduces confidence in conclusions. Here, we review and provide guidance for the most commonly encountered methodological issues when analyzing yield stability in LTEs. The major points we recommend and discuss in individual sections are the following: researchers should (1) make data quality and methodological approaches in the analysis of yield stability from LTEs as transparent as possible, (2) test for and deal with outliers, (3) investigate and include, if present, potentially confounding factors in the statistical model, (4) explore the need for detrending of yield data, (5) account for temporal autocorrelation if necessary, (6) make explicit choice for the stability measures and consider the correlation between some of the measures, (7) consider and resolve dependence of stability measures on the mean yield, (8) explore temporal trends of stability, (9) report standard errors and statistical inference of stability measures where possible. For these issues we discuss the pros and cons of the various methodological approaches and provide solutions and examples for illustration from the analyses of LTE data (Macholdt et al., 2021; Reckling et al., 2021). We highlight a list of 42 yield stability indices that we categorized by their concept and whether they depend on other treatments (10.4228/ZALF.DK.148). We conclude to make ample use of linking up data sets, and to publish data, so that different approaches can be compared by other authors, and finally, consider the impacts of the choice of methods on the results when interpreting results of yield stability analyses. Consistent use of the suggested guidelines and recommendations may provide a basis for robust analyses of yield stability in LTEs, and to subsequently design stable cropping systems that are better adapted to a changing climate.

A method for sustainability assessment in the Mediterranean region: The case of the olive-asparagus agroforestry system in central Italy

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Key words: Olive Agroforestry, wild asparagus, sustainability assessment, indicators, Italy

The Mediterranean region is one of the most vulnerable areas to climatic and anthropic changes (Milano et al., 2012). The region is facing the challenge of feeding a continuously growing population with less available resources, especially water. Moreover, the region is characterized by social and economic challenges (UN, 2020). Agroforestry is defined by the International Centre for Research in Agroforestry as a "dynamic and ecological system of natural resource management which, by integrating trees into farms and agricultural landscapes, contributes to diversifying and sustaining production for greater economic, environmental and social benefit" and could be one solution to some of the environmental, social and economic challenges faced in the Mediterranean region. In central Italy, agroforestry is based on the combination of olive trees with cereals, legumes or fodder crops (Eichhorn et al., 2006). Intercropping olive trees (Olea europaea) with wild asparagus (Asparagus acutifolius L.) is however a novel practice in Italy (Rosati et al., 2021). To our knowledge, no study has been conducted on the sustainability assessment of the olive tree-wild asparagus agroforestry systems in a Mediterranean socio-economic context. Therefore, the aim of this study was to evaluate the environmental, economic and social performance of olive tree-wild asparagus agroforestry systems by developing a practical methodology using a three-dimensional assessment concept. In a participatory approach with stakeholders of the BIODIVERSIFY project, we selected a set of indicators firstly for the environmental dimension e.g. carbon sequestration, and the social dimension e.g. working conditions. For the economic evaluation, we analyzed the profitability of agroforestry systems using a net present value approach (Lambarraa et al., 2016). The time period chosen for the assessment was 50 years, which represents the productive years of an olive tree system. For empirical application, different sources of Italian data were used. With our sustainability assessment of olive tree-wild asparagus agroforestry systems, we aim to provide useful insights for farmers, public and private decision-makers. We will illustrate and discuss the methodological framework and provide results from the three-dimensional evaluation. This aim to provide key information elements in supporting agricultural policy aiming at the increase of the diversification, and the achievement of sustainability and resilience of Mediterranean farming systems.
Reference:


Weed suppression in cover crop mixtures under contrasted levels of resource availability

Dr. Delphine Moreau; Alicia Rouge PhD

INRAE

Cover crop (CC) mixtures appear as a promising agroecological tool for weed management. Although CC suppress weed growth by competing for resources, their suppressive effect under contrasting levels of soil resource availability remains poorly documented. A two field: year experiment was conducted to investigate the weed suppressive effect of four CC mixtures. They were composed of 2 or 8 species including or not legume species and compared to a bare soil control. The experiment included two levels of irrigation and nitrogen fertilisation at CC sowing. The objectives were to assess (i) weed and CC aboveground biomass response to CC mixtures and resource availability, (ii) the weed suppressive effect of CC mixtures across a gradient of CC biomass and (iii) weed community response to CC mixtures and resource availability. CC and weed biomass were mainly influenced by interactions between CC mixtures and fertilisation and between CC mixtures and irrigation, with contrasted effects between field: years. Nitrogen fertilisation increased biomass of non-legume based CC mixtures but this only resulted into a further reduction of weed biomass of little biological relevance. Legume-based CC mixtures suppressed weeds to a greater extent without nitrogen fertilisation in year 2 but not in year 1, possibly due to contrasted initial soil nitrogen availability (lower in year 2). Weed biomass generally benefited more from irrigation than CC mixtures. Among the 33 weed species recorded, weed communities in each plot were dominated by wheat volunteers, Geranium dissectum, Veronica persica and Echinochloa crus-galli, whose biomass varied depending on the interaction between year, CC mixture and resource availability. Our results revealed that competitive outcomes between CC mixtures and weed species were driven by a complex interaction between resource availability and species traits. Further experiments focusing on plant traits should improve our understanding of weed: CC competitive outcomes under various levels of resource availability.
**Carry over effects of cover crop mixtures and management practices on subsequent crops and weeds in no-till**

Dr. Delphine Moreau; Alicia Rouge PhD

INRAE

Cover crop (CC) mixtures appear as a promising agroecological tool to suppress weeds and maintain crop productivity while reducing chemical inputs such as herbicides and nitrogen fertilizers. The weed suppressive effect of CC and CC nitrogen release have been related to CC composition, soil resource availability and CC termination methods but the relative effect of these factors and their interactions remain poorly documented, especially in the case of CC mixtures. Most studies have focused on the subsequent spring crop, and hence, lacked to investigate long-term carry over effects of CC. A two field-year experiment was conducted to investigate the effect of CC mixture (2 or 8 species including or not legume species, compared to a bare soil control), resource availability (water and nitrogen) at CC sowing and CC termination method (rolling and glyphosate, compared to a winterkill control) on weed biomass and productivity of two subsequent unweeded, unfertilized and direct seeded crops (spring barley and winter linseed in year 1 and 2, respectively). In the context of reduction of herbicide use, our experiments showed that the use of CC to reduce weed biomass in the subsequent crop was not relevant when CC were terminated by winter or rolling since CC probably protected weeds from winter instead of creating a physical barrier for weed emergence, weed community composition in crop being mainly represented by weed volunteers. Weed biomass was the main driver of the subsequent crop productivity but the latter was enhanced after fertilised or legume-based CC, probably because of a higher nitrogen release. No relevant long-term effect of CC on the subsequent crop was observed in our experiment, probably because nitrogen was used by the previous crop and weed community composition changed by year. Our results highlight the importance CC composition and management for weed suppression and crop productivity in low-intensity biodiversity-based cropping systems.
Organic intercropping: a resilient strategy for future Mediterranean climate?

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Keywords: climate resilience, grain legumes, intercropping, organic agriculture

The combination of a severe water deficit and high temperatures during the grain filling period is the main constraint for yield in semi-arid Mediterranean environments, characterized by hot and dry summers. Organic field crop production systems in NE Spain are also limited by weeds pressure and available nitrogen. In a context of climate change the productivity of these systems will likely be severely affected (Olesen and Bindi, 2002). Open-top chambers (OTC) are commonly used for temperature, relative humidity and soil moisture manipulation in crop trials, simulating predicted levels of global warming scenarios. Besides the development of improved cultivars, new agronomic strategies and mechanisms will be required to increase the resilience of agroecosystems to face extreme and changing weather conditions in the context of global warming. Resilient farming systems based on higher levels of biodiversity, such as intercropping of cereal and grain legumes, can improve yield and yield stability of organic systems by reducing fertilizer requirements and soil moisture evaporation and suppressing weed competition. These intercropping systems for grain are nowadays uncommon in Spain so their feasibility needs to be assessed. The purpose of this study was to evaluate intercropping for grain production as a strategy to mitigate organic agriculture main limitations in the local context: nitrogen availability, weeds pressure and climate change. An on-farm field trial managed in collaboration with farmers and based on wheat and winter pea intercropping was established in autumn 2021 in Algerri (41°48'31.40"N, 0°38'36.79"E, 321 m absl) (NE Spain) under semiarid rainfed conditions. Wheat and pea sole crops and intercrops –based on a replacement design– were compared in a randomized complete block design with three replications. Within each plot a large OTC based on the design of Welshofer et al. (2018) was established as a sub-plot in order to passively simulate warming conditions. This large chamber design up to 1.5 m height was considered an effective way for intercropping of tall crops, rather than chambers used for small plant communities. Soil moisture and temperature and air temperature within crop canopy were registered inside and outside OTCs with sensors. Crops above-ground biomass was measured as well. A long drought period during winter months severely affected the development of crops, which were outcompeted by weeds in all treatments. According to the first growth season results (2021-2022) crops above-ground biomass at flowering was very low, with an average of 552 and 1320 kg ha\(^{-1}\) for wheat and pea sole crops under current climate and 931 and 1360 kg ha\(^{-1}\) under warming conditions. Given these low values and a very severe competition with weeds the crop was cut for forage. In this regard, land equivalent ratio for biomass of wheat-pea intercrops was (avg ± STD error) 1.47±0.12 and 1.25±0.17 for current climate and warming conditions, respectively. These preliminary results point out the fragility of production systems during very dry years in rainfed Mediterranean semiarid areas and indicate benefits of intercropping when crop productivity is very low and weed pressure is significant.
Farmer-driven development of a harmonised farm-level sustainability self-assessment

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Key words: public goods, sustainability metrics. Multiple definitions and terminologies relating to on-farm sustainability currently exist, and can hinder communication between farmers, key agricultural stakeholders and government. At the same time, the need to collect and collate data for multiple certification schemes, assessments and sustainability decision support tools leads to a duplication of effort for already stretched farmers. In this context, the Sustainable Food Trust’s (SFT) farmers and land managers working group (FWG) came together with researchers to develop a harmonised framework to enable current assessments and tools to align around a common language for on-farm sustainability, to facilitate efforts to reduce the duplication of data collection efforts, and to emphasize the importance of holistic perspectives on sustainability to avoid unintended consequences of change. A proof-of-concept on-farm sustainability self-assessment tool was developed to demonstrate how the framework could provide the basis for practical, holistic assessments of on-farm sustainability as a baseline for improvements in performance. Methods: Existing sustainability assessment tools were shown to exhibit general alignment on broad subject areas to be considered when measuring sustainability (Mullender et al 2017). Based on these areas, the FWG was asked to choose overarching sustainability categories as a framework for defining and assessing on-farm sustainability. Following this, in November 2019, 25 farmers from the FWG attended a workshop to identify key indicators for each category. The group was asked to find consensus on three key indicators per category for which feasible, practical measurement was possible within a realistic timeframe. The core of an existing sustainability assessment tool, the Public Goods Tool (Smith et al 2022) was developed to provide a means to assess performance across the indicators identified. A second workshop, involving the FWG, farm certifiers, farming groups, governmental bodies, and non-governmental organisations/charities was held in February 2020. Attendees were guided through the draft self-assessment tool, trialled data collection protocols (e.g., soil structure assessments) and provided feedback. The tool was modified in the light of these discussions before being piloted on a sample of 27 farms, representing a range of farming systems across England, with feedback collected post-assessment. Results: Eleven categories summing up all aspects of sustainability were chosen by the FWG farmers for the framework: Soil, Water, Air and Climate, Energy and Resource Use, Biodiversity, Livestock Management, Plant and Crop Health, Nutrient Management, Productivity, Human Capital and Social Capital, along with three key indicators for each. The FWG guided the development of the sustainable assessment tool towards the use of outcome-based metrics to measure impacts, rather than management practices. Following the second workshop, the tool was further developed and revised to improve clarity and increase user-friendliness. Post assessment feedback indicated that farmers and land managers were in support of both the broad sustainability categories, and the metrics used to indicate
performance in each of these categories. Implications: The framework provides a holistic overview of all aspects of on-farm sustainability, minimising the risk of unintended consequences of change and enabling farmers to identify opportunities to improve performance across multiple categories. It’s co-development with farmers ensures its relevance and potential to support engagement on sustainability. The proof-of-concept assessment tool demonstrates the use of the framework as a basis for quantifying and assessing continuous improvements in on-farm sustainability. Beyond the farm, a common language for defining sustainability can facilitate easier communication between farmers, government and key supply chain actors as sustainability moves up the political agenda. The framework and assessment tool are currently being further refined with a wide network of stakeholders (see https://www.globalfarmmetric.org/).

Reference:


Smith, L.G. et al (2022)
Agroecological effects of diversifying soybean and wheat cropping systems

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Keywords: Relay intercropping, strip intercropping, diversified farming systems

Diversification of agricultural systems is an option to counteract biodiversity and ecosystem service decline as well as to help farmers create profitable and resilient cropping systems. Our study focuses on intercropping as one promising diversification practice and how it can be implemented on farms in Eastern parts of Germany. While there is ample research on intercropping practices like grain legume-cereal intercropping and forage mixtures, where both crops are harvested together, other forms of intercropping, e.g. relay intercropping (crops are sown and harvested at different periods), strip cropping (crops are grown in strips to allow separate management but ecological interactions), and patch cropping (crops are grown in spatially separated units within a field) have been even less frequently used in Germany and there is little agronomic knowledge of the systems. Thus, the overarching goals of this project are to (1) assess the agronomic constraints and opportunities of soybean and winter wheat relay, strip, and patch cropping for farmers in Germany, (2) study the impacts of the types of cropping (patch, relay, strip) on pest control/pesticide reduction as well as yield potential, and (3) investigate the effects of the cropping system on soil health. We investigate these goals with two experiments. First with a plot trial in Müncheberg, Germany, we study the effects of varied irrigation (rainfed or irrigated), two wheat varieties (Moschus or RGT Reform), and cropping system (sole soy, sole wheat, or soy-wheat relay intercropping) on crop development, disease damage, pest outbreaks, and yield to understand the best management practices for the system. We additionally monitor chemical, biological, and physical indicators of soil health in the plots over a one year period. For our second experiment, we have an on-farm trial implemented within the patchCROP landscape laboratory with field-size trials of wheat and soy strip cropping, relay intercropping, and patch cropping to again test the agronomic potential of the systems in the region. We further investigate the potential of the system for pesticide reduction with pest, pest predation, and natural enemy monitoring. Preliminary results from 2021, the first year of the plot trial, found that productivity in intercropping plots varied between 0.87 and 1.24 in terms of land use equivalency ratios across wheat variety and irrigation treatments. Moreover, there were no significant effects of cropping systems on pest abundance but significantly less fungal disease in one of the wheat varieties (Moschus) over the commonly used variety in the region (RGT Reform) offering initial insight into possible local management recommendations for the system.
Nutrient cycle count, an easy measure of system circularity at different scales

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Keywords: Nutrient cycling, nitrogen, phosphorus, agro-food system

Food systems must become more circular to reduce resource use and emissions to the environment (de Boer and van Ittersum, 2018). To accelerate a transformation towards a more circular food system and improve the scientific debate as a driver, clear indicators are needed to express system performance in terms of circularity, and to evaluate impacts of system changes on circularity.

The Output/Input ratio (O/I) and Output-Input difference (Surplus or Loss) are often used to define nutrient use efficiency in agricultural systems. These are relatively easy to estimate. They do not, however, express system circularity. Instead, several measures of circularity are known, such as the Finn Cycling Index used in ecology (here Finn CI; (Finn, 1980) and the Figge Circularity indicator (Figge et al. (2018)) used to describe material flows in industrial processes. We propose a new indicator for circularity, Nutrient Cycle Count (CyCt), and compare it to the above indicators. CyCt expresses how often a nutrient is used in a particular (chosen) component process, before being dissipated as either exported produce or loss to the environment. We quantify CyCt for nitrogen (N) and phosphorus (P) cycling in four agro-food systems of increasing complexity and scale, from the simple crop-soil system up to cases of regional agro-food systems in Belgium (Flanders and Wallonia) that include both food processing and human consumption. In-between cases are an ‘average Dutch dairy farm’, and ‘livestock farming in The Netherlands’, both excluding food processing and human food consumption.

Highest values for all circularity indicators were found for P in the dairy farm. As for systems with lowest circularity scores, these differed depending on indicator. Finn CI was lowest for N in the crop–soil system. For CyCt it was P in the Flanders agro-food system. Figge Circularity was lowest for N and P in the agro-food systems of both Flanders and Wallonia. The O/I ratio was lowest for N in the dairy farm system. Significant correlations were found between CyCt and Figge Circularity.

Next, we investigated the impact of two system changes on the circularity indicators. First, we changed import of feed concentrates for livestock farming in the Netherlands. This did not affect the Finn CI and Figge Circularity values, but reduced CyCt and O/I. Second, for the same system, we changed the feed to livestock products conversion efficiency. Higher efficiency resulted in a higher O/I ratio, but values of the other indicators decreased due to less manure remaining in the system. In contrast, livestock products in the ‘Flanders’ and ‘Wallonia’ agro-Food systems are not treated as outputs but are regarded as internal flows. Here, increasing feed to livestock products conversion efficiency resulted in higher CyCt and Finn CI.
Our newly proposed cycling indicator CyCt is relatively simply defined and easy to calculate, as compared to the Finn and Figge indicators; and gives insight into cycling which cannot be said of the O/I ratio. Practical application of CyCt, however, is limited to systems with a single and clearly defined ‘use processes within the system, such as feed intake by livestock, or nutrient uptake in crops, or human consumption of agricultural produce.

Reference:


Critical issues for the enhancement of intercropping for sustainable European agriculture

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Intercropping is an agroecological practice for crop diversification which involves growing mixtures of arable crop species in both space and time. It has long been recognized as a way to improve the sustainability of crop production. Although intercropping has been a traditional practice for centuries in many parts of the world, intercropping is not widely used in European agriculture. While intercropping may increase the complexity of operations on farm it can bring benefits of reduced requirements for fertilisers and crop protection chemicals and increased yields in low input and organic farming. On the other hand, sowing, harvesting and separation of grains is perceived as a bottleneck by producers and stakeholders. When it comes to utilising the products of intercrops for feed and food there are many factors to consider around quality, use and price. In terms of policy contributions, cereal/grain legume intercrops, for example, can easily contribute to home grow protein production but also to the EU Climate Action and Biodiversity Targets and the Farm to Fork Strategy at the heart of the European Green Deal. Here we bring together the findings of two EU H2020 projects (ReMIX and DIVERSify) to examine the scientific, technical, and socioeconomic and policy issues around the increased use of intercrops in Europe and we identified 12 “hot topics” scanning the horizon for needs and opportunities to boost intercropping for feed and food in Europe.
Analysing the relationship between yields and farmers' incomes to help the design of more sustainable cropping systems

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Keywords: crop productivity; farm profitability; production situation; reducing pesticide.

Farmers often grow only the few high-yielding crops in the area, and target maximum yields through high levels of inputs. These practices are based on the assumption of a positive relationship between productivity and profitability over a wide range of cropping systems (Woo et al., 2020; Erythrina et al., 2021). Part of the correlation between productivity and profitability could be related to differences in production situation and therefore yield potential, i.e. characteristics that do not depend on farmers’ decisions. For a given production situation, the systems with the highest profitability and the best environmental sustainability could be systems with moderate yields.

The objective of our research is therefore to assess the relationship between productivity and profitability of cropping systems in order subsequently to help design of the most profitable and sustainable cropping systems.

In this study, we use the French DEPHY network database collected on about 3,000 French commercial farms over ten years. Regression tree methods are conducted on the dataset to identify combinations of farm characteristics associated with the production situation to form a regression tree with a range of varied production situation groups. Crop yields are aggregated on the cropping system level rather than on the crop level to represent the overall cropping system productivity in each farm. Productivity is estimated by converting yields into the amount of energy produced by surface unit (GJ ha−1 yr−1), based on the energy content of each given crop calculated by the higher heating value. Profitability (€ ha−1 yr−1) is computed by the monetary value generated by the output of the cropping system. Lasso (least absolute shrinkage and selection operator) regression method (Tibshirani, 1996) is used to compute the marginal yielding effects on profitability. Treatment Frequency Index (TFI), energy use efficiency, and their interactions with productivity are also tested with their explanatory power at profitability in the Lasso regression model. Marginal yielding effects on profitability computed by the Lasso regression method is used to explore the corresponded changes in profitability resulting from a one-unit increase in productivity within each production situation group to assess the relationship between productivity and profitability of cropping systems in a consistent context.
Under the same production potential situation, we will test the relationship between productivity and profitability notably to reveal if an intended reduction in targeted yields and an increase in the efficiency of inputs would lead to maximised overall profits compared to an increased use of inputs targeting high yields. The original oversimplified yield-profit relationship studied here under consistent production conditions from about 3,000 French commercial farms over ten years will question current advices targeting maximum yields instead of targeting maximum income and higher sustainability.

Reference:


Crop Diversification and Digitalisation to Support Transformations in Production
Exploring solutions to control bird damages in crops

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Many crop production chains can be subject to frequent bird damages. Bird species like crows and rooks are often spotted in the fields after sowing, harvesting or soil tillage. With an omnivorous diet, they mainly feed on invertebrates, little rodents, but also on freshly sown seeds or seedlings, causing locally but significant damages. Because of the great spatial heterogeneity of crop damage, the total cost can be considered low, but still difficult to support for some farmers in terms of yield losses due to the lack of plants, adding this to the cost of resowing when fields are suffering high damage.

The objective of this study is to assess bird damages on spring crops in Switzerland and develop new methods allowing farmers to prevent them. At this time, there are only few available solutions, which have been ineffective and raise ethical issues: i) bird repellents used as seed coatings on maize although the homologation of these substances is reaching an end because of their toxicity; ii) frightening devices like air balloons, canons, and distress call playbacks did not show long term efficiency and can be a source of nuisance for neighboring habitations; iii) regulation shooting and nest destructions were proven inefficient.

A survey was sent to Swiss farmers to evaluate the damages caused by birds and link them to agricultural practices and field environment. It confirmed the high spatial heterogeneity of the damage at both the field and landscape scales. The main bird species involved are rooks (Corvus frugilegus) and crows (Corvus corone/cornix), but pigeons were also mentioned in some areas. The biggest issues concerned sunflower and maize.

Two strategies will be tested to target these two crops. The first one consists in sowing spring crops under a cover crop to make it less accessible to birds. The second one offers an alternative resource on the side of the fields. A combination of both would allow a push-pulled system as developed to control insect pests. However, in order to find efficient solutions, a better knowledge of birds’ food preferences is needed. To that end, various seeds will be proposed to captive corvids both with and without non-toxic seed coating, each time changing their color, taste or smell. The experiment will be filmed to assess birds’ behavior.

The current study aims to improve the understanding of corvid behavior in order to offer efficient and durable solutions to prevent damage for a better balance between the economic well-being of farmers and the conservation of bird species.

Keywords: Corvids; damage; maize; resowing; sunflower
Testing of weed control tools as part of the development of a robotics assisted cultivation method for organic sugar beets

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Keywords: organic sugar beet, weed control, robotics assisted

Introduction

The demand for processed organic products such as fruit yogurt, juice and ice cream is steadily increasing, and with it the need for regionally produced organic beet sugar, which is preferable to imported organic sugar cane in terms of ecological and social criteria. Regarding the high and cost-intensive manual labor associated with organic sugar beet cultivation, the aim of the project presented here is to develop a practical cultivation system for organic sugar beet using innovative field robotics and UAS (unmanned Ariel systems) in a participatory process with farmers and business partners from technology and food processing sector.

Methods

Within the zUCKERrübe project, the development of the cultivation method is implemented through a transdisciplinary collaboration between research institutions, practical agricultural enterprises, and technology development companies and institutes.

Using image recognition supported by neural networks (distinction of sugar beet and weeds), a robust robot for autonomous and mechanical weed control in organic sugar beet stands is being developed. The distinction between sugar beet and weeds by the robot will be continuously improved by an "Active Learning" process during the tests. Its intelligent route planning will be controlled via UAS and will enable an efficient approach by identifying and prioritizing weedy hotspots in the field.

Simultaneous to these developments, on-station and on-farm tests on various issues take place at the Wilmersdorf Teaching and Research Station (LFS; Brandenburg, Germany) and at the participating farms in each project year. In April 2021, 36 plots of organic sugar beet were tilled at the LFS to elicit which mechanics and timing of weed removal are most effective in reducing weed cover. The combination of two removal mechanics (electric shock, drilling) and four temporal application patterns (removal at dates: 1, 1+2, 1+3, 2+3) resulted in 8 variations, each applied in four replicates. Weed coverage was bonitized by estimation at four dates. The collected data were analyzed for significant differences in efficiency between mechanics and application patterns using non-parametric statistical tests in SsS 7.1.

The collected data were analyzed for significant differences in efficiency between mechanics and application patterns using non-parametric statistical tests in SsS 7.1.
Results and discussion

The evaluated data show significantly lower weed coverage for the variants in which the mechanism of drilling was applied, compared to the control plots and to those variants with electric shock application. Drilling showed a mean weeding efficiency of 82.17% when compared to the control variant in which no weed removal was applied. The efficiency of electroshock application averaged a low 36.74% across the four temporal application patterns, which corresponds to lower end values reported in literature (Slaughter et al. 2008). No differences were found between the temporal application patterns in terms of weed coverage.

Implications

Last year’s trial results can be used directly in the adaptation of the robot to practical field conditions and in the further development of the prototype. In a larger frame of reference, the results of the project should contribute to an improved economic efficiency of organic sugar beet cultivation and also provide a possibility to reduce herbicide use in this and in other root crops in conventional cultivation (Pandey et al. 2020).

Literature


Remote sensing for irrigation assessment: challenges and opportunities of multisource data use

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Accurate and spatially explicit information on irrigation is essential for sustainable water resource management, crop condition monitoring, and modelling. Although some advances have been made for irrigation mapping using remotely sensed data, most studies are conducted in semi-arid areas, while field-level irrigation mapping remains challenging for temperate regions. This is due to the fact that the differences between irrigated and rainfed fields are not evident in humid areas, especially when using data coming from one sensor. However, the importance of information about irrigation in temperate regions is increasing, as irrigation requirements are expected to increase over the coming years. To assess the applicability of different time series for irrigation mapping at field scale, we used optical and Sentinel-1 (S1) data over northern Germany, an area characterized with heterogeneous field sizes, crop patterns, irrigation systems, and management. An extensive amount of field-scale irrigation data reported by farmers was collected and used as a reference for model training and validation. Several spectral-temporal metrics from integrated Landsat and Sentinel-2 time series were produced. The derived feature set comprises several vegetation indices and Tasseled Cap components which were aggregated over the growing season and specific key phenological stages of winter and summer crop growth. Further, MODIS-based evapotranspiration was integrated to account for water use. Irrigated areas were then classified using the temporal aggregates from remotely sensed time series using random forest (RF) and gradient boosting (XGboost) -based classifiers. In general, XGboost outperformed RF for irrigation mapping with both composites from specific growth stages and growing seasons. Overall accuracy reached satisfactory levels (~ 80 %) despite heterogeneous agricultural management practices. Besides the cross-validation of the classification results, the area of applicability of models was computed, which shows in a spatially explicit manner the uncertainty of the results. The accuracies varied for different crops, with good performance observed for maize. The combined use of optical and radar data enhanced the classification accuracy. Overall, the study presents a framework for field-level irrigation mapping over large areas, which can inform crop models and assist the estimation of water resource demands. Further research will be focused on the transfer of the methods to other areas. The generated irrigation maps will be further used to inform dynamic crop models.
Mapping Of Soil Organic Matter (MOSOM)

Prof. René Gislum; Tomas Bunga; Francesca Ventura; Claudio Ciavatta; Jon Gonzalez; Markus Gandorfer; Antonello Bonfante; Andrea Cruciani; Sara Antognelli

Introduction

Organic carbon (OC) is critical to soil function and productivity, and a main component of and contributor to healthy soil conditions. Soil management plays a critical role in whether the organic carbon remains in the soil or is released to the atmosphere. Agricultural practices can impact both the amount and the composition of soil organic carbon (SOC) and hence also the soil’s physical, biological, biochemical, and chemical conditions, the combination of parameters that defines soil functionality and “soil health”. Farm practices that affect organic carbon therefore impact agricultural productivity and resilience and the carbon cycle itself. While the agricultural sector can impact the carbon cycle on a large scale, often through the release of carbon (mainly as CO2), farmers have a vested interest in retaining and increasing soil organic carbon for individual fields because soil health and crop yield tend to improve when the soil organic carbon level increases. Higher soil organic carbon promotes soil structure or tilth, meaning there is greater physical stability. This improves soil aeration (oxygen in the soil) and water drainage and retention and reduces the risk of erosion and nutrient leaching. Soil organic carbon is also important to chemical composition and biological productivity, including fertility and nutrient holding capacity of a field, as well as the behavior of contaminants and xenobiotics.

A developed technology will be adopted by different service providers throughout Europe, as well as farmers and other agricultural stakeholders interested in remote soil assessment. The planned two-year project from 2021 to 2022 will focus on development of the methodological and technological basis, as well as their initial validation under real market and environmental conditions. EU Farm to Fork Strategy propagates carbon sequestration by farmers as a new green business model supported by the Climate Pact and CEAP.

Aim

The MOSOM project aims to develop an accurate, efficient and convenient tool for remote assessment of organic matter within soil, with cross-European applicability and scalability potential. The proposed solution is based on several different Earth Observation techniques and a unique AI- based analysis architecture that, in combination, results in a beyond state-of-the-art solution for soil property assessment. The reference data will consist of soil samples taken throughout EU. The consortia devoted to developing the technology will form a basis for multiple future applications of the technology, serving for more efficient resource stewardship in Agriculture.

The MOSOM project will empower farmers and other stakeholders to assess soils organic matter remotely, efficiently indicate changes in the topsoil composition and detect dangerous erosion. Such knowledge will create possibilities for more sustainable use of resources as well as more efficient long-term planning of soil usage. The proposed solution follows the
Sustainable Agriculture focus and, when applied within farm management practices, will contribute to the following goals: (1) more sustainable agriculture processes; (2) maintaining yields with less fertilizers; (3) environmentally responsible production; (4) lower climate impact and carbon footprint; (5) increase in carbon sequestration; (6) decrease in soil erosion; (7) preservation of soil fertility conditions as well as informing smarter farming practice.
Sensor-based site-specific nitrogen application compared to uniform nitrogen management in winter wheat

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Keywords: site-specific nitrogen application, remote sensing

Aim: In this study sensor-based, site-specific nitrogen fertilizer trials were carried out on arable heterogeneous fields cultivating winter wheat and winter barley. The effects of site-specific nitrogen fertilization on yield formation, product quality, nitrogen uptake and nitrogen balances compared to uniform nitrogen fertilization were examined. Site-specific nitrogen fertilization results in a redistribution of nitrogen fertilizer within the area. The fertilizer is applied where it is needed according to soil conditions and plant populations at the time of application. Therefore, there is usually a reduction in nitrogen use in low-yield zones and an increase in high-yield zones. In the case of uniform fertilization, this can lead to overfertilization in low-yield zones resulting high N surpluses and potential nitrate losses or nitrogen enrichment in the soil (Mittermayer et al. 2020). In high-yield zones, on the other hand the yield potential is not fully exploited and/or grain N removal by the plants exceeds the N supply and the N stocks in the soil are reduced (negative N balances) (Dalgaard et al. 2012). In this study, the hypothesis that site-specific nitrogen application reduces the variation of N surplus and contributes to reduce the nitrogen loss potential in arable heterogeneous fields was to be examined. Furthermore, it was to clarify whether the yield target can still be achieved by reducing the nitrogen input.

Methods: The site-specific nitrogen fertilizer trials were carried out on four heterogeneous arable fields in southern Germany cultivating winter wheat and winter barley. Three management zones (high yield, medium yield and low yield) were defined within the arable fields. To do so, spatial variation of the vegetation index REIP based on reflectance measurements (Tractor-mounted sensor) was compared with the vegetation index NDVI based on perennial satellite images and georeferenced soil samples (SOC and TN). 20m long plots were created between each tramline. During plant growth for each plot fertilizer demand was calculated using REIP index and a nitrogen fertilizer algorithm based on the online map-overlay method (Maidl 2011). Fertilizer was applied site-specifically alongside uniform nitrogen application at BBCH 32 and BBCH 39. Plant parameters of all plots (grain yield, nitrogen uptake, N surplus) were determined by a combine harvester yield sensing system and laboratory analysis.

Results and discussion: Due to weather conditions such as hail damage during flowering stage, the results are represented by one selected arable field (Itzling 5). The amount of site-specifically applied nitrogen varied greatly throughout the trial (103 up to 233 kg ha-1 compared to uniform applied nitrogen 155 kg ha-1). The mean grain yield was 9.8 t ha 1, which was higher than the expected mean grain yield (8 t ha-1). Thus the mean nitrogen surplus was
negative (-16.5 kg ha-1). Even though nitrogen was applied site-specifically there was great variation in nitrogen surplus throughout the field (-85 up to 40 kg ha-1). When comparing the results of uniform and site-specific nitrogen fertilization, hardly any differences were found in terms of yield formation, product quality, nitrogen uptake. Grain yield varied from 9.8 t ha-1 (low yield zone) up to 10.3 t ha-1 (high yield zone). The grain N withdrawal was between 145 and 188 kg ha-1. Nitrogen balances showed differences between uniform and site-specific application. The Variation of the nitrogen balances of uniform N application varied greater (-28 kg ha-1 up to 10 kg ha-1) than site-specifically application (-28 kg ha-1 up to -16 kg ha-1). As a result of the abundant rainfall during grain filling stages of winter wheat and winter barley, the effects of spatial variability of soil properties within the field on yield formation were not significant.
Estimation of canopy parameters using artificial neural network based radiative transfer model inversion in wheat

Lukas Koppensteiner; Reinhard Neugschwandtner; Sebastian Raubitzek; Philipp Weihs; Norbert Barta; Pablo Rischbeck; Thomas Neubauer; Helmut Wagentrüstl; Andreas Gronauer; Prof. Dr. Hans-Peter Kaul

Keywords: wheat, remote sensing, radiative transfer modelling and artificial neural networks

Canopy parameters are traditionally estimated using empirical relationships. For example, regression analyses between vegetation indices and LAI. These models, however, need to be calibrated and validated continuously. Furthermore, most vegetation indices only use two or three spectral bands and thus do not utilize all relevant spectral information to estimate target canopy parameters (Baret and Buis 2008). An alternative approach is the application of Radiative Transfer Models (RTMs), which were developed to better understand the complex interaction between solar radiation and vegetation canopy (Monteith 1965). In comparison to previously mentioned empirical relationships, RTMs can reduce calibration and validation needs as they generalize well. Furthermore, they allow the exploitation of all relevant spectral information available (Berger et al. 2018). The objective of this study was to estimate canopy parameters in wheat (Triticum aestivum L.) based on an artificial neural network (ANN) inversion of the RTM PROSAIL. A dataset was simulated based on the RTM PROSAIL and typical input parameter ranges for wheat from literature. The simulated dataset was divided into a train and test set. The train set was used to calibrate an artificial neural network to achieve the RTM inversion. The model performance was evaluated using the test set and experimental data. The experimental data is based on a field experiment of autumn- and spring-sown facultative wheat with different nitrogen fertilization levels (0, 5, 10, 15 and 20 g m\(^{-2}\)) conducted in the seasons 2019/20 and 2020/21 at the experimental farm Groß Enzersdorf of the University of Natural Resources and Life Sciences, Vienna (BOKU). Destructive plant samplings and hyperspectral handheld measurements were conducted in an interval of two weeks from March until harvest in both seasons. Results show promising estimations of canopy parameters using ANN based RTM inversion. Future work will include the optimization of ANN structure, model evaluation with more extensive field experimental data and the estimation of canopy parameters using ANN based RTM inversion in other crops.


Quantitative mixed model analysis and principal component analysis of yield and yield components in facultative wheat affected by environment, sowing date and nitrogen fertilization

Lukas Koppensteiner; Prof. Dr. Hans-Peter Kaul; Prof. Dr. Hans-Peter Piepho; Norbert Barta; Helmut Wagentristl; Andreas Gronauer; Reinhard Neugschwandtner

Keywords: wheat, yield components, mixed model analysis and principal component analysis

Yield and yield components of wheat vary with environmental conditions including temperature, precipitation and nutrient supply, especially nitrogen (N) (Geisler 1983). Climate change, however, is expected to change environments. In Central Europe, average temperature will increase and distribution of precipitation will change. Rainfall is expected to increase in winter and early spring and decrease in summer. Earlier sowing of wheat can reduce the risk of heat and drought stress in summer for rainfed production (Trnka et al. 2011).

The objective of this study was to analyse yield and yield components of facultative wheat affected by environments, sowing date and N fertilization using quantitative mixed model analysis and principal component analysis (PCA).

Field experiments with facultative wheat (cv. Lennox) were performed in eastern Austria at the Experimental Farm Groß-Enzersdorf of the University of Natural Resources and Life Sciences, Vienna (BOKU) in the growing seasons 2019/20 and 2020/21. Experimental factors were sowing date (autumn-sowing and spring-sowing), as well as N fertilization (0, 5, 10, 15 and 20 g m-2). At harvest, destructive plant sampling was conducted. Samples were processed to assess yield and yield components including grain yield (g m-2), residual dry matter (g m-2), above-ground dry matter (g m-2), harvest index (%), ear density (ears m-2), grain yield tiller-1 (g), residual dry matter tiller-1 (g), above-ground dry matter tiller-1 (g), grains ear-1, grain density (grains m-2), thousand kernel weight (g) and grain size distribution. For analysis, mixed models were set up according to Piepho et al. (2003) and analysed using ANOVA and post hoc tests. Environment and sowing date were qualitative factors. For the quantitative factor N fertilization first or second order polynomials were estimated. Furthermore, PCA was performed resulting in scores of experimental plots and loading vectors of yield and yield component parameters.

Winter sowing showed generally higher yield and especially higher increase in yield with additional N fertilization compared to spring sowing. Exceeding N fertilization, e.g. > 15 g m-2, was not able to further increase yield. Temperature and precipitation until flowering mainly affected ear density (ears m-2) and grains ear-1. Thousand kernel weight, grain size fractions and harvest index were mainly affected by temperature and precipitation after anthesis. PCA indicated that the factors environment, sowing date and N fertilization explain most of the variation in the experimental data. Furthermore, it presents an overview of relationships between experimental factors, scores of experimental plots as well as yield and furthermore, it presents an overview of relationships between experimental factors, scores of experimental plots as well as yield and yield component parameters.


Potentials and risks of digital technologies in the context of biodiversity protection in agriculture – a review

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Stable and healthy ecosystems are the key for ecosystem service provisioning. The rapid biodiversity loss of flora and fauna in agriculture endangers the provisioning of ecosystem services, on which the food production depends. In the course of Agriculture 4.0, a wide range of digital technologies is used in the agricultural sector. The implementation of digital technologies is a fast-growing trend affecting not only the plant cropping methods and livestock farming, but can also impact biodiversity in agriculture. However, the primary application of digital technologies on farms is aimed to increase or optimise crop yields and management decisions. The protection of biodiversity and thereby the securing of ecosystem service provisioning usually follow as a side effect. The present research examined the point of intersection between the Agriculture 4.0 and biodiversity, in the context of potentials and risks for biodiversity protection in agriculture.

For this purpose, a literature review including scientific and non-scientific research on digital technologies, currently used in agriculture, was conducted. The results were clustered into five categories, based on the technical functionality of the listed digital technologies. 1. Digital technologies for agricultural machinery refer to tools, as well as applications that allow farmers to perform and optimise field processes through spatial data (based on GIS and GPS). 2. The category Sensors and Robots, includes Sensors (active and passive), used by farmers as an additional technical support for information collection. The Robotics’ list comprises sensing-based robotic technologies that depend on the presence of sensors. 3. Drones are unmanned aerial vehicles (UAV), operated by remote control and thus represent a specialized form of sensor-based data collection. 4. Farm management information systems (FMIS) and Decision Support Systems (DSS) are widely used tools aiming at data collection and processing to inform farm management decisions. 5. Digital technologies for citizen science and digital information platforms facilitate information input, output and exchange for farmers. Each of the categories (1.-5.) were split into subcategories that include technologies with primary and respectively secondary impacts on the protection of biodiversity. The final division into subgroups presents an overview of the potentials and risks of every single technology on biodiversity protection.

The review of the five categories revealed that the groups 1. To 3. have the highest potentials for a direct impact on biodiversity protection. Group 1. To 3. Offer i.a. digital solutions for precise or reduced and plant health-orientated applications of fertilizers and pesticides. On the other hand, the use of precise technologies involves risks in terms of further intensification – such as a gapless area management, or computer-assisted robotic weed control, leaving no space for periphery flora and fauna. Groups 4. (Data connection and analysis and supply for
machinery systems) and 5. (data supply) have an indirect impact on biodiversity protection. Practical examples for the potentials of citizen science applications and digital information platforms are mapping and monitoring activities of endangered species that include long-term planning mechanisms within farmers’ decision making on biodiversity-friendly crop rotations. The handling of farm information bears certain risks. Particularly, data sovereignty and protection are still a major problem, causing uncertainty among farmers, when it comes to farm data sharing.
Using Bayesian networks as a participatory tool for assessing the impacts of digital agriculture

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The digital transformation of agriculture implies disruptive changes to the entire agri-food sector, especially in regard to the environmental and socio-economic systems of rural landscapes. Indeed, this raises pressing questions as to whether these changes will in fact promote sustainability. For instance, proponents claim that digitalization could contribute to increased landscape diversity, improved farm resiliency, as well as optimized regional value chains. Skeptics, however, warn that digital agriculture could decrease farmer autonomy, displace low-skilled workers, as well as disturb traditional landscape aesthetics. Unfortunately, assessing the higher-level impacts of digitalization is made difficult by a lack of empirical data, which is partly due to the novelty of digital technologies as well as the rapid pace at which they are being developed and applied. In order to assess the potential impacts of digitalization in the absence of hard data, models are needed that incorporate the knowledge and values of experts and stakeholders. In this study, we employ a participatory Bayesian network methodology as a means to conceptualize the regional impacts of digitalization from the standpoint of key stakeholders from the Brandenburg region such as farmers, researchers, as well as representatives from public administration and civil society. Through multiple stakeholder workshops, a Bayesian network was constructed that represents the synthesized knowledge and values of these stakeholder groups. The resulting Bayesian network sheds light on the relevant impacts of digitalization as well as the overall uncertainty of these impacts. Additionally, the process of co-constructing the Bayesian network served as a useful co-learning tool for the stakeholders involved in the modeling exercise.
The Digital Agricultural Knowledge and Information System (DAKIS): employing digitalisation to enable diverse and multi-functional agricultural systems

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Ecosystem services, biodiversity, digital decision support system, diversification

Agricultural production is expected to ensure food security, support the bioeconomy with renewable resources and energy, become climate neutral, and avoid harmful impacts on the environment. This multiplicity of purposes increases pressure on agricultural lands and can potentially give rise to conflicts between the profitability of farming and the provision of biodiversity and ecosystem services (ESS). Multifunctional and diversified agricultural systems at the landscape level can consolidate these diverse targets by producing multiple amenities while supporting biodiversity and the regeneration of ESS. To successfully design such inherently complex agricultural systems within their specific spatial setting, the use of digital technologies can provide critical innovative support to foster new learning in agricultural decision-making. Indeed, in the past decade, digitalization in agriculture has gained momentum, with numerous different technologies fast emerging and made available to the academic and farming communities. Nevertheless, various challenges remain, such as employing digitalisation to ameliorate trade-offs between different ESS, improving its contribution to environmental sustainability in general, and achieving the suggestion of concrete site-specific agronomic measures. In this context, the deployment of digital agriculture, when intersecting with established modes of decision-making, needs to take into account new demands for sustainability and to aim at harnessing synergies towards new learning opportunities in the Agricultural Knowledge and Innovation system (AKIS). Under this changing AKIS dynamic driven by digitalisation, we present the Digital Agricultural Knowledge and Information System (DAKIS), with the aim to demonstrate an approach that employs digital technologies to enable highly complex decision-making towards diversified and sustainable agricultural systems. To develop the DAKIS, we first identified requirements for a novel tool that promotes the integration of ESS and biodiversity provision in farmers’ decision-making processes, while being concurrent with overall progress on the development of digital tools. We identified the core requirements in an iterative process of exchange with stakeholders and members of the DAKIS developers’ team and refined them by using the results of a literature review. With these requirements in mind, we developed the DAKIS conceptual and technical architecture and provided a proof of concept using a use case on the establishment of grassland buffer patches. In this talk we will present the DAKIS decision support system (DSS) and demonstrate its functionality via the established use case. The
DAKIS is a digital knowledge-based DSS that assimilates in a harmonised manner the diverse drivers affecting agricultural land use and management design to enable site-adapted small-scale multifunctional and diversified agriculture. These drivers include natural and agronomic factors, but also economic and policy considerations as well as socio-cultural preferences and settings. The DAKIS system integrates remote and in situ sensors, artificial intelligence algorithms, and online web-platforms with publicly available real-time databases, farm economics planning modules, modelling of ESS and biodiversity, agent-based modelling, stakeholder-based stated demands, and sustainability impact assessment. Processes considered within DAKIS span from sub-field to regional levels in an interconnected spatially explicit approach. With the help of digital technologies, the DAKIS enables site-adapted agriculture, where plants are grown where optimal conditions prevail and nature-based small-scale management is adopted where and when the provision of biodiversity and ESS can be prioritised. At the same time, it indicates to its users where ESS and biodiversity are demanded and can be specifically promoted. The DAKIS employs digital technologies to embed the consideration of ESS, biodiversity and sustainability into farmers’ decision-making, thus enabling progress in simultaneously achieving farmers’ economic objectives and society’s environmental demands and supporting systemic transitions towards diversified agricultural production systems.
Influence of soil phosphorous variability on the efficiency of remote sensed nitrogen fertilization

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Available soil phosphorous (Ps) may be highly variable even within small fields and may determine high within-field variability in wheat production. The aim was to evaluate the influence of Ps variability on the efficiency of remote sensed nitrogen fertilization. Three fields were sown to durum wheat (Triticum durum Desf.) in Asciano (Tuscany Region) during three growing seasons (2018/2019, 2019/2020, and 2020/2021), under rainfed conditions. Fields were subdivided in 4 plots receiving different inputs of N fertiliser. The first fertilization rate was the same for all plots (65 kg N ha$^{-1}$). The second top dress fertilization was varied according to four different treatments: 1) flat N rate (FR) (65 kg N ha$^{-1}$); 2) a three NDVI-based N management zones (NDVI+) with N rates (52-65-78 kg N ha$^{-1}$) increasing as the NDVI values increase; 3) a three NDVI-based N management zones (NDVI-) with N rates (52-65-78 kg N ha$^{-1}$) increasing as the NDVI values decrease; 4) N rates based on the estimated nitrogen nutrition index from satellite (NNI). A total of 9 soil samples for each treatment were collected, before sowing, and then analyzed to determine soil texture, pH, electric conductivity (CE), total nitrogen (Ns), Ps, organic matter (OM), and lime (CaCO3). At harvesting, 9 samples of aboveground biomass were collected for each treatment in the same location of the soil samples in order to determine the grain weight (BG) and the grain protein concentration (Ncg). Results indicate that differences between treatments in grain yield and protein content were negligible and generally not significant (p > 0.05). In all cases, results showed large within-field variability in BG and Ncg and such variability was significantly correlated (p < 0.05) to variation in soil Ps. On the contrary, no significant relationships were found between both BG and Ncg and the other soil parameters. The relationships between Ps and both BG and Ncg were not consistent across years probably due to the different meteorological conditions. This study suggests that the within-field Ps variability needs to be managed by means of sitospecific fertilization to optimize wheat production.
A systematic review of methods for assessing the performance of conservation agriculture and its ability to cope with climate change in temperate zones

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Cropping systems in temperate zones are suffering from climate change, which is expected to cause even more damage in the future. Beyond the changes in mean conditions of temperature and rainfall, the increased intensity and frequency of extreme weather events (e.g. droughts, heat waves, heavy rainfall or windy episodes) are expected to increase. Historical intensive farming practices, including deep inversion tillage and monoculture, are known to increase vulnerability of cropping systems to such climate hazards, for example by increasing soil erosion or hydric stress. Conservation Agriculture (CA), based on three crop management principles (minimum mechanical soil disturbance, soil cover, and crop diversification), has received strong attention as an alternative for addressing the negative impacts of climate change on cropping systems. The effects of CA on the performance of cropping systems have been discussed in an increasing number of studies and some meta-analysis has evaluated its potential on crop productivity or soil protection. But no recent synthesis provides a description of the research activity on CA’s ability to cope with climate hazards.

This systematic literature review (SLR) aims to gather studies assessing the effectiveness of CA in the face of climate change in temperate zones and synthesize information related to a diversity of contexts (type of soil, geographic location), study design, set of practices, and evaluated performance.

Our SLR approach was guided by Cochrane and Prisma protocols. We first conducted a bibliographic search in the Web of Science to retrieve peer-reviewed English articles on the topic. After screening their titles and abstracts, we excluded off-topic papers and selected the ones that meet five eligibility criteria: (i) study has been conducted in a temperate zone; (ii) it involved one of the nine crops of interest (maize, wheat, barley, sorghum, sunflower, soybean, canola, triticale, pea); (iii) it included at least one CA practice; (iv) it was performed at the plot or farm scale, and (v) it assessed the effectiveness of CA to limit the negative impacts of climate change on cropping systems. A final subset of 162 articles was analyzed and we present here a synthesis of the information we extracted.

Preliminary results showed that most of the selected studies rely on experimental data collected at the plot level over short periods of time (< 5 years) in past and current climatic conditions. Model-based approaches in future conditions are still scarce. With regards to the choice of CA practices to be evaluated, few studies combined simultaneously the three principles of CA. A very large number of studies have evaluated the effects of tillage reduction, often in combination with increased organic soil cover, while very few studies have tested
crop sequences with at least three crops. In terms of performance, we found a broad range of indicators. However, most studies focused on crop productivity and/or soil physical performance. Yet, few studies used an integrated assessment of the farming systems including social and economic attributes such as income, work time, or farmer satisfaction.

Thanks to this synthesis of methods, contexts, and indicators used to assess CA performance in the face of climate change, we were able to identify advances and gaps, as well as new priorities for CA research. The SLR revealed a need for both (i) a system approach to better understand the combined effects of the three different CA practices and their dynamics over time, and (ii) an integrated assessment of CA multi-performance. An interdisciplinary approach could help to address these two points, and would provide more comprehensive information for agricultural advising and public policies.
Creating field management maps for precision agriculture using remote sensing data

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Precision agriculture, a practice based on site-specific crop management within fields, requires a clear delineation of zones to be treated differently, avoiding excessive or insufficient supply of inputs.

Traditionally, zone delineation has been based on farmer’s experience or on sampling on the ground. With the availability of remote sensing data, an integrated approach frequently employed is the use of satellite images to delineate zones that are subsequently characterized by soil sampling.

As remote sensing data become more frequent and precise, a method based solely on remote sensing would eliminate the need for ground sampling, thus saving costs, time and effort. Recent studies focusing on delineating site-specific management zones with remote sensing are based on the development of models (e.g., vegetation indices) to estimate field productivity before the delineation of management zones and/or require image pre-processing to select the timing at which the delineation is performed. In this study, a simplified approach is proposed, in which field heterogeneity areas are mapped with minimal image pre-processing and no basic assumption of timing or relationships between reflectance and crop attributes.

A set of several PlanetScope images (3-m spatial resolution) over three fields, two in Brandenburg, Germany, and one outside Lisbon, Portugal, were selected to visually represent different growth stages and bare soil over three to four years. Images with clouds, hazy or evidencing quality problems were rejected. The selection was done visually to avoid image selection and pre-processing after downloading.

Images from each site were clipped to an area large enough to cover the entire field and stacked into a single database, resulting in a multilayer raster with a number of layers equal to the number of images time’s four bands. Unsupervised cluster analyses were applied on the image stacks to find areas with similar properties and behavior during the time under study. Approaches tested included K-means, Agglomerative Clustering, Affinity Propagation and DBScan.

All methods were tested with different settings. Some of the methods, such as K-means, require an a priori choice of the number of clusters, a subjective decision with a strong impact on the final result. An objective way of determining an appropriate number of clusters needs to be found or developed. In the meantime, it was preferred to start with a large number of clusters to operate at higher resolutions.
The appropriateness of the management maps resulting from the cluster analyses was assessed by considering yield as the main reference variable, since the aim of delineating management zones is to optimize productivity.

The clustering efficiency index (CEI) depends on the within-cluster (or management zone) yield variability respect to the total field variability.

\[
\text{CEI} = 1 - \frac{\text{WCV}}{\text{FV}}
\]

Where:

\[
\text{WCV}, \text{ within-cluster variance, is calculated as:}
\]
\[
\text{WCV} = \frac{\sum (y_{i1} - \text{avy}_1)^2 + \cdots + \sum (y_{ig} - \text{avy}_g)^2}{2n-k}
\]

Where \( y_i \) is the individual yield value, \( \text{avy} \) is the average yield of the cluster, \( 1 \) is cluster 1, and \( g \) is any other cluster, \( n \) is the number of samples and \( k \) the number of clusters.

And where \( \text{FV}, \text{ field variance, is the yield variance of the entire field.} \)

A good clustering approach would tend to minimize \( \text{WCV} \) respect to \( \text{FV} \) and increase CEI.

Preliminary results show that CEI decreases as the number of clusters increases until reaching an optimum number of clusters beyond which CEI stabilizes.

At some sites, the shape and distribution of clusters or management zones tends to be very stable over time, indicating that the productivity pattern observed on the field depends on constant factors such as soil physics. In contrast, some areas have clusters patterns that vary from year to year, suggesting that the productivity spatial distribution is being affected by farming practices or yearly variations.
Cross-scale agricultural landscapes diversification enhances resilience and sustainability: A data science approach

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Keywords: Resilience, landscape, agricultural diversification, GIS

Agricultural landscape diversification is recently gaining strong attention to restore or even enhance the land use complexity. Agricultural landscape diversification can be promoted with digital technologies, including the Internet of Things and remote and proximal sensing. However, agricultural landscape diversification is often considered at a single scale (field, farming system, or landscape). We hypothesize that multiple agricultural diversification strategies can be implemented across scales, that they can enhance resilience and sustainability, and that digitalization can facilitate them to develop. We introduce an overview of the research project that investigates how digitalization can promote diversification of the agricultural system with enhanced resilience and sustainability, especially by taking multiple scales (field, farm, and landscape) into account explicitly. To our best knowledge, this is the first study that evaluates multiple types of agricultural diversification across multiple scales and argues how the multiple scales should be jointly considered to holistically target agricultural diversification at the landscape scale. Cross-scale consideration is necessary but overlooked to account for opinions from various stakeholders who operate at different scales.

We aim (1) to understand the socio-ecological value of agricultural landscape diversification by combining multiple theories, (2) to develop data analytic methods for exploring major types of diversification patterns, and (3) to create a spatial map of Brandenburg that shows which diversification actions can be reasonably implemented in which places in the future. As the first step, we aim to develop a theory about how diversification strategies across field, farming system, and landscape levels can enhance the resilience and sustainability of the agricultural landscape. Our questions are what cross-scale landscape diversification is, and how it can enhance resilience and sustainability at the landscape scale. We have collected more than 70 keywords representing agricultural diversification strategies regarding agricultural practices, such as increasing land complexity or income diversification, and identified a handful number of major strategies. As the second step, we aim to develop statistical and AI methods useful for identifying major types of landscape diversification and for finding synergies and trade-offs in the data of participatory analysis. For this we will conduct a GIS-based landscape clustering over the entire Brandenburg region, Germany. We will jointly consider several aspects which can quantify diversity, e.g., biological diversity, agricultural crop diversity, land use diversity. Therefore, this approach uniquely classifies landscape types based on the multidimensional aspects of ‘diversities’ but not the elements per se.
So far, we have compared the spatial heterogeneity of multiple soil attributes using Rao’s Q index, identifying local “diversity hotspots” of soil conditions. Finally, this project will produce a regional map of Brandenburg that shows the potential of agricultural landscape diversification spatially explicitly: which diversification strategies can reasonably be implemented at which places.

This study contributes to acquire a realistic viewpoint about what kind of diversification strategies exist, how they can enhance resilience and sustainability, and how digitalization plays a facilitative role under some framework conditions. We anticipate that joint actions across multiple scales may bring a synergistic positive impact of agricultural landscape diversification better than actions at a single scale. Meanwhile, it is possible that a collection of locally ideal strategies may not be the best strategies at the larger scales as an emergent cross-scale property. We consider identifying key synergies and trade-offs in diversification-relevant actions and governance options across scales as a major step for advancing the idea of agricultural landscape diversification. This project is a subset of the larger project at ZALF (2022-2025): “Co-designing smart, resilient, sustainable agricultural landscapes with cross-scale diversification (Cross-Div)” that also considers socio-economic and governance aspects of landscape diversification in the end.
Site-specific nutrient management in the era of agriculture 4.0: Why do digital decision-support tools struggle to reach scale in smallholder systems?

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Key words: precision agriculture, digital agriculture, fertilizer recommendations, agronomy at scale, scalability

While many have extolled the potential impacts of digital advisory services for smallholder agriculture, the evidence for sustained uptake of such tools remains limited. In this paper, we combine a survey-metanalysis hybrid method and systematically appraised the extent of and challenges to scaling decision support tools used for site-specific soil nutrient management (SSNM-DST) in smallholder farming systems. Our evaluation drew on relevant literature, apps available in different repositories, and expert opinion. We find that SSNM-DST have struggled to reach scale over the last few decades, regardless of their acclaimed yield benefits, with strong heterogeneity in adoption among intended stakeholders and tools. For example, the log odds of a SSNM-DST reaching 5–10% of the target farmers compared with reaching none, decreases by about two-folds when a technical problem is stated as a reason for the tools’ failure to be used at scale. We find similar decrease in odds ratios when technical, socioeconomic, policy and R&D constraints were mentioned to constrain uptake of SSNM-DST by the national extension system and private business system. Using a Meta regression, we show that the response ratio of using SSNM-DST over Farmer Fertilizer Practice (FFP) varies by non-tool related covariates, such as crop yield under FFP, current and past crop types, acidity class of the soil, temperature and rainfall regimes, and the amount of input under FFP. In general, the SSNM-DST have moved one step ahead compared with the traditional ‘blanket’ fertilizer recommendation by attuning to in-field heterogeneities in soil and crop characteristics, while remaining ‘blanket’ in terms of addressing demographic and socioeconomic heterogeneities among users, which potentially thwart adoption of the tools at scale. While the SSDST possess reasonable applicability and can be labeled ‘ready’ from purely scientific viewpoints, its readiness for system level uptake at scale remains short of accomplished, especially where numerous socio-technical and institutional constraints seem to seem to play great roles.
Implications of intra-plot heterogeneity for yield estimation accuracy: evidence from smallholder maize systems from sub-Saharan Africa

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CIMMYT

Intra-plot heterogeneity in yield is often observed in smallholder farming systems, although its implications for yield measurement remain under-investigated. Using a unique dataset on smallholder maize production in Ethiopia, we quantify the magnitude of inter- and intra-plot heterogeneity, describe the relationship between intra-plot heterogeneity and maize productivity, and document the implications of intra-field heterogeneity on the accuracy of alternative yield estimation protocols. Our data include five common yield estimation protocols, as well as full plot harvests of 230 smallholder maize fields. We surveyed agronomic decisions, biophysical variables, and accessibility characteristics of the surveyed fields. We quantify intra-plot heterogeneity using the coefficient of variation (CV) of stand density, cob weight, and maize grain yield. A generalized linear mixed model is used to explore the relationship between these variables and the method- and heterogeneity-dependence of yield estimation accuracy. We find inter-plot CV values ranging from 32 to 56%, 22 to 73% and 39 to 49% in population density, cob weight and grain yield, respectively. Intra-plot heterogeneity constituted most of this variation, with across-method mean CV values of 41%, 82% and 63%, respectively, of the total variability in population density, cob weight and grain yield. A rise in intra-plot heterogeneity of 0.5% to 0.8% is associated with a significant increase in yield estimation error under alternative yield estimation protocols. Regression analysis shows that interactions in agronomic decisions, input intensity and plot accessibility factors dictate intra-plot heterogeneity and method accuracy in smallholder systems. Intra-plot heterogeneity is larger than inter-plot heterogeneity in the current study area. Our analysis shows that the effect of intra-plot heterogeneity on yield estimation accuracies is method-dependent and yield estimation methods that fail to capture true intra-plot heterogeneity are more error-prone. Results of such estimations should be considered with caution when used as the basis of decision-making.
Deep learning with drone predicting and explaining intra-field crop yield variability among various crop types and management practices in small scale farming

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Keywords: Convolutional neural network, Explainable Artificial Intelligence, Crop YieldPrediction, Transfer Learning

Deep learning image analysis is a powerful predictive tool in agricultural science. While previous studies suggest the promising potential for within-field crop yield prediction using remote sensing, most of them focus only on one crop type at a field scale. Moreover, the current deep learning applications are limited to just prediction, although there is a need to explain why and how the model predicted so. In this presentation, we show a study framework to overcome these issues. We demonstrate our framework on a subset of the agricultural experiment PatchCROP conducted in 2020. The data set comprises 30 field arrangements at subfield scale (called patches) that are unique in terms of crop rotations, soil properties and management practices. Particularly, we test predicting performance of these 30 conditions, i.e. on crop type’s lupine, soybean, summer oats, sunflower, phacelia and maize under conventional, reduced pesticide and reduced pesticide plus flower strip practices. Initial results indicate satisfactory performance of R2 of 0.73 for the crop type summer oats.

Of these field arrangements UAV remote sensing observations had been taken using RGB and multi-spectral cameras. We combine these high resolution RGB and lower resolution multi-spectral UAV remote sensing images to train the well-established pre-trained convolutional neural network for crop yield prediction, and then apply explainable artificial intelligence methods to reveal if the rationales for making the predictions are agronomically plausible. We assume that higher resolution of RGB images allow for individual plant part identification and thus crop type determination, whereas the reflection values of multi-spectral bands have been shown to be important features for crop yield prediction. A model that exploits both shape and reflectance at small scale is a decisive next step towards developing a general crop yield prediction model. Whereas convolutional neural networks inherently employ the ability to exploit both shape and reflectance, the complexity of such characteristics is directly linked to a model’s architecture. Thus, we compare different architecture types and test generalization of our approach at three levels; for individual crop type and management practice; for individual crop type but different field management practices; and at field scale to test for generalization across crop types as well as management practices. Moreover, we discuss strategies to bridge the gap between the high data demand of deep learning and data availability in agricultural or environmental data sets. For instance, we employ a sliding window strategy to artificially increase data availability, but also we utilize transfer learning, a technique that transfers model training to a more readily available data set. Having that, to
improve trust in intrinsic black box deep learning models we propose to study the prediction’s underlying spatial configuration using explainable artificial intelligence techniques. We either offer explanations for the model’s decisions using model agnostic approaches like LIME or interpretations using techniques like gradient propagation and saliency maps to illuminate the models internal feature maps and thus show the reasoning behind the model. We anticipate that predicting yield for multiple crop types at small scales using remote sensing can be a valuable source for decision making for future precision agriculture.
Compost Fertilization in Organic Agriculture – A Comparison of the Impact on Corn Plants by Using Field Spectroscopy

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Keywords:
Organic agriculture, compost fertilization, reflection measurements

With regard on climate change and due to the availability of nutrients such as nitrogen and phosphorus, a recycling of nutrients is becoming more and more important. This applies not only to conventional cultivation systems, but also in particular to organic farming. One way to recycle nutrients is the use of compost. Unlike mineral fertilization, the release of nutrients from organic fertilization is slower. It is therefore much more difficult for the farmer to determine the effect of organic fertilizers on the crop and on the soil. In this situation, plant sensors can help farmers identify these possible effects more quickly. In conventional farming systems, crop sensors have already proofed their ability to guide efficient fertilizing. Since they enable to record the growth of the biomass, they also offer the possibility to detect the influence of various organic fertilizers on the growth of plants.

To analyze the effects of compost fertilization in organic agriculture, in 2018 a field trial was established at the organic research station of the Technical University of Munich. In 2018 and in 2021 eight different organic fertilizers (biogas digestate, mature stable manure, fresh and mature organic waste compost, fresh and mature green compost as well as microbial carbonized compost) with two different amounts (180 and 360 kg N/ha) were applied for three years, along with an unfertilized control variant. The fertilization was carried out in accordance with German fertilizer regulation. In 2020 and in 2021 to detect the influence of fertilization on corn plants (zea mays), at six different stages of plant development reflection measurements were taken. The reflection measurements were conducted with a handheld field spectrometer in a range of 400 up to 800 nm and a resolution of 3 nm.

Detecting the development of small corn plants is not very accurate, because of a strong influence of the visible soil. However, even at very early stages of the plant development (V4, BBCH 14) the vegetation indices NDVI, REIP and SR (780/740) show the differences between the different composts with relatively low values that indicates lower biomass production. During the further growing season, conversion processes within the soil became also visible. Depending on water content and the increasing temperatures of the soil, more nitrogen became available to the plants. Therefore, the differences in the biomass production of the plants and an effect of the full application rate of organic waste as well as of green compost became visible especially at higher growth stages (V18, BBCH 32) of the plants. The plant height and the corresponding calculated vegetation indices of the reflection measurements confirmed this increase in biomass production also in increasing correlation coefficients from $R^2=0.3$ in V4 (BBCH 14) to $R^2=0.7$ at V18 (BBCH 32).
The results presented in this study show that sensor measurements react sensitively to organic fertilizers and thereby show the effects of a compost fertilization on plants and soil, especially during the vegetation period. This offers the farmer a fast and non-destructive decision support about what kind of compost and how much is necessary on the specific field to suit the needs of the plants in his crop rotation.
Validation of high-resolution soil moisture data in north-eastern Austria

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Soil water is one of the most important resources for crop production and is influenced by climate, soil and hydrological conditions as well as vegetation. Precipitation, irrigation and the capillary rise of groundwater to the root zone increase the effective field capacity, while soil evaporation, plant transpiration, runoff and infiltration losses reduce the available water capacity. In many Central European regions, drought prone conditions can be encountered during the growing season, leading in insufficient soil water availability and thus being one of the main reasons of yield reduction or even crop failure. With a changing climate, it is assumed that drought periods during the growing season will become more frequent and severe in these regions over the next decades.

Remote sensing-based soil moisture products are successfully used at large spatial scales, but not easily available for very high spatial resolution, yet they would offer an increasing application potential in agriculture. For example, the processing for practical usages is very time consuming and therefore expensive through personnel costs.

Modern soil moisture estimations at crop field level are currently carried out using three different approaches: in-situ measurements such as TDR or FDR, remote sensing techniques using thermal infrared (TIR) or microwaves, and soil-crop water balance modelling approaches. In our study we compared these three approaches at various spatial scales. On a 17 ha experimental field in Rutzendorf (48° 12′ N, 16° 33′ E) in the northeast of Austria in the Marchfeld region, high-resolution in-situ soil moisture measurements were carried out in 2019. Winter wheat was grown in the field, where the soil can be characterized as Chernozem with significant local variations in available field capacity. To obtain information on the spatial distribution of soil moisture in the top soil layer (0-10 cm), a 50 m grid with 65 grid points, each with 2 soil moisture sensors (capacitance probes), was set up for permanent in-situ soil moisture measurements during the main growth period of the wheat growing season. In addition, a handheld TDR sensor system was used to collect grid data as reference samples two times. A meteorological station was located as well within the experimental field, which conducted additional FDR-SM measurements at depths of 10, 20, 30 and 40 cm. The ASCAT and Sentinel-1 satellite data used for comparison to the in-situ measurements currently provide 100 m spatial grid size soil moisture. Additionally, simulated soil water contents from two dynamic crop growth models, DSSAT and AquaCrop, as well as a simplified soil-crop water balance model (ARIS) were included in the comparison.

In a further step, the three different approaches were evaluated. It could be observed that the spatial variability in the field, represented by the in-situ measurements, cannot be
captured with the same spatial variation accuracy using the satellite sensor products studied as well as the crop water balance simulation methods, due to different reasons. Nevertheless, the analysis presented a good temporal correlation at the 17 ha field-level mean soil moisture estimation between the three different approaches. Thus, it could be demonstrated that complementary methods can estimate field-level soil moisture temporal variation quite well, which is an important tool for determining soil moisture stress thresholds for crop production and therefore an essential issue for increasing the resilience and resource efficiency of agricultural systems through adaptation measures.
Comparing the performance parameters of an agricultural robot with conventional agricultural machineries. Case seeding operation

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Keywords: agricultural robot, fuel consumption, simulation, route, planning

In this paper, the performance of an agricultural robot in seeding operation was compared with the conventional agricultural machinery one. The robot can perform precisely the site-specific agricultural operations including seedbed preparation, seeding, hoeing, weeding, harrowing, soil sampling, spraying and mowing. The used robot (version 150D) is designed for harder field work, where PTO and external hydraulics are required for example in seeding and harrowing operations. This version of robot is equipped with two 75hp Kubota diesel engines; one engine is dedicated to propulsion while the other runs the PTO and external hydraulic system. The approximate weight of the robot is 3100 kg. Its forward speed in autonomous mode is up to 8 km/h and the high speed in manual mode is up to 10 km/h. The robot has 2-wheel steering (able to do zero turn). Different operational factors such as total productive time/distance, total unproductive time/distance, field efficiency, field capacity and fuel consumption were considered in the comparison. The driven plan with the robot was analyzed and the mentioned operational parameters were calculated and compared with the results of the simulation model for the conventional machineries. Three different field tests, with sizes equal to 7.5, 4.16 and 0.56 hectares, located in Denmark were considered in this study. Two different scenarios were defined for the comparison of robotic system and conventional method, first considering the same working width, and second choosing a bigger working width for the tractor. The analysis of the collected data from field tests show that the tractor has in both scenarios 4-30 % better field efficiency than the robot, due to the bigger working width and working speed of the tractor. Moreover, the tractor has a bigger field capacity in comparison with the robot. The theoretical field capacity of this robot is equal to 2.4 ha/hr when it operates with the maximum speed equal to 8 km/hr. The comparison of the fuel consumption shows that the robot has up to 39.8 % less consumption for the first scenario between all the fields and up to 22.4 % saving for the second scenario. Based on the results, it can be concluded that the shape of a field is an important factor that can affect the field efficiency and field capacity of the robot.

Reference:


It takes a village to raise a digital twin

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In precision agriculture, farmers need precise, real-time information about the status of crops, soils and livestock, as well as information about the likely outcome of management decisions. Several decades ago, the use of crop growth models for this purpose has been proposed but it has proven difficult to obtain the input data required to run crop growth models for commercial farms in a timely manner, if at all. In this paper we document how in the case of Farmmaps input data is obtained, and how simulation results are presented to farmers. We consider that the crop growth models used have been extensively validated during the past decades; hence this paper focuses on the application of these models in commercial farming. Farmmaps is a web-based platform developed by Wageningen University & Research, in collaboration with farmers and a software development company; it is owned by a not-for-profit foundation. Farmmaps offers various precision agriculture applications, some of which are offered for a fee. The revenue thus obtained allows purchasing the world-wide weather and satellite data needed to offer the services. Farmmaps links to other data sources, such as the national soils database, soil analysis labs, and commercially available Farm Management Information Systems (FMIS) that are used by farmers in The Netherlands. The precision agriculture applications available on Farmmaps have been developed in close collaboration with farmers, which ensures that they meet a real, practical need and that farmers have a keen appreciation of what the applications can do. One of the applications available on Farmmaps is a digital twin for arable crops called the Digital Future Farm (DFF). The DFF consists of dynamic models of arable crops and grass, as well as a method to use real-time data from sensors to keep the models synchronized. The DFF provides a comprehensive overview of the current state of crops and soil. The DFF can also be used to predict the future state (by using forecast and/or stochastic weather). Finally, the DFF can be used to investigate the expected outcome of alternative management scenarios, especially with respect to fertilization and irrigation. Simulation output of the DFF is presented in tables and graphs that have been designed together with the farmers that use them. The title of this paper is an attempt to express the salient fact that it took a community of farmers, scientists, software companies, data providers, sensor providers, and others (“the village”) to bring the digital twin (“a child”) to maturity.