LANDSCAPE 2018

Landscape 2018

Frontiers of agricultural landscape research

Book of Abstracts

Leibniz Centre for Agricultural Landscape Research (ZALF)

Leibniz Association

Landscape 2018

Frontiers of agricultural landscape research

12–16 March 2018

Berlin, Germany, Adlershof con.vent

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Imprint

Book of Abstracts: Landscape 2018
12–16 March 2018, Berlin, Germany, Adlershof con.vent

Publisher

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

Photo credits:
Front page: fotoVoyager (iStock), Page 2: Petair (Fotolia)

These Book of Abstracts are available in PDF format and can be ordered at landscape2018@zalf.de.

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Sponsoring

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Welcome

Agricultural landscapes are a construct at the interface between natural processes and human activities. Land management introduces changes to natural processes on the one side and evokes feedbacks on human activities on the other side. This leads to societal challenges and trade-offs regarding societal demands, such as expressed in the Sustainable Development Goals of the UN Agenda 2030. Relevant examples of such challenges include the sustainable intensification of agricultural production, food security, adaptation and mitigation of climate change, opportunities and risks related to emerging technologies in agricultural production, supply-demand interactions of ecosystem services in the rural-urban continuum. Knowledge about the underlying processes of landscape dynamics at all relevant spatial and temporal scales is the prerequisite for sustainable landscape management and respective governance instruments.

The aim of the conference is to present recent advances in agricultural landscape research to enhance the development of sustainable agricultural land use and landscape strategies. The particular objective is to present and discuss key findings from relevant disciplinary and interdisciplinary approaches as well as from basic and application-oriented research.

Thematic areas:

- The functioning of landscapes, with a focus on element cycles and microbiomes including approaches to scale up from individual processes to the landscape scale.
- Sustainable land use practices and appropriate governance systems, which secure the provision of food and fibre as well as other ecosystem services and biodiversity.
- Advances in science toward the development of an integrated landscape theory.

The topic of the conference, *Frontiers of Agricultural Landscape Research*, fills a thematic niche that is cross-cutting to numerous international scientific organizations but is not represented as a core topic in any of these. The conference brings together researchers from all over the world working in the field of agricultural landscape research. It illustrates the state of research in this field, its relation to other research fields and the challenges associated to scientific questions as well as to providing the evidence base for decisions on sustainable landscape management in policy, administration and practice.

We intend to jointly use the momentum generated by the conference as a seed for follow up activities and to establish an international network of agricultural landscape research.

We are looking forward to your scientific insights, ideas, critical thoughts and to lively discussions about the scientific contribution to sustainable landscape management.

Frank Ewert
Conference Chair
ZALF Müncheberg

Mark Rounsevell
Conference Chair
KIT Garmisch

Katharina helming
Conference Host
ZALF Müncheberg

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Idea- vs Data-Driven Microbial Modeling for Soil Carbon Dynamics

Yiqi Luo

Center for Ecosystem Science and Society, Department of Biological Science, Northern Arizona University, Flagstaff, AZ 86011, USA

Department of Earth System Science, Tsinghua University, Beijing, China

Abstract

Microorganisms have long been known to catalyze almost all the soil organic carbon (SOC) transformation processes, such as decomposition, stabilization, and mineralization. Representing microbial processes in Earth system models (ESMs) has the potential to improve projections of SOC dynamics. Many ideas have recently been proposed to represent microbial processes in soil carbon dynamic models. In this talk, I will critically evaluate those ideas with observation. Based on the evaluation, I will suggest the research community to examine empirical evidence from experiments and observation on (1) relationships of microbial functions with environmental factors (2) microbial effects on decomposition, stabilization, and other key soil processes related to SOC dynamics.

Short Biography

Yiqi Luo is Professor of Ecology at Northern Arizona University. His major research issues include (1) how global change alters the structure and function of terrestrial ecosystems, and (2) how terrestrial ecosystems regulate climate change. To address these issues, Dr. Luo's laboratory has conducted global change experiments, data synthesis, data-model integration, model development, and theoretical analysis. Recently, he has developed a general theory of land carbon storage dynamics, which has the potential to fundamentally transform land carbon cycle research. He has published two books and more than 350 papers in peer-reviewed journals, such as *Science, Nature,* and *PNAS*. His Google Scholar citation is nearly 25,000 with *h*-index of 81. He was elected fellow of American Association for the Advancement of Science (AAAS) in 2013, American Geophysical Union (AGU) in 2016, and Ecological Society of America in 2018. More information can be found at http://www2.nau.edu/luo-lab/?home.

Landscape, biodiversity and agroecological services

Sandrine Petit

INRA, UMR Agroécologie – AgroSup Dijon, INRA, Univ. Bourgogne Franche-Comté, F-21000 Dijon, France

Abstract

Agriculture is facing the challenge to ensure global food security with minimal impacts on the environment. Over the last decade, agroecological options have been investigated that could represent alternative approaches for mainstream agriculture to meet this challenge. These options aim at integrating services delivered by biodiversity and by all its associated biotic interactions. Such services can be promoted through land management strategies ranging from in-field single agricultural practices to their deployment at larger spatial scales. In this talk, we focus on the impact of land management strategies at different spatial scales on the delivery of a specific agroecological service, crop pest biological control. We describe the multiple and interactive effects of in-field and landscape scale management on the control of arable weeds and insect pests and make an attempt to integrate these findings in the development of landscape research strategies aiming at promoting the delivery of agroecological services.

Short Biography

Sandrine Petit is Research Director at the French National Research Institute of Agriculture (INRA); she currently leads a research group on sustainable weed management and is deputy director of a large Agroecology Research Unit in Dijon. She is a landscape ecologist interested in the dynamics of biodiversity in dynamic and heterogeneous agricultural mosaics at different scales. Before joining INRA in 2007, she developed research for 9 years within Land Use Research Group at the Centre for Ecology and Hydrology (CEH Lancaster, UK) on the dynamics of agricultural landscapes, its impact on biodiversity and on the assessment of landscape multifunctionality. Since joining INRA, she focuses on disentangling the relative contribution of local and landscape scale management on communities of cultivated fields, with a focus on weed communities and weed biological control agents such as weed seed-eating carabid beetles, as well as on the intensity and stability of trophic interactions within these systems.

Landscape science: the role of models, data and theory

Marcel van Oijen

Centre for Ecology and Hydrology (CEH-Edinburgh), United Kingdom

Abstract

The scientific study of agricultural landscapes is still in its infancy. There are models for landscape components such as fields and farms, and for transport processes such as the spread of pollutants and organisms via air, land and water. There even exist some preliminary models at the landscape level. But the representation of landscapes in models remains incomplete, and data for model parameterisation and testing are still limited. Progress is hampered by the absence of rigorous landscape theory to base these models on. But what could such a theory look like? Which of the many services that landscapes provide can be covered by theory? Can any general theory help us understand, predict or manage the dynamics of any single landscape? The role of future landscape theory may have to be modest: providing initial estimates for parameters and processes, with continued requirement for new measurements to refine those estimates. We discuss the possible role of Bayesian probability theory in this, using examples from work on a coffee-growing area in Central America and a reconstruction of land-use change history in the UK.

Short Biography

Marcel van Oijen is an environmental scientist. In 1985, he moved to Wageningen (Netherlands), where he studied the ecophysiology of potato and wheat, using both experimentation and modelling. He developed models for the impacts on these crops of climate change, air pollution, soil compaction, pests and diseases. In 1999 he moved to his current position at the Centre for Ecology and Hydrology in Edinburgh (Scotland) to work on forests, grasslands, agroforestry systems, and land-use change. This implied a shift from ecophysiology to biogeochemistry, and from crop productivity to multiple ecosystem services. He develops and applies Bayesian methods for parameter estimation and model selection. These were used in various UK- and EU-funded projects, where van Oijen was leading work packages on model comparison and uncertainty quantification. In recent years, he started developing methods for spatial scaling, adaptive sampling and risk analysis.

I. Landscape Functioning
Element Cycles and Microbiomes

Scientific Committee

Joergen Olesen (Aarhus University, Denmark)

Andreas Richter (University of Vienna, Austria)

Pete Smith (Sciences University of Aberdeen, Scotland, United Kingdom)

Harry Vereecken (FZ Juelich, University Bonn, Germany)

Climate and land use change as well as management practices determine carbon and nitrogen dynamics in agricultural landscapes, which affect greenhouse gas (GHG) emissions and C and N sequestration. The relevance of soil microbiome properties as relevant regulative forces at the landscape scale is largely unresolved. Modelling approaches at regional to global scales will also greatly benefit from better knowledge about soil microbiology.

The session's focus is on element cycles and microbiomes in agricultural systems from a landscape perspective. The session aims to present state-of-the-art knowledge of the link between C and N dynamics and microbiomes of agricultural landscapes (including land-atmosphere interactions) and identifies research needs in the fields of soil microbiology, soil science, and related disciplines to improve our understanding and modelling of the role of the microbiome on landscape processes.

Session Keynotes

Andreas Richter (University of Vienna, Austria)

Jorgen Olesen (Aarhus University, Denmark)

Session Chairs

Laurent Philippot (INRA, France)

Steffen Kolb (ZALF, Germany)

Oral Presentations

Keynote: Sustainable management of carbon, nitrogen and phosphorus cycles at landscape scales

Jørgen Olesen

University of Aarhus, Denmark, Dept. of Agroecology Aarhus University Blichers Allé 20, Postboks 50, 8830 Tjele, Denmark, e-mail: jeo@agro.au.dk

Jørgen E. Olesen is professor in agriculture and climate change at Aarhus University, Department of Agroecology, where he leads the section on Climate and Water. He has very broad experience of the interaction between agricultural (and agroecosystem) activities and the environment. This involves both the effect of agriculture on environment and the effect of environmental change on agroecosystems in Europe and globally. He has participated in expert panels of the EU, The World Bank and FAO. He has also contributed as an author to IPCC assessment reports. He was a member of the Commission on Climate Change Policy, and a member of the Commission on Nature and Climate, both under the Danish government, and a member of the Danish Ethical Council. He chairs the food and bioenergy group of the CONCITO think tank in Denmark. He is currently a member of the FACCE Scientific Advisory Board.

Terrestrial carbon dioxide removal potential of pyrolytic treated biomass produced by sustainable carbon farming

Hans-Peter Schmidt[1] – Constanze Werner[2] – Dieter Gerten[2] – Wolfgang Lucht[2] – Claudia Kammann[3]

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Introduction

Conventional models for the assessment of terrestrial carbon dioxide removal (tCDR), i.e. the calculation of the negative emission potential, are mainly based on biomass-producing plantations (BPs) and subsequent bioenergy production with carbon capture and storage (BE-CCS) (Rogelj *et al.*, 2015). The assessment of the global BPs potential of these models is based on a limited (exemplified-type) number of tree and grass species cultivated in intensive monoculture systems with high inputs of irrigation water, chemical fertilization and pesticides (Boysen *et al.*, 2016). Boysen *et al.,* (2017) showed that the large-scale extension of such BPs would put global ecosystems under major pressure. These forms of BE-CCS cannot be regarded as a sustainable form of land management and are thus not suited to counterbalance delayed decarbonization actions. The supposed massive switch from fossil fuel energy production to bioenergy production (170 EJ y-1, (Smith *et al.*, 2015)) is furthermore economically extremely unlikely, considering that solar and wind energy production costs are expected to decrease below 0.03 USD per kWh, while prices for bioenergy production without CCS range already from 0.06 to 0.30 USD. Hence, real-world tCDR approaches have to be set up in such a way that (1) global ecosystems and renewable natural resources are protected, i.e. that planetary boundaries are not transgressed any further, (2) that food security is guaranteed, and (3) that the long-term economic viability of the tCDR systems can be assured.

Our study investigates new tCDR approaches combining biomass pyrolysis carbon capture and storage (BPy-CCS) with sustainable, resource-efficient carbon farming systems (CFS) such as agroforestry, silvopasture, and perennial cropping. CFS allow for higher C-throughput, lower fertilization needs, improved climate resilience, combined food-feed-biomass production, biodiversity enhancement, lower irrigation needs, and no to low pesticide treatments (Toensmeier, 2016). To sequester the carbon accumulated annually in the biomass of CFS, the mixed woody and leafy biomass has to be shred and then pyrolysed resulting in the transformation of the biomass into a solid (biochar), a liquid (bio-oil) and syngas. Biochar is then used as an organic nutrient carrier and applied back to the soil of the CFS to restitute extracted macro- and micronutrients, enhance plant growth with reduced inputs of chemical fertilizers and improve soil physical properties (Lehmann and Joseph, 2015). The generated bio-oil can be safely sequestered in subsoil storages with MRT > 1000 years or alternatively be used as raw material for the chemical industry or other carbon storing materials. The aim of this study is to assess the carbon sequestration potential and costs of various CFS cultivated landscapes combined with BPy-CCS to contribute to tCDR without increasing the pressure on native, biodiverse ecosystems.

Materials and Methods

Our approach uses six general CFS scenarios (forest gardens, perennial cropping, agroforestry, silvopasture, marine and mixed cropping) and calculates the respective carbon potential on a per hectare basis in different climates. The respective C-outputs feed the BPy-CCS scenarios (from torrefaction to high-temperature pyrolysis with solid and liquid sequestration, soil application, fossil fuel compensation, and mixed material uses).

The calculations are delivered in an open-access database designed to be extendable to include further scenarios and details to estimate and optimize the BPy-CCS potential of advanced agro-biomass land management systems.

Results and Discussion

The investigated systems delivered annual carbon sequestration potentials between 1.8 t ha^{-1} (sylvo-pastoral in dry Mediterranean climate) and 13.8 t ha^{-1} (silvo-arable in humid subtropics). Costs are currently estimated at 60 to 120 USD per tCO_2 without including the benefits of enhanced land productivity, improved ecosystem services, and the use as advanced carbon-based material.

Conclusions

Carbon farming systems combined with BPy-CCS were compared to conventional monoculture BE-CCS. BPy-CCS carbon farming systems show higher global C-efficiency at lower economic costs with a positive rather than negative effect with regard to planetary boundaries such as biosphere integrity, freshwater use, biochemical flows and land-system change (Rockström *et al*., 2009). They are hence ecologically and economically viable strategies to accompany (but not substitute) industrial decarbonization and serve as supporting action for strong climate change mitigation.

Acknowledgements

The authors gratefully acknowledge funding by the BMBF (Grant 01LS1620A and Grant 01LS1620B)

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Considering management-induced temporal changes of soil hydraulic properties in hydrological systems

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Introduction

Human activities such as agricultural management practices (AMP) and land-use change as well as changes in atmospheric boundary conditions alter soil pore space and structure. Such practices for e.g. AMP such as conservation agriculture, crop-rotation and intercropping, are often undertaken with a view to improve soil structure and mitigate the detrimental effects of soil erosion and land-degradation. They are relevant to meet the growing demand for agricultural products amidst occurrence of extreme weather conditions as well as to sustainably manage our soil and water resources. Planning such adaptation measures are often based on the application of numerical models to predict the impact of hypothetical changes in land-use and changing climatic conditions on plant growth and water balance components. In these models, soil hydraulic properties (SHP) are usually considered to be temporally constant. However, previous studies have shown that SHP and carbon are temporally dynamic due to changes in management practices and land-use. If the dynamics in soil structure is neglected, the uncertainty of the model increases which leads to incorrect planning and a more resource-consuming land-use. This talk aims to present state-of-the-art knowledge on impacts of AMP on SHP and addresses the question: Why should we consider management-induced temporal dynamics of SHP in hydrological systems?

Materials and Methods

The temporal variations in SHP due to AMP and the effect of inclusion of time-variant SHP in hydrological models are reviewed using contemporary peer-reviewed literature. To facilitate predictive-modelling of management-induced changes in SHP, combined field and lab methods are done to characterize SHP from saturated to dry conditions. The dynamics of soil pore space geometry as a function of time and pore radius will be captured using the stochastic modeling approach by Or *et al.,* (2000) and Leij *et al.,* (2002a,b). The pore size distribution is assumed to follow a lognormal distriibution as discussed in Kosugi (1996). Furthermore, the temporal changes in saturated hydraulic conductivity and consequently, the behaviour of unsaturated hydraulic conductivity and carbon dynamics will also be obtained.

Results and Discussion

From previously published studies, it is seen that though SHP are subject to spatial and temporal variations, the studies are not consistent in their findings due to different methods of characterization of SHP (field and laboratory methods), differences in experimental design and measurements during different stages of plant growth. Therefore, there is a need for harmonization of research methodologies for the generalization of the impacts of different AMP on SHP and the water & carbon cycle. Furthermore, the spatial and temporal variability of soil structure has often overshadowed any measured differences between management treatments. So, the effect of variation in soil structure to weather/climate should be studied separately from management-induced impacts. In addition, the inclusion of time-variant SHP and carbon dynamics in simulation studies tends to increase the accuracy of model results. So, the next steps are to capture the temporal evolution of soil pore space and then to predict the changes in the hydraulic conductivity function and carbon turnover. The approach by Or *et al.,* (2000) and Leij *et al.,* (2002a,b) has not yet been applied to a more complex time series of measured hydraulic parameters. The model will be combined with predicting changes in soil hydraulic conductivity function and will then be incorporated in hydrological models.

Conclusions

It is expected that the incorporation of time variant SHP in hydrological modelling studies will increase our capacity to assess the impacts of different agricultural management practices on land water balance and carbon dynamics. Furthermore, the ability to measure and predict management induced alterations in soil structure would enable better evaluation of how new management systems can ensure sustainable development. Finally, the development of tools for modelling management-induced changes in soil structure and soil properties may help to identify areas where additional research is needed

Acknowledgements

This work was supported by the German Research Foundation (DFG) under SCHW 1448/6-1 and the Austrian Science Fund (FWF) under I-2122 B16

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SCREESOM – screening methods for a cost effective detection of supply with SOM in arable and grassland soils

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Introduction

Soil organic matter (SOM) is a pivotal constituent of soils. It is influencing fundamental soil functions such as nutrient, water and contaminant retention or erosion protection due to main conservation of stable aggregates (Jandl *et al.,* 2014). In addition, soil carbon pools gain increasing importance as carbon sinks in the light of climate change (Wiesmeier *et al.,* 2012). However, knowledge on temporal and spatial variability of SOM on field scale is insufficient (Jandl *et al.,* 2014).

Against this background, an accurate estimation of SOM concentrations and stocks and changes to them is mandatory in order to understand C cycling and to build reliable climate scenarios. Further accurate estimation would enable to understand the influence of soil management on SOM and to evaluate management practices. To achieve this, it is necessary to monitor soil in long term approaches. Due to the efforts and costs for SOM analysis and soil analysis in general, it is necessary to establish fast, spatial and accurate analysis of SOM and other soil parameters with a low effort.

Spectroscopic analysis using the Vis-NIR and MIR are appropriate for soil analysis (Vohland *et al.,* 2014) but still not in use as routine method in labs or in the field "on-the-go". A reason therefore are calibration models which are excluding many factors influencing soils.

Materials and Methods

Analysis of soil samples was conducted in-situ with spectroscopic methods. Therefore, the wavelengths of VisNIR (ASD FieldSpec 4 Wide-Res) and MIR (Hand-held FTIR Spectrometer Agilent 4300) were used. Beside the spectroscopic measurement soil color (Konica Minolta chroma meter CR410) was determined in situ. Conventional soil analysis was conducted for the analysis of total C and N, pedogenic oxides, and clay content. Samples were collected as mixed topsoil and undisturbed samples. Samples were collected with a split tube sampler. Profile samples were separated in horizons. Overall about 200 samples will be collected from four different geological parent rock materials. As geological parent rock substrate Black Jurassic, Devonian, shell limestone and Rotliegend were selected. About ¾ and ¼ of the samples were taken from arable and grassland, respectively.

Results and Discussion

Soil sampling shows that common sampling and analysis is less influenced by boundary conditions such as poor weather compared to spectroscopic approaches. High soil moisture, resulting after a rainfall event, disturbs soil analysis among a spectroscopic contact probe, e.g. by water absorption. This applies especially to MIR. Difficulties are different depending to the parent material and the soil texture.

Beside the comparison of the methods we want to analyze the depth profile of SOM concentrations in arable and grassland soil from four different geological parent materials. The effect of land use is investigated by comparing neighboring arable and grassland soils. Further ongoing analyses are aimed to identify soil properties affecting the SOM estimation with spectroscopic methods so that they can be integrated into calibration models. The information from soil color determination will be related to spectroscopic properties of the soils. In addition, we compare common soil analysis and spectroscopic analysis with each other concerning accuracy, time requirement, reproducibility and costs.

Conclusions

Aim of the study is to compare the accuracy of conventional and spectroscopic approaches for soil analyses. Challenge of the study is the use of spectroscopy techniques "on-the-go" in the field. First results show that the practical applicability of Vis-NIR and especially of MIR is restricted by soil moisture conditions.

Acknowledgements

We thank the Environmental Federal Agency (EFA/UBA) for founding this project. SCREESOM is financed by UFO-Plan 2016, FKZ: 3716 73 208 0, AZ:Z 6-91 007-4/35.

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Influence of food production and consumption on river water quality in the Ishikari River watershed in Hokkaido, Japan

Ryusuke Hatano – Mako Abe – Kanta Kuramochi

Research Faculty of Agriculture, Hokkaido University, Japan

Urbanization and intensive agricultural land uses are the main causes of water pollution, and recent climate change is increasing the problems of droughts and floods in watershed. Especially N (N) cycling has increased as food production became more intensive with economic growth and increased surplus reactive N in agricultural field and watershed increased N concentration in stream water. Increase of upland proportion significantly increases stream nitrate concentration. Therefore, nutrient management in field and land use proportion are main factors to keep water quality. Eutrophication is caused by unbalance of bio elements. Silicone is important element for diatoms feeding fishes. But, when the molar ratio of silicon to total N ratio (Si/TN) of stream water is less than 2.7 and the molar ratio of silicon to total phosphorus (Si/TP) is less than 54.3, growth of the dinoflagelliform causing the problem like as it produces shellfish poison is increasing in water. As silica is released into stream water with chemical weathering of silicates, therefore silica supply is low in organic soil. In this paper, water quality in Ishikari river which is the longest river in Hokkaido was investigated. The watershed includes major cities of Sapporo and Asahikawa and major agricultural area especially for paddy rice cultivation. Therefore, the purpose of this research was to investigate the actual condition of stream water quality in the Ishikari River, to clarify the relationship between stream water quality and land use, and to consider the influence of farming activities on stream water quality.

Materials and Methods

Ishikari river watershed is second largest in Japan and largest in Hokkaido (14,330km^2 in area and 268km in length), which includes population of 3 million (54% of Hokkaido). Climate in Ishikari river watershed is semi boreal with deep snow in winter, mean annual precipitation is 1,126 mm and mean annual temperature is 8.9°C. Land use is composed of forests (63%), arable lands (31%), rivers, lakes and ponds (3%) and urban area (3%), and soil type is composed of forest soils (68%), lowland soils (23%), peat soils (5%) and others. Water sampling was carried out at 20 points from upstream to downstream of the main stream of Ishikari river at three times in 2016, on May 18 to 20 (seeding period after snow melting season), August 10 to 12 (crop growing season), and November 9 to 11 (winter season). At the time of sampling, water temperature, pH, EC and DO were measured by using multi water sensors. Water samples were put in a cooler box with ice, then brought to the laboratory and kept at 4°C in a refrigerator until water analysis. Suspended solids (SS), TN, TP, TOC, Cl^-, NO_3^-, NO_2^-, PO_4^{3-}, SO_4^{2-}, HCO_3^-, Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+, SiO_2 and chemical oxygen demand (COD) were measured in the laboratory.

Stream material loads at each sampling point was calculated by multiplying the material concentrations and the flow rate. Difference between the inflow stream load and outflow stream load in the sub watershed between two adjacent sampling points was obtained as a stream load increment. The stream load increment per unit area was obtained by dividing it by the sub-watershed area to compare with land use proportion.

Land use in the watershed was classified into paddy field, upland field, forest, urban area, and others (water bodies) every 50m mesh from the national land numerical information. Each stream load increment of N, P and K was compared with each applied amount of N, P and K fertilizer and each load of N and P from livestock excreta in sub-watershed. Applied amounts of N, P and K fertilizer were obtained from regional recommendation of fertilizer application rate and the cultivation area of each crop. Livestock excreta N and P loads were obtained from unit amount of excreta load and the number of heads of each animal.

Results and Discussion

Flow rate and stream material loads intended to increase from upstream to downstream. In May and August, stream load increments per unit area were positively correlated with proportions of paddy field and upland field, and negatively correlated with forest proportion, but not significantly correlated with urban proportion. The stream load increments per unit area of SS, TP, TN and TOC were significantly higher in May than in August and November. This is due to surface runoff with snowmelt as well as agricultural activities. On the other hand, in August, there was a highly significant positive correlation between upland proportion and stream load increments per unit area of NO_3^-, NO_2^-, SO_4^{2-}, Ca^{2+}, Mg^{2+} and SiO_2. This indicates that with nitrate leaching as a trigger the subsurface runoff of materials from mainly upland fields into the river. Increase of SiO_2 might be caused by denitrification as there was also the increase of HCO_3^-. In November when water temperature decreased to near 0 °C, there was no significant correlation between land use proportion and the stream load increments per unit area. In May and August, there were significant correlations between stream N, P and K load increments and applied amounts of chemical N, P and K fertilizer, and also stream N and P load increments and livestock N and P loads. Since there was no significant correlation with urban area in any season, it was suggested that the stream water qualities of Ishikari river were greatly influenced by agricultural land use especially upland field managements. Molar ratios of Si/TN and Si/TP of stream water decreased from upper to lower stream. The ratio less than threshold of eutrophication (2.7 for Si/TN and 54.3 for Si/TP) were found from middle stream for Si/TN in May and from upper stream for Si/TP in May and August. Peat soils distributed along the stream from the middle stream of the watershed has usually weak silica supply power, but peat soils can highly release N and phosphorous with peat decomposition accelerated by drainage and tillage. Reducing fertilizer application in peat land is important to conserve the water quality.

Conclusion

Stream water qualities of the Ishikari River were greatly influenced by agricultural activities in the watershed during the snow melting season and crop growing season. There is a concern of eutrophication by N and phosphorus in snow melting season in the wide range of the Ishikari River. Improvement of peatland management becomes important under climate change as well as reducing chemical N and P fertilizer and livestock N and P loads.

Impact of soil erosion status on C fluxes and C storage of heterogeneous croplands

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Introduction

One of the most important feedbacks on C dynamics in agricultural landscapes results from soil erosion. It has been hypothesized to constitute an overall sink for atmospheric CO_2. But this hypothesis is much debated, mainly because of the difficulties associated with establishing robust carbon budgets of erosion-deposition processes (Sanderman and Berhe, 2017).

The interdisciplinary research project "CarboZALF" was designed to face this challenge. For the first time ever, it should allow to quantify site-specific feedbacks of soil erosion with the atmosphere, i.e. the effect of erosion on C fluxes and soil C stock change (Sommer *et al.,* 2016).

Materials and Methods

For this purpose an experimental site (6 ha) was established and instrumented in the hummocky ground moraine landscape of NE Germany in 2009. Experimental plots were designed in a way to represent typical, spatial soil domains as well as hypothesized distinct C process domains of the soil landscape. In addition, we induced transient erosion/deposition states by manipulation of the soil surface layer. Along a full gradient of soil erosion and deposition, including an Albic Cutanic Luvisol (non eroded, flat terrain) Calcaric Regosol (top slope position, strongly eroded), Calcic Cutanic Luvisol (mid slope position, eroded), and Endogleyic Colluvic Regosol (hollow, depositional soil), we measured the dynamics of all relevant C fluxes – net CO_2 exchange, CH_4, dissolved organic and inorganic C (DOC, DIC), C-import, C-export by farming practice in order to create soil-specific, full annual C balances, indicating changes in the soil C stocks. In connection with this, a long-term (> 6yr) monitoring system for climate, soil water, temperature and redox dynamics, C and nutrient fluxes, and plant biomass dynamics was established at the experimental plots. Moreover, we tested the ability of automated chamber systems designed by ourselves for investigating temporal and spatial dynamics of C gas flux exchange (Hoffmann *et al.,* 2017). The investigations were done with an energy crop rotation (maize, sorghum, winter wheat, alfalfa).

Results and Discussion

The changes in soil C stocks were mainly influenced by the CO_2 fluxes and the C export, all other fluxes played a minor role. Moreover, the soil C stock changes were subject to a high intra and inter annual variability similar to the CO_2 fluxes, ranging from C stock gains up to - 80 g C m^{-2} a^{-1} and C stock losses up to 250 g m^{-2} a^{-1}.

However, in the long run the strongly eroded site acted as a strong soil C sink (- 150 g m^{-2} a^{-1}) and the eroded site as a moderate soil C sink (- 75 g m^{-2} a^{-1}), whereas no clear trend can be stated for deposition site (hollow position) and the non-eroded site.

In view of these results it is not more possible to completely dismiss the hypothesis about the promotion of the CO_2 or C sink function of landscapes by erosion. Moreover, there was a strong spatial variability of the soil C stock changes in the short and the long run. Interestingly, there is a close relationship between the soil C stock changes and the spatial variability of the soil stock down to 1 m and the soil N stock of the plough layer itself. In sum, the whole soil C stock variability can precisely described by a model only based on the length of the agricultural growing season in combination with the soil C and N stocks. Therefore, with these results it was proven that automated chamber systems can indeed accurately quantify CO_2 flux and soil C stock dynamics at pedon scale (Hoffmann *et al.*, 2017).

Conclusions

In order to scale up the erosion effects from the pedon to the landscape scale, we will further combine empirical and process-based models with approaches for continuous and high resolution mapping and modelling of the spatial soil C stock variability and remote sensing methods quantifying plant growth dynamics.

Acknowledgements

This work was supported by the Brandenburg Ministry of Infrastructure and Agriculture (MIL) and the Federal Agency for Renewable Resources (FNR). The authors want to express their special thanks to Marten Schmidt and Peter Rakowski for excellent operational and technical maintenance during the study period as well as to the employees of the ZALF research station, Dedelow, for establishing and maintaining the CarboZALF-D field trial.

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Dissolved organic nitrogen and carbon in small agricultural streams

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Introduction

Agriculture activities strongly impact organic matter processing in soils and these alterations potentially propagate to dissolved organic matter (DOM) in streams draining agricultural landscapes. The effects of agricultural land use on amount and composition of fluvial DOM observed so far are diverse (Stanley *et al.*, 2011). While comparatively much information is available on dissolved organic carbon (DOC; Stanley *et al.*, 2012), knowledge on dissolved organic nitrogen (DON) in agricultural streams is scarce. Since DOM and in particular DON may act as important nutrient source (Wiegner *et al.*, 2006) it is important to know how agriculture affects DOC and DON concentration and composition in streams.

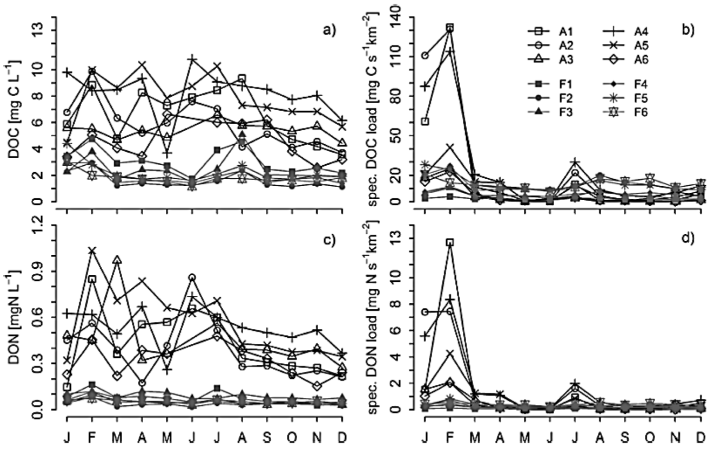
Materials and Methods

To assess seasonal variations of DOM amount and composition, we studied 6 agricultural and 6 forest streams in the Northeastern German Lowlands. Sampling was performed on a monthly basis for one year. DOM composition was determined using absorbance and fluorescence spectroscopy and subsequent PARAFAC analysis. Size exclusion chromatography (SEC, LC-OCD-OND; Huber *et al.*, 2011) was used to measure DOC and DON concentration and DOC and DON SEC size fractions (humic-like (HS), non-humic high molecular weight (HMWS) and low molecular weight (LMWS) substances).

Results and Discussion

DOC and DON concentration were consistently higher in agricultural compared to forest streams (Figure 1 a, c). In particular during periods of high discharge, high DOC and DON loads occurred in agricultural streams (Figure 1b, d). Although not all discharge events were covered by the monthly sampling, the results show that DOC and DON export is mainly discharge driven and more variable than in near natural reference systems. DOM composition differed between agricultural and forest streams (permutational MANOVA: $R^2=0.18$; $p < 0.001$; Figure 2) and was best explained by C:N ratio of DOM, the contribution of microbial produced DOM (C3, FI, freshness index) and the contribution of HS-like DOM to total DOM.

The overall terrestrial character of DOM in agricultural and forest streams (high $SUVA_{254}$ and HIX; > 75% HS-like material; mainly terrestrial derived PARAFAC components), which was observed consistently over the year indicates that soil is the main sources of DOC and DON in the investigated streams. The comparatively high concentrations of DON, mainly in the HS-like fraction indicate that agriculture is an important source of DON in streams. This confirms what has been suggested in studies from soil science before, namely that in agricultural soils DON leaching may be an important pathway of DOM loss (van Kessel *et al.*, 2009).



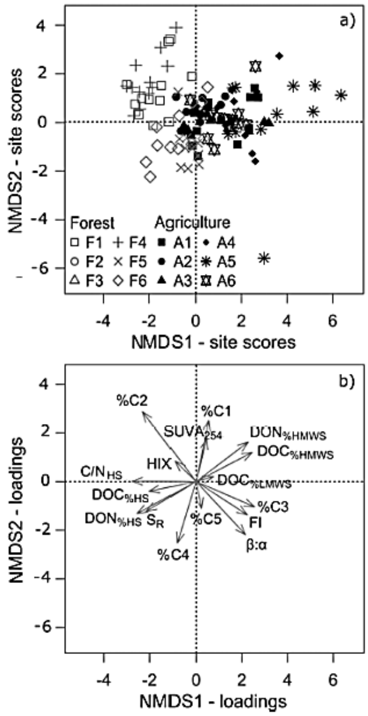


Figure 1 (left). **Seasonal variation of DOC (a, c) and DON (b, d) concentration (a, c) and loads (b, d) in agricultural (black) and forest (grey) streams.** ***Figure 2 (right).*** **NMDS scores (a) and loadings (b) for DOM composition in agricultural (black) and forest (grey) streams. Figures taken from Heinz *et al.*, 2015.**

Conclusions

Our results show that agricultural soils can be an important source of DOC and in particular DON to streams. The more microbial character and the markedly lower C:N ratio of this terrestrial derived DOM in agricultural streams point to a strong influence of agricultural practices on organic matter processing in soils, which results in export of altered DOM to streams. The altered composition, e.g. the low C:N ratio potentially influences the fate of this agricultural DOM, and hence may have strong effects on aquatic ecosystems.

Acknowledgements

We thank S. Schell, T. Rossoll, C. Theel and J. Wagner for their support in the lab and field work.

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Land use change implications on the soil C sequestration potential of peri-urban environments

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Introduction

Urban populations worldwide have exceeded rural populations and will account for most future population growth (United Nations, 2014). This population growth and rural to urban migration increasingly result in urban sprawl, which causes rapid land use change from native forests, rural pastures and commercial agriculture into smaller, residential properties with turf grass species, i.e. peri-urban environments. Soil carbon (C) and nitrogen (N) cycling has the potential to contribute to climate change by emitting greenhouse gases (GHG) (IPCC, 2013). On the other hand, soils can remove GHGs from the atmosphere by storing C and N in soil organic matter (SOM), i.e. C sequestration. The C sequestration potential of peri-urban environments is often neglected due to the fragmented distribution of these land areas and partially sealed soils. This omission potentially represents an underestimate of the global terrestrial C pool. Unsealed peri-urban soils have the potential to increase C sequestration though increased ecosystem productivity from higher management inputs such as fertilization and irrigation (Raciti *et al.*, 2011). This study identified the long-term effect of land use change on the C sequestration potential of peri-urban environments.

Materials and Methods

A soil survey was conducted on the dominant land uses at 18 sites in the Samford Valley, Australia, an area of rapid peri-urbanization. The predominately sandy top soils were analyzed for total C, which was then fractionated according to turnover velocity into the active, slow and resistant soil C pools within 0–10 cm and 10–20 cm soil layers. The C fractionation scheme used was based on a simplified version of the CENTURY model pools (Parton, 1996) based on the concepts of Skjemstad *et al.,* (2004) and Baldock *et al.,* (2012).

Results and Discussion

Total soil C varied widely across sampling sites from 17.3 to 46.6 t C ha^{-1}, with the widest C ranges in pasture soils. The turf grass land use showed no significant difference in total C when compared to forest and pasture. Overall, the slow soil C pool was dominant across all land use types with 1.1% C on average (Figure 1), which suggests soil C storage in the long term.

These biogeochemical data illustrate that land use change into peri-urban environments can support C sequestration in subtropical sandy soils. Soils of secondary forest, pasture and turf grass land use had on average the same C sequestration rates, regardless of plant cover. Practices during land use change such as top soil displacement and soil disturbance for construction have a stronger influence than the land use. Incorporated clay material during construction can significantly affect C sequestration into more stable SOM fractions of peri-urban environments.

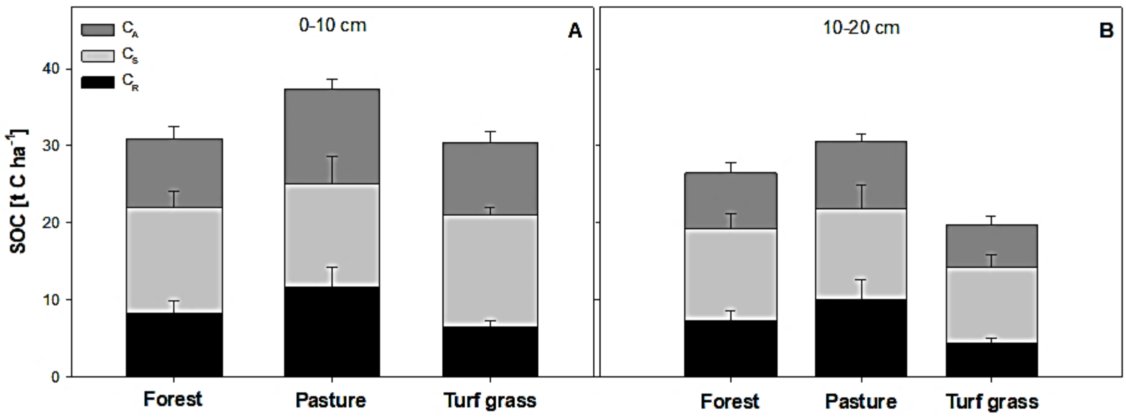

Figure 1. **Soil organic C average of in the form of active C (CA), slow C (CS) and resistant C (CR) per land use type with standard error for 0–10 cm soil depth (A) and 10–20 cm soil depth (B).**

Conclusions

This study proves that peri-urban environments can store substantial amounts of soil C. However, the higher management of turf grass systems does not result in higher C sequestration and cannot negate the higher emissions resulting from fertilizer and irrigation practices.

Acknowledgements

The study was aided by the Central Analytical Research Facility (CARF) within the Institute for Future Environments (IFE), Queensland University of Technology (QUT). Moreton Bay Regional Council for information and access to public sites; Samford Valley Research Facility (SERF) and community provided private access to residential properties.

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Links between plant rhizodeposition and N cycling in grassland systems

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Introduction

Plant–microbe interactions actively control nitrogen (N) cycling in the ecosystem. Plants stimulate microbial activity in the rhizosphere through a release of organic compounds from living roots. The plant rhizodeposition is composed of two main groups of compounds, soluble root exudates and more complex root lysates originating from the turnover of root hairs and root cortex. The amount of compounds released from the roots and the proportion of exudates and lysates may affect microbial activity in the rhizosphere, with important implications for C and N cycling. Plant nutritional strategy seems to be an important factor affecting plant rhizodeposition flux and composition of the compounds, with an effect on resulting N availability in the system. Fast-growing competitive (N-rich) plant species have larger photosynthetic capacity and larger N requirements than slower-growing conservative (N-poor) ones. It is thus expected that they release more soluble exudates to the soil and, therefore, their presence is connected with bacterial-dominated soil microbial communities, providing fast soil N cycling. The opposite is true for conservative plants, which have a strategy of high resource conservation in long-lived tissues. They produce litter of poor quality, slowly decomposed by fungal-dominated soil microbial communities, and root exudation is likely smaller. In consequence, the soil N transformation rates are slower and soil N availability is lower. Our objective was to compare the rhizodeposition pattern (ie. total investment into belowground C flux, the contribution of exudates to the rhizodeposition, the quality of exuded compounds), the coupling of the plant–microbe interactions covering plant N requirement in time and space, and the consequences for C and N cycling associated with conservative (*Carex acuta*) versus competitive (*Glyceria maxima*) plant.

Materials and Methods

We combined an assessment of root exudation by a $^{13}CO_2$ pulse labeling with determination of root growth to estimate belowground C fluxes. We studied seasonal changes in plant, microbial, and soil soluble N pools and net microbial N transformations to interconnect the C and N cycling in the systems dominated by these species. We further determined the composition of root exudates and root metabolite content.

Results and Discussion

We showed that competitive *Glyceria*, as compared to conservative *Carex*, appears to affect soil N cycling through a more direct temporal and spatial influence on soil microbes due to a larger investment into root exudation with significantly higher proportion of sugars. This makes the system highly dynamic, with faster soil N cycling and pronounced seasonal N redistribution between plants and microbes. The conservative *Carex*, irrespective of its larger root system, invested less C to exudation.

The *Carex* thus had a smaller direct effect on the soil N cycle through exudation, which made the plant–soil relation less dynamic, less responsive to environmental changes, but also less susceptible to N leakage after disturbance, compared to systems with competitive *Glyceria*.

Conclusions

In summary, we showed that differences in soil N cycling associated with competitive versus conservative plants are closely connected with their different investments into root exudation, which govern the coupling of plant–microbe interactions in time and space. We have also additional information about the composition of the three main metabolite groups, sugars, amino acids and organic acids, which significantly differed between the plant species. Moreover, our data indicated that *Glyceria* strongly controls the quality of exuded compounds while the exudates released from roots of *Carex* strongly resembled the composition of the root metabolite pool.

Acknowledgements

Financial support was provided by the Grant Agency of the Czech Republic (16-21743S) and by SoWa Research Infrastructure funded by the Ministry of Education, Youth and Sports of the Czech Republic (LM2015075).

Landscape-scale BVOC emission from energy crops – A modelling approach

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Introduction

Biogenic volatile organic compounds (BVOCs) emitted from vegetation have significant effects on the biosphere (Peñuelas and Staudt, 2010), mediating biotic interactions, and on the atmosphere, influencing its warming potential, the formation of particulates and the concentration of tropospheric ozone. As the amount and composition of BVOC emissions vary with species, changes in land use and structure of plant communities play an important role in biosphere-atmosphere feedbacks (Miresmailli *et al.*, 2013). Major changes in the agricultural landscapes derive from the global mandate of developing renewable energy, which promotes widespread adoption of bioenergy crops. Recent experimental work (Wiß *et al.*, 2017) made available data for calibration of BVOC emission models at the field scale for relevant energy crops. Once validated at the plot level, simulation models can be effectively used to scale-up predictions at a range of scales (Ewert *et al.*, 2011). On these bases, we present here an approach to estimate –by means of process-based simulation– potential BVOC emissions from maize and rapeseed in the German state of Brandenburg, where such emissions are dominated by agriculture (Karl *et al.*, 2009).

Materials and Methods

The crop module of the agro-ecosystem simulation model MONICA (Nendel *et al.*, 2011) was extended to allow for the simulation of monoterpene and isoprene emissions from the canopy. Two alternate approaches (Guenther, 2006; Grote *et al.*, 2014), differing in structure and mechanisms, were selected. An hourly solution of the Farquhar photosynthesis model (Yin and Struik, 2009) was implemented to guarantee full compatibility between the crop and emission models. The modelling solution is calibrated using data from dedicated field experiments carried out in Dedelow, NE Germany, where BVOC fluxes from maize (Wiß *et al.*, 2017) and rapeseed were monitored during the growing seasons 2015–2016 by means of automated large chambers and PTR mass spectrometry. The modelling solution is then applied to simulate the potential emission of BVOCs originated by maize and rapeseed over the entire state of Brandenburg. Each crop is simulated as monoculture over a 1 km^2 resolution grid covering the entire study area, characterized by meteorological conditions (1995–2012) provided by the German Weather Service (DWD) and soil physical and chemical characteristics retrieved from the soil geological survey map (BÜK300) available for Brandenburg. For each pixel, hourly, daily and cumulated BVOC emissions over the growing season are recorded in order to assess their variability at different temporal scales.

Results and Discussion

The ultimate mechanistic description of the processes underlying the emission of BVOCs from vegetation is yet to come, as physiological controls on isoprene and monoterpene emissions remain partially unresolved. However, such uncertainty does not prevent different models to achieve acceptable performance, with the preference of a particular model over others depending on the availability of data for model parameterization (Niinemets *et al.*, 2013). These considerations also hold for the version of MONICA used in this study, which yields similar results regardless the emission model selected. The coupling with a full-blown crop model allows for the dynamic quantification of factors that influence patterns in BVOC emissions, such as the amount of photosynthetically active radiation reaching the leaf surface, phenological development and possible stressors the crop is exposed to. At the scale of the study area, this approach lays the foundations for an accurate estimation of BVOC emissions from established energy crops.

Conclusions

The current study is a first step towards a BVOCs emission inventory from energy crops in Germany. Preliminary results encourage the adoption of a modelling approach to account for the known plant-environment interactions that influence emission patterns. Future activities will be focused on the refinement of the simulation setup by replacing monoculture with realistic crop rotations and considering the actual land use in Brandenburg.

Acknowledgements

This work received funding from the VOCE research project – Emissionen von flüchtigen organischen Kohlenstoffverbindungen aus dem Energiepflanzenanbau (22025712).

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Coupling crop model with different water balance and root water uptake approaches: an analysis of the predictive capacity in simulating spatially variable CO_2 and H_2O fluxes and crop growth process

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Introduction

Accurate modelling of how soil water stress affects canopy exchange processes is crucial for reliable predictions in heterogenous fields and landscapes from crop models and land surface models (LSMs). Current crop models and LSMs that use a coupled photosynthesis-stomatal conductance model (A – gs) for simulating canopy CO2 and H2O exchange account for water stress via a stress factor which is simply calculated either from soil water content or soil water potential and thus ignores the specific stomatal behavior of different plant species. Those models do not involve hydraulic and/or chemical signaling that captures the feedbacks within the entire soil-root-xylem-leaf-atmosphere system. Although the hydraulic linkage between the root and shoot as the long distance signal that regulates stomata, is likely to affect predictions of gas exchange, net canopy assimilation, biomass, and soil water dynamics, this complete linkage is rarely considered in many crop models and LSMs.

Materials and Methods

We modified the original LINTULCC2 crop model (Rodriguez *et al.*, 2001) which has a detailed calculation of leaf energy balances and the coupled (A – g_s) model and linked it with Couvreur's root water uptake model (RWU) (Couvreur *et al.*, 2014) and HILLFLOW 1D water balance model (Bronstert and Plate, 1997) in order to explicitly represent stomata regulation to water depletion while involving the whole plant hydraulic signal. We carried out a comprehensive comparision of three simulation scenarios: (i) HILLFLOW 1D-Couvreur's RWU-modified LintulCC2, (ii) HILLFLOW 1D-Feddes-modified LintulCC2, (iii) and the original LintulCC2 which considers a tipping-bucket (TB) water balance approach. We evaluated model predictions for hourly gross assimilation rate (Pn), actual transpiration (T_{act}), soil water content (SWC), leaf area index (LAI) and above ground dried biomass using a data collected from a wheat field grown in 2016 under three water supply regimes (sheltered, rain-fed and irrigated) and two soil types (stony and loamy) in Western Germany. Scenario (i) considers the whole plant hydraulic conductance while scenarios (ii) and (iii) do not.

Results and Discussion

Figure 1 compares the observed and simulated Pn for scenarios (i), (ii) and (iii) under all studied water regimes, and respectively displays their corresponding R^2 (0.56, 0.53 and 0.42) and RMSE (7.45, 7.92 and 10.29 micromole m^{-2} s^{-1}).

Based on these statistics it can be seen that scenarios (i) and (ii) which use a physically based water balance approach out-performs scenario (iii) where a TB water balance approach is used. Under optimum water conditions, all scenarios had a similar performace for Pn prediction (R^2 = 0.65 for all models). The R^2 of scenarios (i) ,(ii) and (iii) for Pn under severe drought were 0.42, 0.40 and 0.25 respectively, indicating that model performance declined in the order of scenario (i) >= (ii) > (iii). A similar performance order was observed for the predicted seasonal water content profiles and above ground biomass.

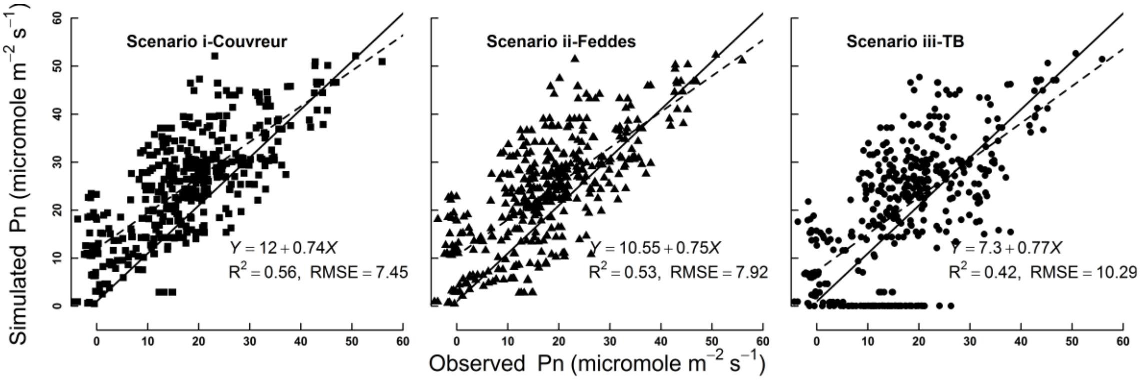

Figure 1. **Hourly instantaneous Pn simulated by three simulation scenarios versus measured data (n = 388).**

Conclusions

The better performance by using Couvreur approach (scenario (i)) as compared to the conventional approaches (scenarios (ii) and iii)) could be attributed to the consideration of the hydraulic conductance from root to shoot in the coupled A-g_s model. Consideration of stomatal control thus improved the prediction of canopy gas exchange and other outputs under a wide range of water and soil conditions that may occur in heteronenous fields and landscapes. The newly coupled model (modified LINTULCC2 with Couvreur method) requires futher testing for other crop types.

Acknowledgements

This study is part of the Transregional collaborative Research Center 32 – Pattern in Soil-Vegetation-Atmosphere-Systems (TR32), funded by the German Science Foundation (DFG)

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Modeling ecosystem services in transition zones of forest to agricultural land in Europe

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Introduction

Fragmentation of landscapes is a dynamic ecological process, which is partly driven by humans. Fragmented landscapes are characterised by the occurrence of discontinuities or variations in prevalent or native land cover and habitat properties (Strayer *et al.*, 2003). The transition zones between different ecotopes are influenced by active and passive exchange of matter and energy and have different properties than native forest or plain pasture or agricultural land. Some taxa clearly respond positively or negatively to changes in microclimate in these transition zones as does matter cycling (e.g. decomposition and biomass production; e.g. Magnago *et al.*, 2015).

Most of the research concerning transition zones and their effects has focused on diversity and abundance of animals and plants (see Ries *et al.*, 2004 for a review). Studies on abiotic effects are rare and difficult to compare (Murcia, 1995). The transition zones' influence on water and matter cycling is even less understood. Nevertheless, depending on their defined width, transition zones may take a considerable share in the spatial dimension of terrestrial ecosystems, leaving a large part of the biosphere largely unconsidered in research and assessment. Globally, Haddad *et al.*, (2015) calculated that 20% of forested land was located in a forested transition zone of 100 m width, but the 100 m threshold may not be applicable in general (see Schmidt *et al.*, 2017 for a review). We (1) link measured microclimate and biogeochemical factors with remotely sensed data to understand the underlying effects for altered ecosystem services in transition zones compared to the core matrix and (2) use this understanding to calculate the area of forested transition zones for Europe.

Materials and Methods

First, we measured microclimate in two transition zones in Brandenburg, Germany. Further, litterfall, aboveground biomass, soil carbon and nitrogen stocks were measured in transects from forest to agricultural field. Second, we are comparing the gathered ground truth data with Sentinel 2 remote sensing data in order to develop modelling approaches to estimate the influence of transition zones on several ecosystem services on a broader scale (landscape level). This approach shall be used to improve the output of established models for transition zones and to predict ecosystem services like yields from crops and carbon sequestration by trees in transition zones. The extent of transition zones will be calculated for Europe using CORINE Land Cover data while specifying and crosschecking the results with Biotope Mapping and Sentinel 2 data from Brandenburg.

Results and Discussion

In both approaches, measurements in the field and multispectral data from Sentinel 2 we found S-shaped gradients in transition zones. As the review of literature (Schmidt *et al.*, 2017) and our results approve a smaller transition zone than 100 m we calculated the share of transition zones for different extends of the transition zone for the federal state of Brandenburg in Germany (Table 1) using Biotope Mapping.

Table 1. **Percentage of transition zone of total land use type area for the federal state of Brandenburg, Germany. The length refers to the distance perpendicular to the edges of the adjacent land use.**

Share in% in Brandenburg	**20 m**	**50 m**	**100 m**	**500 m**
Agricultural field	7	15	26	
Forest	12	25	41	97

We found that trees are smaller in a transition zone of approximately 50 m. As for Brandenburg, this is a share of 25% of the forested area. The calculated extent of transition zones in Europe and the magnitude of other ecosystem services will allow predictions on the impact of transition zones and the related human-made fragmentation of landscapes.

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Soil structure effects on flow and transport indicating the link to soil and crop management

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Abstract

Structured soils are characterized by inter-aggregate spaces and biopores forming a connected 3D network of larger (macro) pores superimposed on the textural pore system of the soil matrix. In arable soils, such a **macropore network** is relatively stable in subsoils; in topsoils, soil structure is repeatedly disturbed under conventional tillage. Thus, soil management, in combination with cropping practices, is indirectly controlling the structure formation. In agricultural landscapes, soil erosion effects of profile truncation and colluviation further affect the soil structure distribution at the field scale.

Soil structure and macropore networks are important with respect to non-equilibrium and preferential flow processes, which limit the quantitative analysis of water and element cycles. Predictive soil-crop models that assume local geo-hydro-chemical equilibrium cannot be applied when water and solutes preferentially move along soil macropores and bypass a lower permeable soil matrix. The inclusion of structural effects in such quantitative models is still hampered by the complexity of the 3D macropore network.

Model analyses and observations indicate that mass transfer of water and solutes between aggregates and inter-aggregate pores or biopores seems to be a key for understanding non-equilibrium type preferential flow processes (Gerke *et al.*, 2013). The inter-domain mass transfer is controlled by properties of biopore walls and crack coatings at the interface between macropores and soil matrix. These properties often differ from those of the soil matrix with respect to texture, organic matter (OM), pore geometry, density, and porosity; differences further depend on soil parent material, crops, and soil management. Small-scale maps of the OM composition of intact aggregate coatings and burrow walls reveal characteristic mm-scale spatial distribution of OM sorption properties and potential wettability. Mass transfer parameters can also affect flow and transport at larger spatial scales. Future preferential flow analyses should distinguish whether macropores are created by decayed roots from wheat, maize, and lucerne or by earthworms, cracks with clay-organic coatings), and thus more or less permeable or reactive among other factors. This presentation analyses interactions between pedologic and hydrologic processes focussing on macropore surface properties and on the application of macroscopic mass transfer terms in dual-permeability numerical models (Gerke, 2012). Aim is to better predict the preferential transport in soil landscapes depending on tillage and crop rotations by linking land use effects with soil structure and transport properties.

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Long-term modelling of hourly evapotranspiration and soil water contents

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Introduction

Real evapotranspiration (ETr) is a key variable for hydrology, agronomy and meteorology. In addition to atmospheric conditions, ETr is also influenced by vegetation type, phenology and soil water storage. Modelling of root water uptake by vegetation cover is an essential part of deterministic hydrological models and a prerequisite for an accurate simulation of ETr. In the last years, new so called compensatory root water uptake models were developed for a more adequate description of soil water extraction by plant roots. Compensatory means that reduced root water uptake in upper stressed parts of the soil is compensated by an increased uptake in deeper unstressed soil layers. However, only a few studies using short-term experimental field data for the validation of such root water uptake models are published until now (e.g., Deb *et al.*, 2013). Therefore, a further verification of such compensatory root water uptake approaches using field experiments with a higher measurement frequency and longer investigation periods was recommended in these studies.

Materials and Methods

We analysed a 10-years period from 2003–2012 with hourly rates of ETr derived from Eddy-Covariance (EC)-measurements and soil water contents monitored by Time Domain Reflectometry-probes at the grass-covered boundary layer field site Falkenberg of the Lindenberg Meteorological Observatory-Richard-Aßmann-Observatory, operated by the German Meteorological Service (e.g., Beyrich *et al.*, 2006). Hourly measured data and this 10 years period with varying meteorological and soil hydrological conditions enable a detailed analysis of the temporal dynamics of ETr and soil water contents near the soil surface, and, thus, a more rigorous test of computer codes for modelling ETr, root water uptake and soil water fluxes as compared to shorter periods. Observed ETr-rates and soil water contents were compared with those simulated by a modelling approach consisting of the Penman-Monteith equation and of the soil water flux model Hydrus-1D (Simunek *et al.*, 2013) using an uncompensatory and a compensatory root water uptake model. The objective of our study was an analysis of the impact of the application of uncompensated and compensated root water uptake on the model outputs to give a further experimental verification of root water uptake models (Wegehenkel *et al.*, 2017).

Results and Discussion

The comparison of simulated soil water contents and ETr-rates with the measured ones suggested a satisfactory model performance. The calibration of soil hydraulic parameters and the estimation of an appropriate rooting depth of grass cover showed the highest impact on the simulation quality.

The application of compensatory RWU in our study led to a decrease in the model performance as compared to the simulation quality achieved by the application of uncompensatory RWU. In addition, the application of RWU-compensation resulted in a switching between high and low RWU-rates with a rapid unnatural decrease of RWU under dry conditions. This shortcoming of the compensatory RWU-model used in our study was reported in other simulation studies (e.g. Peters, 2016), but was not yet validated by experimental field data.

Conclusions

Our results substantiated the necessity of a further improvement of compensatory RWU-models as well as the measurement of spatial root density distribution in the soil profile and maximum rooting depth at experimental fields with vegetation cover. In our study, we used time series of hourly-ETr-rates measured by the EC-method without a closure of the energy balance. A comparison of simulated ETr-rates with those measured by EC processed with a closure of the energy balance should be the subject of a following study.

Acknowledgements

This study was financially supported by the German Federal Ministry of Consumer Protection, Food and Agriculture and the Ministry of Agriculture, Environmental Protection and Regional Planning of the Federal State of Brandenburg (Germany).

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Small area, big impact – small lentic waterbodies in the agricultural landscape

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The global number and area of small lentic water bodies <1 ha (hereafter ponds) has been estimated at 3.48 x 10^9 and >0.8 billion km^{-2}. For example, Northeast Germany is coined by >150.000 ponds called kettle holes, with densities of up to 40 per km^2. Owing to their size and pronounced wet-dry cycles, ponds are closely linked to the terrestrial surrounding. Thus they are hotspots for biodiversity at a regional level and significantly contribute to the global carbon cycle. At the same time, they are vulnerable to the impact of intensive land use practices. Hence, studying the functioning of ponds in the agricultural landscape improves our understanding of the role of individual ponds within pond networks (Figure 1). Pond networks provide societally relevant ecosystem services that cannot be provided by the surrounding homogeneous agricultural landscape, calling for integrated pond-landscape approaches. The ZALF working group “Small standing water bodies in the agricultural landscape” aims to tackle this challenge by using an interdisciplinary approach.

The Agroscapelab Quillow (Uckermark region, Northeast Germany) provides the core area for studying ponds in the agricultural landscape. These mainly refer to glacially created kettle holes which formed 10,000 years ago. The study area offers a well-established research infrastructure. Our interdisciplinary group uses a variety of methods including intensive field measurements of water chemistry, macrophyte distribution and hydrology, lab experiments studying effects of sediment desiccation and rewetting on biogeochemical processes and the development of process-based biogeochemical and statistical models.

In the following we highlight some of the major results of our working group. Hydrogeomorphological (HGM) variables such as depth, size, shore slope or hydroperiod vary widely among the water bodies, and have been used to establish HGM types of kettle holes (Kalettka and Rudat, 2006). Fostered by their highly variable hydroperiod, kettle holes act as refuge area for amphibian plants and animals that are often under threat (Berger *et al.*, 2011; Pätzig *et al.*, 2012). The kettle hole vegetation is tightly coupled to biogeochemical processes. For example, massive occurrence of floating-leaf plants interrelates with the phosphorous release into the water body (Kleeberg *et al.,* 2016). Results of a kettle hole biogeochemical model suggest a major contribution of submerged macrophyte decomposition to the internal phosphorus recycling (Onandia *et al.*, in prep.). Kettle holes were found to retain substances entering the system via surface and subsurface water inflow (Lischeid *et al.*, 2017; Nitzsche *et al.*, 2017). The water supply seems to depend on their position in the landscape (Figure 1). The release or mineralization of matter is boosted by rapid fluctuations of redox conditions (Lischeid and Kalettka, 2012; Kleeberg *et al.*, 2016; Reverey *et al.*, 2016).

Sediment dry-wet cycles further leave a biogeochemical and microbial legacy, thus determining rates and directions of biogeochemical processes in the future (Reverey *et al.*, in prep.). Additionally, kettle holes influence the landscape metabolism, *e.g.* by the release of greenhouse gases, carbon sequestration or nitrogen turnover (Premke *et al.*, 2016; Reverey *et al.*, 2016).

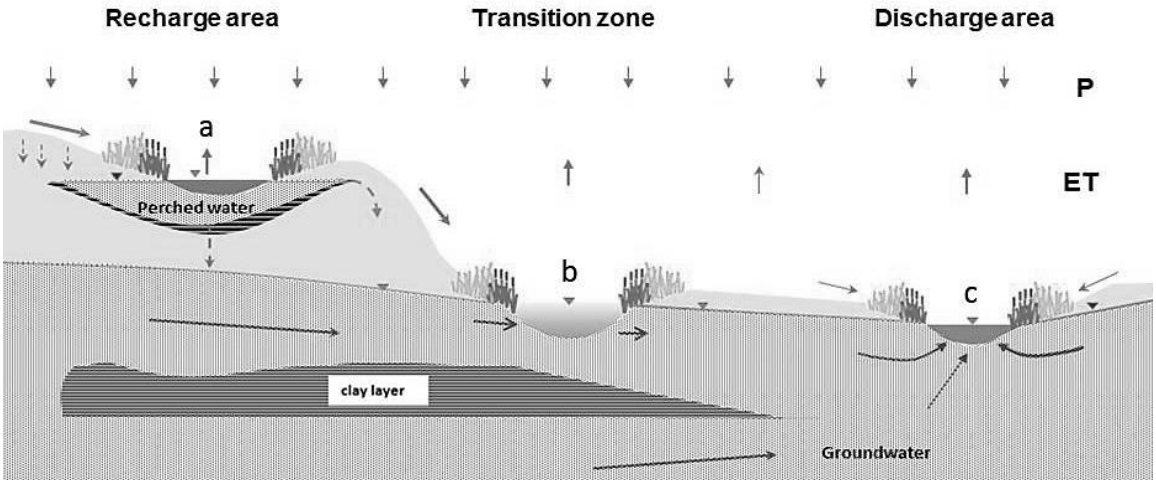

Figure 1. **Kettle hole hydrology in dependency on their position in the top-down landscape transect: a) surface run-off and perched water over impermeable layers nearby the soil surface, infiltration into deeper layers in dependence on the water table hight, b) surface run-off and groundwater flow , groundwater upstream to lower situated regions; c) mainly groundwater flow into kettle holes, surface run-off lower.**

Despite an increasing scientific awareness, a comprehensive understanding of ponds is still hampered by their high spatial and temporal variability and high number on a regional and global scale. A holistic picture of ponds and pond networks would help to better understand their role in the agricultural landscape, allow risk assessment, and support conservation and management in order to maintain their ecosystem services.

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Preferential flow through biopores from plot to catchment scale

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Introduction

In the CAOS project ("Catchments as organized systems"; Zehe *et al.*, 2014) the main aim is to disentangle the different factors driving hydrological processes at catchment scale. In the catchment scale model, which is developed within this project, preferential flow through macropores will be included. Though macropore flow is widely recognized as an important process in hydrology, mainly during high intensity rainfall, the parameterization of macropores at larger scale remains a big challenge due to the high spatio-temporal variability. In this study, we investigated flow in macropores created by earthworms and other soil dwelling organisms. Here, we present a statistical method to investigate complex environmental data sets in order to find an adequate system structure separating between direct and indirect effects, verifying directions of related effects. With this method, we studied the relationships between earthworms and macropores in a small-scale catchment in Luxembourg. Our main question was: Do earthworms affect the spatial and temporal distribution of hydrologically effective macropore networks, or in other words: do we need earthworm distributions to explain macropore flow?

Materials and Methods

We sampled earthworms and performed infiltration experiments with a dye tracer at six fields on six dates during one year (2015–2016). A set of temporally or spatially variant predictor variables, such as soil water content, soil texture and land use was used to estimate the spatiotemporal distribution of earthworms, macropores and macropore effectiveness, applying generalized linear mixed effects models. In order to verify the earthworm-macropore system, we applied piecewise structural equation modelling (also known as confirmatory path analysis; Lefcheck, 2016).

Results and Discussion

We found an adequate system structure (Fisher's $C=16.16$, $P=0.304$) for a system of three regression models. Earthworm abundance was the only effect on macropore densities while earthworm abundance itself was related directly to water and clay content and land use. However, the hydrological effectiveness of macropores is only partly driven by earthworm abundances, but additionally by water content. Simply said: macropores in the Wollefsbach catchment are made by earthworms, so we need information about them to predict spatiotemporal variations in macropore numbers. But the relative amount of hydrologically effective macropores is driven by a complex interplay between biotic factors (e.g. coating by earthworms) and abiotic constraints (e.g. water content and related matric head).

These results are valuable at various aspects: (i) by applying piecewise structural-equation modelling we identified an adequate and reliable system structure and thus a valid process-based description of macropore flow; (ii) we use this system for predicting time-series and maps of hydrologically effective macropores as an important input for hydrological models.

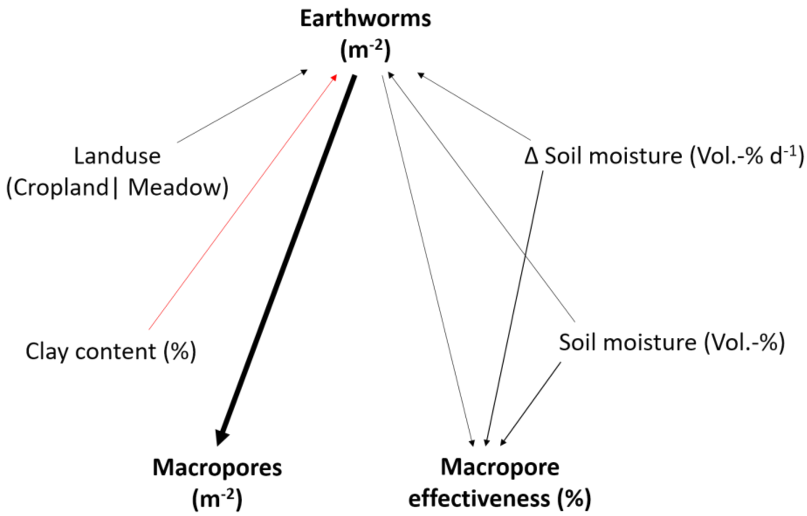

Figure 1. **Earthworm-macropore system with positive relationships indicated by black arrows, negative relationships by red arrows. Thickness of arrows corresponds to strength of the effect.**

Conclusions

We successfully applied piecewise structural equation modelling to identify an earthworm-macropore system, where we found corroborating evidence for the strong effect of earthworms on macropores, while the hydrological effectiveness of the macropores depends on both biotic and abiotic factors. Applying methods like structural equation models helps to disentangle complex relationships in data sets, especially the separation of direct from indirect relationships. This provides a desired and important basis for the parameterization of spatiotemporal distributions of macropores for catchment scale hydrological models.

Acknowledgements

We thank Theresa Blume and Tobias Vetter from GFZ Potsdam for provision of data from automated sensor clusters, Malte Neuper from KIT for data from the meteorological station Useldange, the Luxembourg Institute of Science and Technology in Esch-sur-Alzette for providing laboratory space and equipment. We thank the farmer Mario Kleer and the flight club Useldange CLVV for providing access to the six fields. Finally, we acknowledge funding by the German Science Foundation (grants nos. SCHR1000/6-2 and SCHA1719/1-2).

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Soil microbial influence of natural landscape elements and landscape structure on agricultural fields

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Introduction

Industrial agriculture enabled increasing yields, however often with a detrimental effect on the environment. At field scale, agricultural management selects for certain soil microorganisms and functions, hence reducing biodiversity and potentially also reducing water and nutrient cycling. At landscape scale, simply structured areas with few natural landscape elements are for the farmer easier to manage compared with complex areas. However, natural landscape elements may provide regulating and supporting ecosystem services. Our objective was 1) to evaluate natural landscape elements as stepping stones for soil biodiversity by quantifying soil microbial diversity and abundance along transition zones from natural landscape elements into agricultural fields and 2) to investigate the impact of landscape structure on soil microorganism and crop production along natural-agricultural transition zones.

Materials and Methods

Arbuscular mycorrhizal fungi in roots of winter wheat plants, soil microbial diversity and winter wheat yield were investigated along transects from natural landscape elements, like hedgerows and in-field ponds, into agricultural fields. Furthermore, compositional and configurational landscape metrics were calculated to quantify the impact of landscape structure on soil microorganisms and crop production.

Results and Discussion

First results from transect measurements in an intensively managed agricultural landscape in North-east Germany showed that arbuscular mycorrhizal root colonization and fungal diversity as well as carbon, nitrogen and phosphorous content in the soil decreased from natural landscape elements into agricultural fields. In contrast, bacterial diversity, winter-wheat grain yield, and biomass yield increased from natural landscape elements into the intensively managed agricultural fields. Landscape complexity had a weak positive effect on biomass production. In general, abiotic and biotic parameters varied along natural-agricultural habitat transition zones. This may be the effect of both the natural landscape elements and the intensive agricultural management.

Conclusions

Farmers are under pressure to produce high yields as well as contribute to ecosystem services like water and nutrient cycling and biodiversity maintenance. The maintenance and implementation of natural landscape elements may be a tool for farmers and policy to improve the contribution of the farmer and the agricultural landscapes to supporting and regulating ecosystem services.

Soil organic carbon drives microbial diversity under different land use types – Lessons from a European cross-continental study

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Land use and land use change have dramatic consequences for above-ground biodiversity, but their impact on soil microbial communities is only poorly understood. In this study, 19 European sites representing croplands, grasslands, and forests, and the main land conversion types were selected to characterize soil microbial abundance and bacterial diversity across a continental scale. Abundance was analyzed by qPCR of bacterial, archaeal and fungal rRNA genes, and bacterial community structure by 16S rRNA gene T-RFLP profiling and DNA sequencing. The abundance of Bacteria and Fungi but not Archaea responded to land use change. The site was the major determinant of the soil bacterial community structure (16S rRNA gene diversity), explaining 38% of the variation. While the quantity of soil organic carbon (SOC) only explained 8% of the variation, their importance strongly increased when SOC was differentiated by its physical and chemical properties, which together explained 23%. This was above the impact of soil pH (14%) and land use type (11%). SOC associated with silt and clay particles and particulate organic matter were the most influential SOC fractions, while chemically resistant C was the least. Cropland soils had the highest bacterial diversity, followed by grasslands and forests. Several taxa showed a significant response to land use change: Croplands to grassland conversions caused an increase of Verrucomicrobia; croplands to forest increased Rhizobiales but decreased Bacteroidetes and Nitrospirae; and grasslands to cropland increased Gemmatimonadetes but decreased Verrucomicrobia and Planctomycetes. Network analysis identified associations between particular SOC fractions and specific bacterial taxa. This study demonstrates that land use, land use change, and the composition of the SOC have specific effects on the soil microbial community structure which can be consistently observed across a continental scale.

Does crop rotational diversity increase soil microbial resistance and resilience to drought and flooding?

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Introduction

Future climate scenarios indicate more frequent and stronger extreme weather events. This includes more severe droughts but also an increase in heavy rain events and flooding (Trenberth *et al.*, 2003; Kirtman *et al.*, 2013). Agricultural systems are of special interest in this context because of their role in food security but also because of their potentially changing role in global carbon and nutrient cycling under these extreme conditions (Austin *et al.*, 2004; Urban *et al.*, 2015) Plant diversification strategies like more complex crop rotations which support more diverse soil microbial communities (Tiemann *et al.*, 2015) with higher functional redundancy might be more resistant to drought and flooding and could help to reduce impacts on microbial carbon and nutrient cycling.

Materials and Methods

To test how crop diversification affects the response of soil microbial processes to drought and flooding and reoccurring drought and flooding, we manipulated water regimes in lab incubation experiments using soils from four long term rotation experiments across the USA, including a low (one or two crops) vs. high (>3 crops) diversity rotations at each site. The sites range from low precipitation (Colorado), over intermediate precipitation (Michigan and South Dakota) to high precipitation in Maryland. Replicate sets of samples were either allowed to dry out, were gradually flooded or kept at a constant water content (control). We monitored CO2 production during five stress cycles. Additionally, we determined microbial biomass, enzyme activities and N pools during the first and last stress cycle in soils from the precipitation extremes.

Results and Discussion

After a total incubation length of 165 days and five stress cycles only the soils from short rotations in Maryland and South Dakota that had been subjected to reoccurring drought showed significantly less cumulative CO2 loss compared to their respective controls. All the other sites and rotation length did not significantly differ from control when subjected to reoccurring drought or flooding. A Principal component analysis using all measured parameters of Colorado and Maryland soils showed a clear clustering of samples by site and in case of Maryland also by rotation length before the first stress. During the stress, samples were significantly separated by the treatment (drought and flooding). Immediately after the stress, samples again clustered by site and rotation length. After four stress cycles, soils from the long rotation in Colorado were the only samples that did not show a significant response to the laboratory treatments anymore.

Conclusions

Our results indicate that agricultural soils, irrespective of the climatic region they are from and the rotation regime, are highly susceptible to changes in water content, especially drought. We did however also find that all tested soils quickly recovered from the applied stress treatment and that plant diversification might help to increase the microbial resistance to water stress in certain soil systems.

Acknowledgements

This work is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2014-67019-21716. We would like to thank Boone Meeden, Kathie Slebodnik and Richie Shepardson for help in the lab.

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Peaks of in situ N_2O emissions are influenced by N_2O producing and reducing microbial communities across arable soils

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Introduction

Agriculture is the main source of terrestrial N2O emissions, a potent greenhouse gas and the main cause of ozone depletion ((Hu *et al.*, 2015). The reduction of N2O into N2 by microorganisms carrying the nitrous oxide reductase gene (nosZ) is the only known biological process eliminating this greenhouse gas. Recent studies showed that a previously unknown clade of N2O-reducers (nosZII) was related to the potential capacity of the soil to act as a N2O sink (see Hallin *et al.*, 2017 and references therein). However little is known about how this group responds to different agricultural practices. Here, we investigated how N2O-producers and N2O-reducers were affected by agricultural practices across a range of cropping systems in order to evaluate the consequences for N2O emissions

Materials and Methods

Soil samples were collected in spring 2014 from 4 experimental sites in France, which undergo a large range of agricultural practices. The abundance of both ammonia oxidizers and denitrifiers was quantified by real-time qPCR, and the diversity of both nosZ clades was determined by 454 pyrosequencing. Denitrification and nitrification potential activities as well as in situ N2O emissions were also assessed. The physical and chemical soil characteristics were measured for all samples (INRA Laboratory of Soil Analysis, Arras, France)

Results and Discussion

Overall, greatest differences in microbial activity, diversity and abundance were observed between sites rather than between agricultural practices at each site. To better understand the contribution of abiotic and biotic factors to the in situ N_2O emissions, we subdivided more than 59.000 field measurements into fractions from low to high rates. We found that the low N2O emission rates were mainly explained by variation in soil properties (up to 59%), while the high rates were explained by variation in abundance and diversity of microbial communities (up to 68%). Notably, the diversity of the nosZII clade but not of the nosZI clade was important to explain the variation of in situ N_2O emissions fractions (Figure 1).

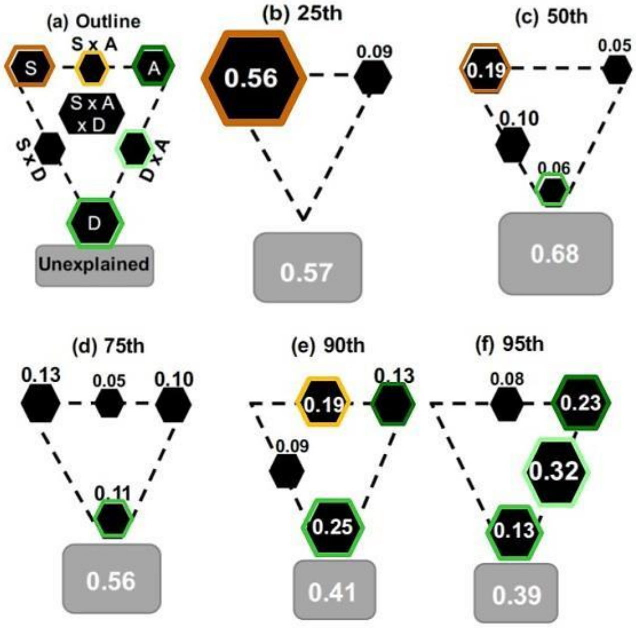

Figure 1. **Variation partitioning of in situ N2O emissions. (a) Variance of in situ N2O emissions was partitioned into soil physicochemical properties (S), abundance of N2O-producers and abundance of N2O-reducers (A), diversity of N2O-reducers (D), and by combinations of predictors. Geometric areas are proportional to the respective percentages of explained variation. The edges of the triangles depict the variation explained by each factor alone, while percentages of variation explained by interactions of two or all factors are indicated on the sides and in the middle of the triangles, respectively. (b) Variance partitioning of basal in situ N2O emissions (25% fraction), (c) variance partitioning of median in situ N2O emissions (50% fraction), (d), (e), (f) and (g) correspond to the variation partitioning of high N2O emissions of 75%, 90%, 95% and 99%, respectively. All numbers represent percentages. Only variance fractions ≥ 0.05% are shown.**

Conclusions

Our results highlight the higher sensitivity of the nosZII- than nosZI-community to environmental factors. However, despite significant variations in the nosZII community across the sites examined, only a few of the studied agricultural practices resulted in shifts on the diversity of this community. Nevertheless, comparison of all plots across the different sites showed for the first time that a higher diversity of the nosZII community was concomitant with lower in situ fluxes. Moreover, our work also indicates that microbial communities were more important for explaining variations in high than in low N2O emissions. This work emphasizes the consideration that the N2O-reducing community should have when addressing process-related N2O fluxes, particularly in studies aiming at mitigating emissions.

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Role of methanol utilizing bacteria in carbon dynamics from landscape scale perspective: the microbial influence on net methanol fluxes

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Introduction

Landscapes, especially agricultural and managed grasslands exhibit a high degree of spatial variability in several physicochemical characteristics such as in soil, organic matter pool and emissions of trace gases (Bowles *et al.*, 2014). These trace gases (e.g. CO_2, CH_4 and CH_3OH) which are radiatively active enhances "greenhouse" effect and influence carbon dynamics (Batjes, 1996). Microbes in soil and on plants mediate many biochemical transformations of organic compounds that contribute to essential ecosystem functions such as carbon and nitrogen cycling (Bowles *et al.*, 2014). Thus, the current study aims to get a hint on the microbial influence on one of the essential trace gases (methanol) and their contribution to one of the major biogeochemical cycles such as carbon in an ecosystem.

Methanol is one of three most abundant reactive volatile organic compounds (VOCs) and contributes to the overall oxidative capacity of the troposphere and also to ozone depletion (Stacheter *et al.*, 2013). Grasslands exhibit higher methanol emissions than forests and may be net sinks, i.e. they are globally affecting the carbon dynamics. Often the emitted methanol (~80–90%) is of plant origin (Galbally and Kirstine, 2002). The phyllosphere can be regarded as a favoured habitat of methanol-utilizing microorganisms being as abundant as up to 17% of the total phyllosphere microbiome (Wellner *et al.*, 2011; Mizuno *et al.*, 2012). But the information regarding rhizosphere methanol utilizers is still scarce. Few studies suggested that the estimated global emission rate of methanol is considerably higher than the observed emission rates of terrestrial ecosystems. Thus, methanol utilizers of the plant microbiome are crucial in mitigating the emission rates through methanol consumption (Kolb, 2009). But still information about the local sinks within plant habitat for methanol consumption is unknown. The current study aims to identify and localize the key methanol utilizers and hotspots for methanol consumption within the selected plants of a managed grassland in Germany. Hence, the main objective of our study was to understand methanol utilizer's contribution to methanol fluxes into atmosphere from a managed grassland. Therefore, answering our central motivation to find the role of methanol utilizing bacteria in carbon dynamics from landscape scale perspective.

Materials and Methods

We address the main objective by the identification of active methanol utilizers of four grassland plant species by DNA and RNA stable isotope probing (SIP) and metatranscriptomics at different growth stages (germination and flowering). We used gas-tight plant growth chambers to investigate the phyllosphere, endosphere, and rhizosphere of complete and intact grassland plants to avoid physical harms, which may lead to change of methanol fluxes. Before addressing the main objective, initial experiments were done on excised plant parts (leaves, roots, rhizospheric soil) to find the adequate concentration of methanol concentration (100 µM or 1 mM) and to choose time points for methanol consumption (6h, 12h, 24h and 48h).

To investigate this, RNA was extracted for the samples from above mentioned incubation time points and concentration.

Later, terminal restriction fragment length polymorphism (TRFLP) was done to find the similarities and dissimilarities between their bacterial community patterns. For the second objective to localize hotspots of methanol oxidation within the selected plants, we will employ radioactive labelling approach to determine methanol rates by adding [^{14}C1]-methanol to excised plant parts and later by measuring trapped ^{14}CO2.

Results and Outlook

Excised plant parts from two different plant species (i.e *Poa trivialis*, *Taraxacum officinale*) clearly showed distinct differences with in the bacterial community patterns. Thus, giving a hint about specific plant species are associated with specific methanol utilizers. Based on these results, main labelling experiments will be conducted using 1 mM [$^{13}C_1$]-methanol. We will measure the phyllospheric and rhizospheric methanol production and will identify those methanol utilizers that will have incorporated ^{13}C from supplemented [$^{13}C_1$]-methanol. Additional to the taxonomic identities, the metatranscriptome data of the labelled microbiome will deliver insights (i) in preferred metabolic pathways for methanol assimilation and dissimilation and (ii) in further metabolic interactions with the host plants. Furthermore, radioactive labeling approach using [^{14}C1]-methanol will give more insights into the methanol sinks in the grasslands. The central question about microbial mediated methanol fluxes over space and time in landscape scale will be measured too and thus showing their contribution in carbon dynamics.

Acknowledgements

We thank our terrestrial microbiology group especially Eileen Kroeber, Andreas Ulrich, Steffan Wirth and Rainer Fuchs for their help in organizing lab equipment's for conducting experiments. Ilona Bartelt and Marco Hoffmann, are acknowledged for their technical assistance for growing plants and during conducting experiments. We would like to thank Thomas Kaiser, Axel Behrendt and Undine Behrendt for their advices in plant species selection and assisting us during soil sampling in the grasslands. This work was financially supported by Deutsche Forschungsgemeinschaft (DFG) which is headed by Dr. habil. Steffen Kolb.

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I. Poster Session

Landscape Functioning

Element Cycles and Microbiomes

Authors alphabetical

Assessing viability of apple production under replant constraints at field level

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Introduction

Long-term monoculture has unfavourable effects on yield and quality of many crops including fruit production. Apple production areas in Europe have developed historically in the vicinity of urban areas in mostly densely used agricultural area with low potentials for expansion, plot exchange or set-aside. Soil based production constraints, such as apple replant disease (ARD), constitute a widespread impediment on achieving profitability in organic and conventional fruit production. The impact is measurable in terms of stunted growth, via assays of soil and in reduced yields. Its persistence is exacerbated by the phase out of chemical fumigation and biocide usage. Methods for regulation have been researched abundantly. The challenge lies in the maintenance of economically viable production within given sites. A pilot study in Brandenburg, Germany has the objective to identify a suitable threshold indicator for the economic impact of ARD. The aim is to achieve a reference scale for ARD impact in order to compare management measures from the farmers´ commercial perspective of apple production.

Methods

The reference scale was set up based on statistical analysis of site-specific data in a long-term field test site for apple production comprising generative and vegetative growth effects on yield. ARD damage was indicated by comparison of trunk cross-sectional area (csa), abundance of fungi populations using qPCR and specific cumulative yield. Economic effects were estimated by relating ecologically indicated growth and yield reduction with the contribution margin in a break-even analysis.

Results and Discussion

Impact classification showed reduced yields depending on ARD efficiency compared to the expected yield by cultivar and site. By taking into account the correlation with farm performance indicators a threshold for operating under economically sustainable terms was calculated. The results contribute to an assessment of production areas by classifying yield suppression and distribution of ARD within orchard plantations. The reference scale for ARD impact can be applied to identify whether areas are economically viable, and whether management strategies appear profitable.

Acknowledgements

This research was conducted in the frame of BONARES Ordiamur, funded by BMBF (2015–2018).

Effects of soil fauna plant microbe interactions primary succession

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Introduction

During succession, plants interact with soil macrofauna either directly e.g. by herbivory or indirectly by effect of litter on soil decomposer community which feedback to plants via soil formation and nutrient cycling. Here I am presenting several studies conducted in one chronosequence of post mining sites in Czech Republic indicating cooperative effect of various interactions between plants and soil macrofauna on plant community and soil development.

Results and Discussion

Study of plant community along chronosequence show abrupt change in plant community which correspond with time of earthworm colonization in these sites and also by micromorphological evidence of starting organo-mineral A layer formation due to ants activity. This is consistent with fact results of laboratory experiment showing that earthworm inoculation promotes plant growth. More detailed investigation show that plants typical for early and intermediate succession stages show negative plant soil feedback this negative feedback is however less severe if the soil is affected by activity of earthworms or isopodes. When plants grow in competition, then earthworm presence promotes competition of late succession plants against early succession plants. In later succession soil there is larger effect of earthworm presence on plant growth, but in early succession soils earthworms have larger legacy effect e.i. effect which persist when earthworms has been removed from soil. Manipulation experiments show that development of early succession plans has to teach certain level of biomass production and litter accumulation to allow earthworm to establish. In intermediate succession stages asymmetric competition of ectomycorrhizal plants vs. AMF ones was observed. Earthworm colonization can release this competition. Laboratory and field experiment also show that beside worm colonization root herbivory by Elateridae larvae support replacement of early succession plants by late succession ones. These examples show that interactions between soil fauna and plant play important role in plant succession and soil development during ecosystem recovery.

Variability of stable isotope signatures of organic matter in differently tilled sandy soil

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Introduction

Stable isotopic signatures of organic matter at natural abundances (ð^{13}C, ð^{15}N) are integrative indicators of biogeochemical processing of organic matter in soils. Information about field scale spatial variability of isotopic signatures is scarce even though such information is essential to understanding isotopic signals in landscapes affected by land use.

Aim of this study was to explore the spatial variability of ð^{13}C and ð^{15}N values of organic matter in sandy arable soil, their relationship to soil properties and the effect of tillage (conventional, reduced).

Materials and Methods

The study was carried out at a 74 ha field belonging to the Komturei Lietzen, Märkisch-Oderland, Brandenburg, a highly variable sandy loam with luvisols as dominating soil type (Joschko *et al.*, 2009), with 42 plots (15 m x 2 m) under reduced and conventional tillage. In August 2004, 4–6 soil samples from 0–15 cm and 15–30 cm soil depth were taken from each plot with an auger and pooled. Subsequently, the samples were air-dried and sieved (2 mm). Isotopic signatures were determined with a mass spectrometer IRMS (Finnigan) at the Max-Planck-Institute (MPI-BGC) in Jena.

Results and Discussion

Mean values of ð^{13}C in 0–15 cm, where tillage occured in both tillage variants, were identical under reduced and conventional tillage (-26.8 ‰). Variability was slightly higher under reduced tillage (SD 0.64) compared to conventional tillage (SD 0.24). In contrast, significant differences between the tillage variants were found in 15–30 cm: mean values of ð^{13}C were significantly higher, i.e. enriched under reduced tillage (-26.2 ‰, SD 0.33) compared to conventional tillage (-26.8 ‰, SD 0.19). The maximum difference in ð^{13}C values was about 2.5 ‰ between plots.

Mean ð^{15}N values in 0–15 cm were again nearly identical (+5 ‰); in 15–30 cm mean ð^{15}N values were significantly more enriched in ^{15}N in reduced tillage (+5.8 ‰, SD 0.71) compared to conventional tillage (+5.2 ‰, SD 5.2). Overall range (variation width) of ð^{15}N values in 0–30 cm was 3.5 ‰. Simple correlation analysis yielded weak positive relationships between ð^{13}C and soil properties such as clay and organic carbon content.

Most interestingly, only the relationship to plant available phosphorous yielded a higher correlation coefficient (r=0.68). In case of ð^{15}N, only weak relationships to soil properties were found. Spatial analyses revealed significant positive relationships between ð^{13}C and plant available phosphorous in 0–15 cm and 15–30 cm (Figure 1).

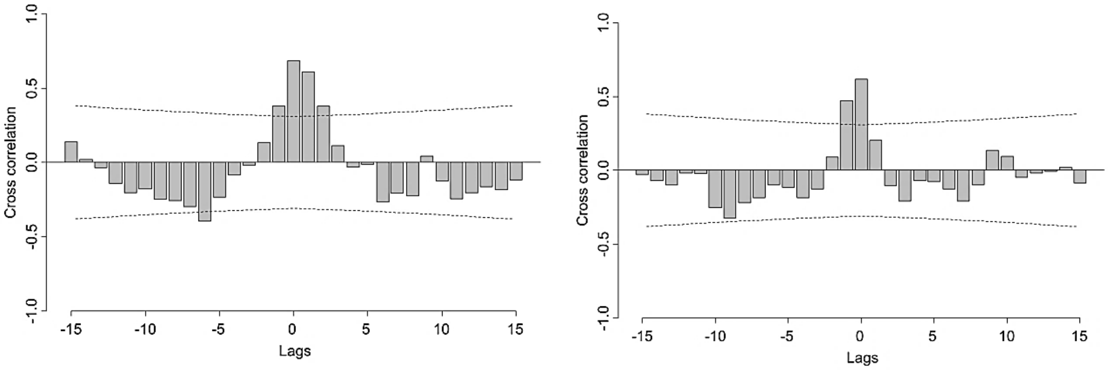

Figure 1. **Crosscorrelation between ð^{13}C values and plant available phosphorus in 0–15 cm soil depth (left) and in 15–30 cm soil depth (right).**

Close relationship between ð^{13}C values to phosphorous are possibly related to nutrient limitation of microbial biomass responsible for carbon transformation processes.

Conclusions

Both isotope signatures showed considerably spatial variability, which may amount to 3.5 ‰ in ð^{15}N, and which have to be considered when comparing different land management systems. Strong relationships to soil properties should also be considered.

With respect to the optimal sampling strategy for stable isotope signatures in soil, techniques of spatial statistics should be applied which consider the locations of observations (e.g. transect sampling), otherwise important information may be lost (Nielsen and Wendroth, 2003).

Acknowledgements

We thank Graf Gebhard von Hardenberg for the possibility to carry out this study. We thank the Landwirtschaftliche Rentenbank for financial support.

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Biogeochemical functions and controls of soil biota in agrolandscapes: new chances by combining monitoring approaches with C-N simulation modelling

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Introduction

Information about in situ biogeochemical functions and controls of soil biota is scarce. Results from plot experiments may not easily be upscaled to the landscape scale. Progress is to be expected from combinations of modeling and monitoring approaches in the field.

The objective of this study was to analyze the relationships between carbon dynamics modelled with CANDY Carbon Balance (CCB) and soil biological activity (earthworm abundance) in tilled sandy soil.

Materials and Methods

Investigations are based on an observational study (since 1996) on a 74 ha field in Lietzen, 20 km east of Müncheberg (Northeast Germany), with 42 plots (15 m x 2 m) under reduced and conventional tillage, on heterogeneous sandy loam soil with luvisols as dominant soil type (Joschko *et al.*, 2009; Schirrmann *et al.*, 2016). The climate is semiarid with an annual precipitation of 528 mm (1951–2000). Conventional tillage comprised annual ploughing to 25 cm depth while reduced tillage was done with a precision cultivator to 15–18 cm depth. Crop rotation was cereal dominated. Input of organic matter consisted in annual residual straw plus an application of lake sediments in two years. Earthworms were assessed by handsorting 0.25 m^2 of soil at 42 plots (until 2007).

CANDY Carbon Balance (CCB) is a simplified version of the carbon dynamic model CANDY (Franko *et al.*, 2011). It describes the turnover of decomposable carbon in annual time steps for average site conditions depending on crop yields and input rates of fresh organic matter (FOM). CCB could be validated with the Lietzen data.

Results and Discussion

Between 1996 and 2010 organic carbon pools increased in 90% out of 42 plots under reduced and conventional tillage. Average earthworm abundances were spatially highly variable and were positively correlated with modelled soil carbon stocks. Average earthworm abundances were positively related to average carbon stocks (C in SOM); the spatial analysis of plots under reduced tillage revealed coinciding maxima and minima. Earthworm abundances were negatively correlated with the biological active time (BAT) indicating different mineralization conditions at the 42 plots (Figure 1). Earthworm abundances were however not related to the C input measured as easily decomposable carbon (C in FOM) (not shown).

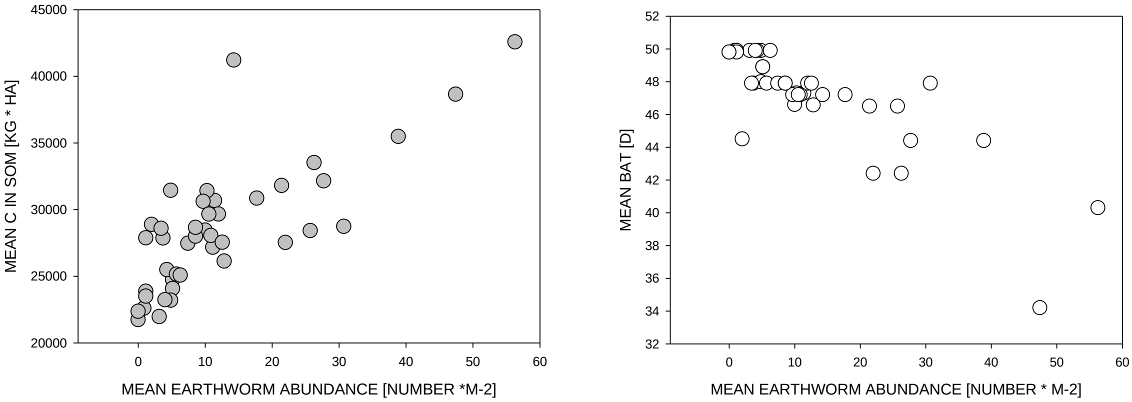

***Figure 1*. Relationship between average earthworm abundances and C stocks (C in SOM) (left) and the biological active time at each plot (BAT) (right).**

Conclusions

In some cases, close relationships between earthworms and modeled carbon pools (average carbon stocks, C in SOM) were found. They may possibly be related to site-specific functions of earthworms in the carbon cycle rather than to controlling factors. However, further research is necessary; the combination of monitoring with C-N simulation modeling seems promising. The ultimate goal is the inclusion of soil biota into C-N simulation models at landscape scales.

Acknowledgements

We thank Graf Gebhard von Hardenberg for the possibility to carry out this study on his property (Komturei Lietzen). We also thank the Landwirtschaftliche Rentenbank for support of this study.

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Spatial variability of the effects of biochar on soybean-rhizobium symbiosis and plant growth on sandy soil

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Abstract:

High nitrogen fixation ability of rhizobium soybean is considered as an effective approach to reduce inorganic N fertilizer application. Nevertheless, limiting of water and nutrient retention capacity in sandy soils are critical factors for crop growth. Thus, we introduced biochar as a soil amendment to improve soil quality. Two-year-round field experiment was established to estimate the effect of biochar application (associated with inoculation) on soybean growth and soil properties with and without irrigation condition. Black cherry wood derived biochar was produced through slow pyrolysis at 450℃, it was applied by 10 t ha^{-1} to sandy loamy moraine soil in north-eastern Germany.

Our results indicate no significant effect of biochar on plant growth (yield and plant dry weight), soil nutrients content (total C, total N, total S, P, K, Ca and Mg), plant nutrients content (N, P, K and Mg) and soil enzymes activity (fluorescein diacetate, protease, acid and alkaline phosphomonoestrase). Biochar application increased soil C/N. Nodule number was increased significantly with biochar application but the nodule leghemoglobin content was not increased. Higher plant nitrogen derived from nitrogen fixation was suggested due to biochar application. Since soil enzyme activity showed no correlation with root nitrogen content, it implied that biochar application affected the root nitrogen uptake in addition to the biological nitrogen fixation.

Ecosystem service of aquifer systems – Redox based degradation and retention of nitrate

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Introduction

Groundwater resources play a crucial role in the whole water cycle. Therefore, its quality must be of high standard and the directives defining water quality must be complied. However, there are still many water bodies in agricultural landscapes which do not show a good chemical status or are endangered to lose their good chemical status. In many cases, nitrate from land use is the reason for this issue and unclear cause effects still complicate a constructive problem analysis.

Standard approaches of hydrological analysis often fail describing the needed spatial and reactive correlations between local land use management (source) and contaminated aquatic environments (effects). Under impacts of changing land use management and natural boundary conditions unknown process interactions occur. Balance of oxidizing and reducing compounds will dynamically change and the further development of affected water bodies remain uncertain and problematic (Lauva *et al.,* 2012). Therefore the principle item of our approach is an innovative GIS based tool for the spatial and temporal analysis and evaluation of nitrate dynamics in large scale aquifer systems to assess the denitrification potential of aquatic systems in the agricultural landscape.

Materials and Methods

A GIS embedded grid-based conceptual hydrogeologic 3D-model served as the basic tool for a joint modeling of the hydraulic and hydrochemical processes. All required geographic and basic hydrogeological information are present as thematic maps in combination with data available from public institutions, e.g. Geological Surveys and Environmental Offices. To ensure an integrated water resources management, the approach represents the hydrogeological structure below the topographic surface and the complex hydrological properties of the landscape elements. The available, mostly limited hydrological and hydrogeological information from external data sources are integrated into 3D-GIS based conceptual data model. Based on this data model, regional aquifer structures are educed and indicator based hydraulic parameter distributions estimated. Beside these structure requirements the model considers recommendations for the geochemical reactivity of stated hydrostratigraphic units to calculate spatial distribution and reactivity of redox fronts – basis for the valuation of the in situ nitrate reduction potential in aquifer systems. The geo-data infrastructure is designed for interactive data managing, allowing progressive implementation of user-specific, local/regional data (for example drilling profiles, geological thematic maps, geochemical data etc.) for continuous evaluations.

Results and Discussion

Nitrate is transported conservatively in oxic environments but as soon as nitrate enriched water encounters an anoxic environment which is accommodated by bacteria, nitrate is denitrificated. Based on a regional hydraulic and geochemical characterization of the entire aquifer system the presented approach spatially distinguishes good nitrate retention under reducing conditions and low denitrification rates under oxidizing conditions in different gradual classes. The results are very sensitive with respect to multitude of dynamic external influences affecting the ecosystem service potential of redox controlled aquifer systems. The degradation process is not infinite and depends on the chemical reduction capacity of the aquifer system – controlled by the availability of organic material – and the flow dynamics of the underground (Hansen *et al.,* 2014; Merz *et al.,* 2009). Observations indicate that due to increasing nitrate flux latent oxidation processes in the aquifer system occur connected with negative impacts of the groundwater redox state. Groundwater head dynamics with a trend to decreasing groundwater recharge rates are triggering this process affecting the reduction potential for nitrate and the dynamic interactions between groundwater and surface water (Böttcher *et al.,* 2015).

Conclusions

Due to the high system complexity, involved hydraulic-geochemical processes do not allow a simple, linear interpolation of the future development. There is a substantial uncertainty in the future magnitudes and rates. Therefore, the presented approach of redox based catchment-scale nitrate modeling focuses on a clear cause and effect analysis including balancing of subsurface flow and substance dynamics in agricultural landscapes under different land use practices. The spatial accuracy can be adapted according to the available data base with regard to structure, numerical format, spatial resolution and complexity of the joining numerical models – simulating transport und geochemical reactions. This system approach will help getting a realistic imaging of the nitrate contamination path together with an assessment of the buffer capacity of the redox system as an ecosystem service under pressure of climate change and land use influence.

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Consequences of decreasing atmospheric sulfur depositions on sulfur supply and fertilization of narrow leaf lupin

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Introduction

High seed yield and symbiotic N_2 fixation rates of grain legumes can only be achieved with adequate nutrient supply, as is the supply of sulphur (S). The N_2 fixation rate of legumes is tightly linked to a sufficient supply of S to the plant (Lange, 1998). The S supply of the plants via atmospheric inputs decreases significantly in many regions of the world. The main reason is declining S emissions since the 1970s and 1980s in many parts of the world, including Europe (Pedersen *et al.*, 1998). These diminishing atmospheric S deposits have led, inter alia, to S deficiency in plants (Scherer, 2001). Information on the amount of S content in grain and straw, as well as absolute demand per hectare of narrow leaf lupin have not yet been studied from field trials. For this reason, the S uptake by narrow leaf lupin was investigated in field trial series.

Materials and Methods

In the years 2012–2014, field trials were conducted at several sites in Germany investigating the S fertilization of narrow leaf lupin on long-term (> 10 years) organically farmed arable land. The field trials were carried out in the randomized block experiment with four replications. The fertilizers Kieserite - $MgSO_4$ (K), Gypsum - $CaSO_4$ (G) and Elemental S (E) were applied before sowing (40 kg S ha^{-1}). In addition, a leaf fertilization with Epsom salt - $MgSO_4$ (B), was performed at three dates between BBCH 31 and BBCH on 60 of the lupins (total application 8.4 kg S ha^{-1}). To compare the results also a control variant not fertilized with S was used (O). The narrow leaf lupin (cv. Boregine) was sown at seed density of 95 germinating seeds m^{-2}.

Results and Discussion

Under the given environmental conditions, the fertilization of narrow leaf lupin did not increase seed yield. Average of S accumulation in the shoot of the lupin was only 12.0 kg ha^{-1} to 13.7 kg ha^{-1}. The bulk of the absorbed sulphur was accumulated in the straw of the lupin (average S harvest index: 0.42). The N/S ratio required for optimum growth in the youngest opened leaf at flowering of the lupin was about 20% (S content: 0.24% S in DM). The low S requirement of the lupin was fully covered by plant-available sulphur from the soil, as well as atmospheric sulphur deposition in all tested environments. The apparent S recovery from the fertilizers Kieserite, Gypsum and Epsom salt was comparatively low and amounted to 3.6%, 2.9% and 11.6%, respectively. Fertilization with Kieserite, Gypsum and Epsom salt resulted in a partial significant increase in the S content in the seed and straw of the narrow leaf lupin, as well as in a partly significant narrowing of the N/S ratios in the plant. On the other hand, elemental sulphur was not able to increase the S content in the plant during the year of application.

Conclusions

Under the environmental conditions of the conducted experiments, the fertilization of narrow leaf lupin with various S containing fertilizers did not increase seed yields. In comparison to soybean (Devi *et al.*, 2012), the low S requirement of the narrow leaf lupin was apparently adequately covered by the content of plant available sulphur from the soil, as well as the atmospheric sulphur deposition. In addition, plants such as the narrow leaf lupin also fits the S uptake to their physiological requirements (Hawkeford and de Kok, 2006), what explains the low apparent S recovery of the generally adequate S fertilizers Kieserite, Gypsum and Epsom salt (Devi *et al.*, 2012; Eriksen *et al.*, 2002; Pekarskas and Spruogis, 2008; Vrataric *et al.*, 2006). However, Kieserite, Gypsum and Epsom salt are suitable to increase the S content and the S accumulation in the plant, although not always significantly, and to narrow the N/S ratio. Elemental sulphur, on the other hand, is not suitable to increase the S content in the plant, even in the case of the narrow leaf lupin, in the year of application, what is also confirmed by other researchers (Jolivet, 1993; Pedersen *et al.*, 1998; Wen *et al.*, 2003).

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A proposal to enhance ecosystem services provision in rural landscapes – a study case in Brazil

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Introduction

The agroecosystem concept can be used to analyze food systems as wholes, including their complex sets and outputs, as well as the interconnections between their components, resulting in benefits for the whole system (Gliessman, 2006).

A term that has been widely used to indicate the many functions and benefits provided by agroecosystems is "multifunctional agriculture" (MFA).

The multifunctional capacity of agroecosystems is directly linked to the provision of ES, defined as the benefits people obtain from ecosystems. The Food and Agriculture Organization of the United Nations (FAO, 2011) stresses that healthy ecosystems provide a variety of vital goods and services that contribute directly or indirectly to human well-being, in economic, social and environmental spheres.

Although agroecosystems may have low ES values per unit area, when compared with other ecosystems, they offer the best chance of increasing global ES – given the proportion of land devoted to agriculture worldwide – by defining appropriate goals for agricultural and land use management regimes that favor the provision of these services (Porter *et al.*, 2009). In other words, it is possible and essential to improve ES provision from agriculture through agricultural management practices.

Hence, the objective of this work is to present an approach to evaluate soil functions in agroecosystems and their impact on environmental services (ES).

Materials and Methods

The case study is the Pito Aceso watershed, located in the mountainous region of Rio de Janeiro State – Brazil. This area is a typical landscape of this region, with a mosaic of land use types and steep relief.

A framework that established the link between agroecosystems and ES provision was developed, considering the criteria of management and agroecosystem establishment in the study area. A set of soil parameters that can be used as indicators to monitor the changes in the agroecosystems was also considered in this framework.

The criteria for the agroecosystem development were based on existing knowledge of the site associated with gathered information through interviews with farmers and further stakeholders, and small field studies on social, economic, environmental and agricultural aspects.

Results and Discussion

A matrix that evidences the relationship among the criteria for the establishment and management of the agroecosystems, in the study areas, and the environmental services (ES) types, soil functions, potential soil indicator, ES benefits, and policy relevance was created (Table 1).

Some results showed that ES types more affected by deployment and management of agroecosystems are supporting and provisioning services, what demonstrated the potential of agriculture management provide multiple services besides food, fiber and energy. "No fire use" and "agricultural consortium" were the criteria for deployment and management of agroecosystems with higher potential for increasing ES provision and biomass stock in soil and litter was the soil parameters to be used as indicator to monitor the impact (Turetta *et al.*, 2016).

Table 1. **An example of the matrix – the whole matrix can be found in Turetta *et al.,* (2016).**

Criteria	ES type			Associated soil functions	Soil parameters or potential soil indicator	ES benefits
	provisioning	supporting	regulating			
No fire use	+++	+++	+++	Water infiltration/ Habitat	Soil porosity; bulk density; and others	Co2 mitigation; and others

Conclusions

1. Agroecosystems represent a way to practice multifunctional agriculture, as well as a source of environmental services (ES) provision; 2. An approach to assess soil functions in agroecosystems and their impacts on ES provision should consider as criteria the establishment and management of agroecosystems, taking into consideration the specificities of each area and a set of indicators to monitor changes.

Acknowledgements

To Empresa Brasileira de Pesquisa Agropecuária (Embrapa, project No. 02.12.01.03500.00), for financial support.

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II. Land Use and Governance
Managing Ecosystem Services and Biodiversity at the Landscape Scale

Scientific Committee

Leon Braat (Wageningen University & Research, The Netherlands)

Brendan Fisher (University of Vermont, USA)

Adrienne Grêt-Regamey (ETH Zuerich, Switzerland)

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Sustainable use of agricultural landscapes requires research on land use strategies at the landscape scale that focusses not only on the provision of agricultural commodities, but also on the provision of ecosystem services and biodiversity by means of adapted management and governance approaches. The integration of diverse societal preferences at the landscape scale can reveal and thus help to avoid or minimize land use conflicts.

This session addresses the fundamental questions: a) if and how can agricultural landscapes be managed and governed under economic pressure, and b) which innovations in land management and social systems support the development of multifunctional landscapes?

Session Keynotes

Christine Fürst (Martin Luther University Halle-Wittenberg, Germany)

Brendan Fisher (University of Vermont, USA)

Session Chairs

Sonoko Bellingrath-Kimura (ZALF, Humboldt University of Berlin, Germany)

Bettina Matzdorf (ZALF, University Hannover, Germany)

Oral Presentations

Keynote: can we derive “optimal" governance strategies for co-developing land use and governance approaches?

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My presentation will build on the process in IPBES (Intergovernmental Panel for Biodiversity and Ecosystem Services, Region ECA, Chapter 6) and experience of how the assessment of land use impacts needs to be transformed to inform diverse actor groups in a way that provides them equal access to decision making processes through digestible knowledge that they can use for argue their point of view on decision processes. I wish to question the reliability of recommendations for specific governance approaches as these would require fixing preferences of actors for the one or other way to be involved. Fluctuations in the actor environment, economic and political drivers at multiple scales, learning processes and generation changes lead to high dynamics in how actors feel addressed, wish to be involved, accept and engage in diverse governmental and non-governmental governance approaches to develop multifunctional landscapes. Consequently, permanent interaction, time investment in establishing long-lasting actor-interactions, low-threshold information distribution and closeness to societal processes are key requests to coordinate in a societally positively perceived manner the development of agricultural landscapes so that these provide sustainably currently and prospectively demanded services and benefits to all related actors.

Impacts of environmental changes on the provision of agricultural ecosystem services under different climate and land management scenarios

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Introduction

Agroecosystems provide us with a wide range of ecosystem services (ESS), including provisioning, regulating, supporting and cultural services (Power, 2010). The collaborative research project COMTESS (Sustainable coastal land management: Trade-offs in ecosystem services) investigates the impact of climate change, sea level rise and different land management options on ESS provision by extensively and intensively used landscapes along the German North and Baltic sea coast.

Materials and Methods

A chain of hydrological, ecological and socio-economic models predicts the impact of changing climate, sea level and land use on hydrology, species composition and eventually ecosystem service provision of four study regions from 2010 to 2100. We compare four land management options (LMOs): trend (business as usual, i.e. mainly dairy farming), stakeholder-based (co-developed with local stakeholders; very similar to trend), carbon sequestration (reduced pumping raises groundwater levels; reed growth in wet areas sequesters carbon) and multiple land use (similar to carbon sequestration, but reed is harvested). We consider ESS as vegetation-mediated (e.g. forage production) or directly depending on hydrology (e.g. reduced flood risk due to retention of excess water in polders). Vegetation-mediated services are modelled depending on the distribution of individual plant species (statistical species distribution models). Plant traits, i.e. the community-weighted mean (CWM) of the resulting species composition on a site, are then related to ecosystem services (e.g. fodder marginal income is related to the CWM of species-specific grassland utilization indicator values).

Results and Discussion

Our simulations show that despite the projected decrease of precipitation in the region until 2100 (WETTREG; Enke *et al.*, 2005), rising sea levels (1.05 m linear sea level rise assumed until 2100; Grinsted, 2015) will lead to excess water which needs to be pumped into the sea if groundwater levels are to be kept at their current levels in the trend and stakeholder-based management options (FEFLOW; Kliesch *et al.*, 2016). While increased pumping can compensate rising groundwater levels, it cannot mitigate salinity increases as a result of higher evapotranspiration due to warming temperatures (WETTREG; Enke *et al.*, 2005). The resulting environmental changes (Figure 1a) affect ESS provision differently in alternative LMOs (Figure 1b).

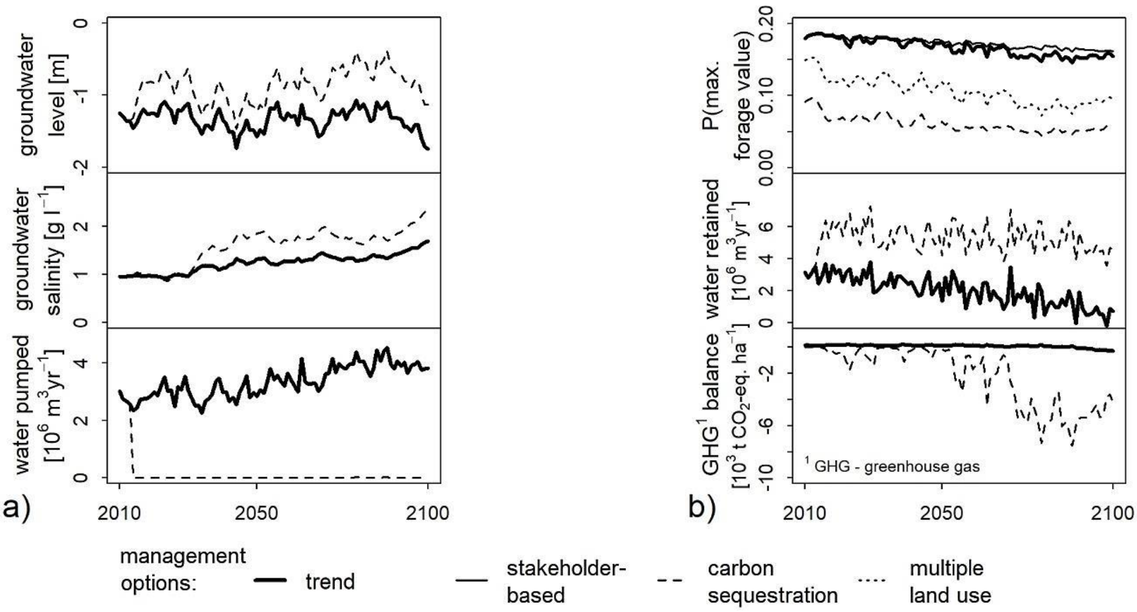

***Figure 1*. Simulated environmental changes (a) and their effects on ecosystem service (ESS) provision (b) as area-weighted means for scenario region Michaelsdorf at the German Baltic Sea coast for emission scenario A2 and 1.05 m sea level rise. Note: for hydrological conditions and ESS, trend equals stakeholder-based and carbon sequestration equals multiple land use, as these are only further distinguished by land use intensity.**

Conclusions

Our spatiotemporally explicit quantification of ESS provision allows analyzing trade-offs between individual ecosystem services (Cebrián-Piqueras *et al.*, 2017) as well as comparing alternative land management options over time (Figure 1b).

Acknowledgements

The collaborative research project “Sustainable coastal land management: Trade-offs in ecosystem services” was funded by the German Federal Ministry of Education and Research (grant number 01LL0911).

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Use of spatially explicit census data of grassland intensities for holistic ecosystem service mapping

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Introduction

Grasslands play a critical role in providing ecosystem services (ES) such as fodder for livestock production, carbon storage or landscape maintenance. Grassland intensity highly influences the level of ES provision. Scientific analyses including mapping exercises often do not consider intensity levels in the assessment of grassland ES (Lavorel *et al.,* 2017) or focus on policies addressing single ES (Huber *et al.,* 2017). In this context, we here analyze the spatial distribution of multiple ES in Swiss grasslands, along a gradient of management intensity.

Materials and Methods

In our analysis, we study five ES indicators, extracted from diverse sources, from field campaigns including quality and quantity of forage, CO_2 fluxes, soil erodibility, bee abundance, water regulation index and landscape diversity index (Table 1). To assess the spatial distribution of these indicators, we use spatially explicit census data from two Swiss Cantons (Zürich and Solothurn) that give information about the observed location of grasslands parcels and their management practices.

Table 1. **Grassland ES, indicator and data source.**

Ecosystem service	**Indicator**	**Data source**
Food production	Fodder quantity (dt/ha)	Swiss field data (Census data)
Pollination	Bee abundance	BioBio (Lüscher *et al.*, 2016)
Climate regulation	CO_2-Fluxes (gC m^{-2})	FLUXNET (https://fluxnet.fluxdata.org/)
Water regulation	Water exchange (index)	
Habitat/Biodiversity/Landscape	Shannon diversity (index)	SALCA & BioBio (Lüscher *et al.*, 2017)

For two management regime (meadows and pastures) and three intensity levels (intensive, less intensive, extensive), we calculate the supply of the different ES. These calculations comprise both expected levels of ES provisions as well as the variabilities of these provisions over time and space. We also calculate additional ES indicators on landscape level such landscape diversity (e.g. Grêt-Regamey *et al.*, 2013). We then map the estimated values for each management intensity on the available census data.

Preliminary Results

Results are based on a grassland typology based on their management characteristics. They show the supply of ES indicators supply, diverse in terms of their associated issue (direct economic or ecological benefits), biophysical processes and their spatiotemporal variability, in grassland-dominated landscapes and highlight the impact of management practices (Figure 1).

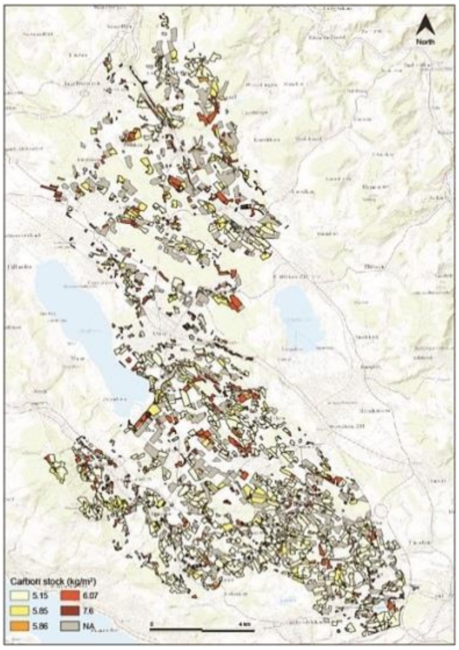

Figure 1. **Spatial distribution of vegetation carbon stock in Canton of Zürich (very preliminary results).**

Conclusion

Our study addresses a set of provisioning, regulating and cultural ES. It constitutes a first important step in a more comprehensive analysis of the impact of land-use intensification on grassland ES supply. The investigation of the spatial distribution of ES supply at the landscape level in combination with an economic valuation should support the development of innovative policy and governance measures such as auctions or payments for ES (Meyer *et al.*, 2015; Uthes and Matzdorf, 2013).

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Site and management situation of heterogeneous fen grassland in northeast Germany

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Introduction

Fen grasslands are the predominating grassland type in northeast Germany. During long periods of intensive drainage, large fen grassland areas in Brandenburg were developed on former plain mires on sandy subsoil of very varying elevation causing varying thicknesses of the shallow (0.6 – 1.2 m) top peat layers too. Peatland subsidence resulting from consolidation, shrinkage (compaction) and mineralization in temperate regions amounts to 2–25 mm per year, depending on site conditions (peatland type, peat type, hydrology and climate), drainage intensity (time, duration and depth of water level drawdown) and land use (grassland or arable use) (Mundel, 1976; Schothorst, 1977; Lehrkamp, 1987; Eggelsmann, 1990). It significantly complicates the water management and the grassland utilization. In the paper the grassland situation of a typical heterogeneous fen site near Paulinenaue (northeast Germany, 52 o 68′N, 12 o 72′E, mean annual temperature 9.2°C, mean annual precipitation 534mm), which is drained and used since 1718, is described and evaluated.

Materials and Methods

The actual surface profile of the former plain site was derived from a digital elevation model DGM 2 (LBGR, 2014). The peat soil profile was described according to the German soil description guideline “Bodenkundliche Kartieranleitung KA5” (AG Boden, 2005). The above ground biomass was harvested and analysed by the NIRS method.

Results and Discussion

Within the pasture site, the soil characteristics (Table 1) changed with a different intensity leading to soil types with different peat layers (thickness, C content and physical structure). Depending on the resulting soil conditions, the surface elevation varied by 0.6 m (29.1 – 28.5 m a.s.l.). Depending on the current surface elevation, the site characteristics varied between ‘wet’, ‘moist’ and ‘moderate moist’, causing a different forage quality of the varying plant communities in the grass sward (Table 2).

Conclusions

As a result of the long term drainage and depending on the varying peat layer thickness above the varying subsoil elevation, the decline of the site elevation was very heterogeneous within the pasture site. Beside the different soil characteristics, mainly the actual elevation variation caused different groundwater tables and, therefore, different growth conditions for the fodder species within the grassland sward.

Therefore, the grassland situation of pastures on those fen sites is very heterogeneous. There is a risk to overestimate the contribution of parts of the pasture to the animal nutrition. A uniform management of such heterogeneous pastures seems to be impossible. Spatial knowledge on the forage quality is a precondition for the management where precision farming methods should be proofed and integrated.

Table 1. **Soil profile at different elevations within the pasture site.**

Site	Soil typ	Horizon[1]	Parent material[1]	C_{org}, (M.%)
'wet'	Eutric Histosol – 'Erdniedermoor'	nHv	og-Ha	43.17
	(Profile No. 28)	nHa	og-Hnr	46.76
		nHw	og-Hnr	51.05
		nHr	og-Hnr	48.15
'moist'	Eutric Histosol – 'Erdniedermoor'	nHv	og-Ha	32.04
	< 0.7 m peat layer thickness	nHa	og-Ha	33.39
	(Profile No. 27)	aGhw	fo-mS	8.26
		aGo	fo-mS	0.22
‚moderate moist'	Eutric Histosol – 'Mulmniedermoor'	nHm	og-Ha	16.29
	< 0.7 m peat layer thickness	nHa	og-Ha	17.65
	(Profile No. 30)	fFw	fl-Fms	9.63
		Go	fo-mS	0.15

1 abbr. based on AG Boden (2005)

Table 2. **Forage quality data in the different parts of the pasture site (Tukey, p<0.05, different letters indicate significant differences).**

Pasture part		wet	moist	moderate moist
Main species		*Juncus articulates, Carex hirta, Alopecurus geniculatus*	*Phalaris arundinacea, Poa trivialis*	*Elymus repens, Holcus lanatus*
Forage quality				
XP	g kg DM^{-1}	135.5^a	127.0^a	116.6^a
ADF	g kg DM^{-1}	334.0^a	310.5^b	342.8^a
ME	MJ kg DM^{-1}	9.05^a	9.72^b	9.23^a

XP – crude protein, ADF – Acid detergent fibre, ME – Metabolizable Energy

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From global to local – addressing future landscapes view and features migrating global agroecoloical zones to local agroecoloical zones

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Introduction

The well-known and clear main role and service of Cropland ecosystems and landscapes is to provide Food. At the same time that food should be in **sufficient Quantities** to feed the constantly growing population and at the same time should be of **adequate Quality** to provide us with the healthiest way of life. And last but not least, this food must be provided and must be available both today and in the future – **Sustainability**.

These three "simple" requirements can be achieved only if they are provided the best possible conditions for their implementation – utmost compliance of local ecological diversity with crop requirements. It is well known that most of our food initially comes from soil – directly or indirectly. This circumstance makes the soil extremely valuable and indispensable resource in our survival. Based on this we will try to present our vision of how to reach the desired quantity and quality of food in sustainable way by analyzing and providing the best possible growing conditions for crops to the prevailing local ecological conditions – including most suitable and critical factors for crop productivity, or with other words to shrink the concepts of Global Agro-Ecological Zoning[1] to Local one.

Materials and Methods

We used our detailed field data available on the characteristics of the soil units, climatic and topographic conditions and compared them with the requirements and needs for the growth not only of the main agricultural crops grown in the country but also of alternative culture to respond adequately to changing climatic conditions. Most of our data was successfully migrated from field records, field soil maps, climatic records and hard copy topo maps into GIS environment, so that in consequence this information can be easily processed, modeled and presented.

As Mr. Alan Matthews said at the second debate on the future of the CAP based in Sofia in September 2017: "We cannot escape from climate change." In this regard, no matter how well a farm is built, how well the crops are cultivated traditionally, the methods of soil cultivation are applied and the formation of agricultural landscapes are established, etc., some changes, depending on climate change will be quite visible. Drought and loss of soil fertility will lead to a change of basic crops with more dry-dwelling ones, the soil management practices and cultivation techniques will also change, and the agricultural landscapes will be transformed as a whole.

It is therefore important to carry out a very detailed and accurate analysis of the environment on the suitability and rearing of a different set of crops to ensure easy migration from one type of crop to another without greatly affecting farm development, landscapes formation and food supplies as general.

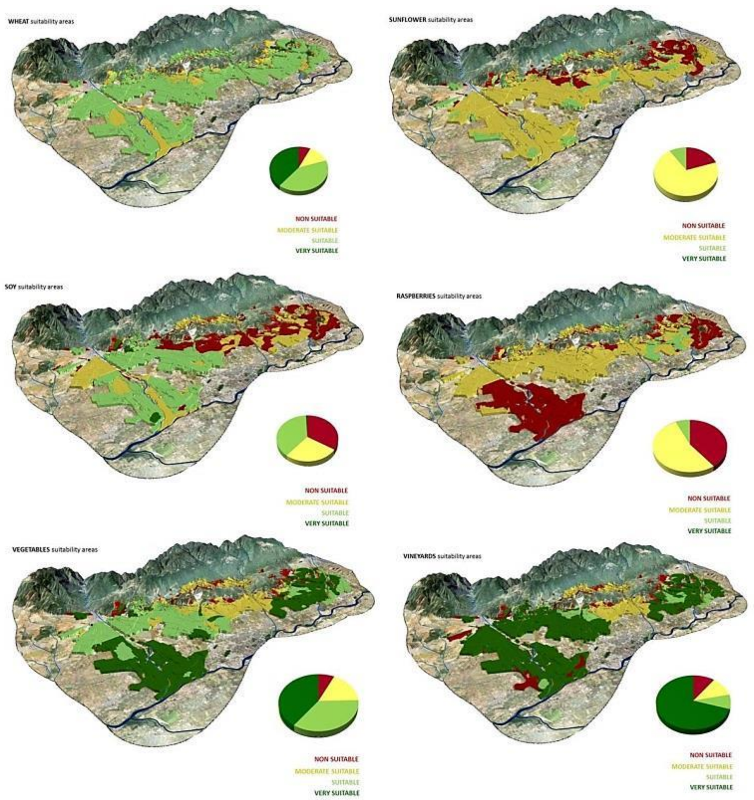

***Figure 1*. How the landscapes change their appearance depending on their suitability for different crops growing (pilot region "YAKATA" – part of Thracian valley – South Bulgaria).**

Results and Discussion

As a result we received many interesting and useful maps (including and 3D view) with precisely defined areas and landscapes of the territory with high natural potential for growing a particular type of crop on the one hand, and on the other there were outlined unsuitable and areas with more or less constraints for other species growing.

Conclusions

These suitability maps could be used as an indispensable tool in the planning, addressing and implementing the new CAP measures; source of assessment, mapping and valuation of agricultural Landscapes and ecosystem services; and as they are inspired by existing nature potential, they could even be a tool for planning and applying the sustainable Nature Based Solutions in agricultural landscapes.

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Measuring biodiversity driven ecosystem functions at the landscape scale – Impacts of landscape heterogeneity, biotope elements and land use

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Introduction

Biological diversity in European agricultural landscapes is under strong decline. Projections of future development predict further declines (Pereira *et al.,* 2010). Industrial agriculture enabled high productivity often results in negative effects on biodiversity (MEA, 2005). Quantifying and monetarizing the value of biodiversity through its contribution to agroecosystem functions (ESF) is a new attempt to draw the attention of the existing feedback loops between agricultural production and biodiversity.

Landscape heterogeneity, biotope elements and land use intensity are some of the key impacts on biodiversity. With the present approach, we try to quantify the impact of these factors not only on biodiversity but on their ecosystem function supply. Methods of the Rapid Ecosystem Function Assessment (REFA) (Meyer *et al.,* 2015) are used to quantify the supply of selected ecosystem functions empirically. Using REFA methods allows to measure the ecosystem functions directly. Doing so avoids over/under estimation of ESF as occurring by indirect estimates (e.g. trait related indication).

Materials and Methods

Field investigations have been carried out in the AgroScapeLab Quillow, an entire watershed located in the northeastern German lowlands from 2015 till 2017. The region is a typical agricultural area of 250 km^2 size. Within this area, single arable fields have been selected for the investigations based on a preliminary landscape GIS analysis regarding landscape heterogeneity gradients, the occurrence of two typical regional biotope elements (kettle holes and hedges) and information on the land management practices. The selection of study sites was related to the following factors: A – landscape heterogeneity (2 levels); B – adjacent biotope element (kettle hole, hedge and control); 3 – land use (2 levels of crop –pre crop combination). On each single field plot transect (with 5 levels) have been arranged from the adjacent biotope towards the middle of the field to identity the spatial range of the particular edge effects. The analyses of ESF focused at multiple aspects of biomass production, nutrient supply and pest control. The investigations followed REFA (Meyer *et al.*, 2015) method suggestions.

Results and Discussion

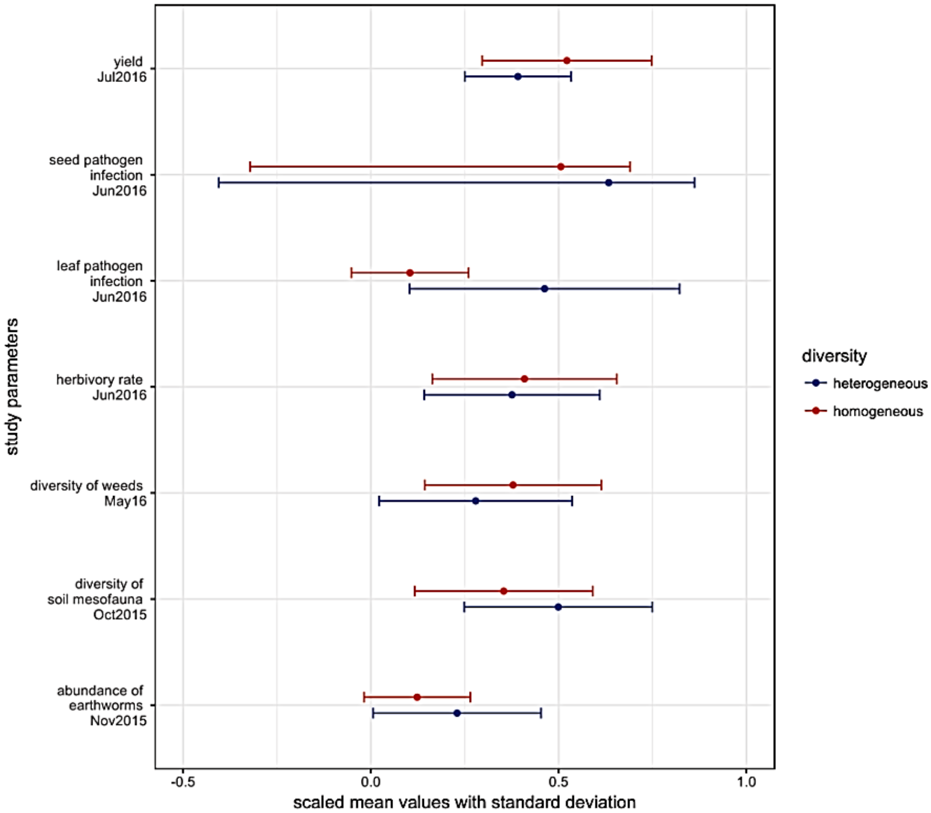

***Figure 1*. Summary graph for the impact of landscape heterogeneity on selected ESF functions from field measurements in 2016 (single ESF parameters are standardized).**

Conclusions

The first results draw a puzzled picture for the singular ESF and the investigated factors. The applied methods served well and are feasible for quantifying ESF supply empirically. Measuring ESF directly may improve ESF assessments by avoiding over/under estimation of impacts. The results are integrating numerous interactions as typical for the landscape scale and agrarian land use impacts and thus provide more realistic insights.

Acknowledgements

The investigations are part of the BiodivERsA/FACCE project "BASIL" (Funding body in Germany is the Ministry for Education and Research).

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How biodiversity services of farms can be recorded, evaluated and visualized in a practical way

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Introduction

For decades, a continuous loss of species diversity in agricultural landscapes has been observed (Stoate *et al.*, 2001). By now, food companies and retailer have begun to discover the importance of biodiversity issues for their policies (Kempa, 2013) due to the consumer's increasing demand for green products. Food companies are aware of the crucial role that farmers play in preserving and promoting species diversity since the farmer's decision about the local management intensity is one important aspect to conserve biodiversity in agricultural fields and adjacent habitats (e.g. Gonthier *et al.*, 2014). Thus, especially in order to ensure consumer trust, food companies demand a transparent, practical and reliable documentation of the biodiversity status on their supplier farms. Such information could be used for targeted marketing activities on the one hand and also to encourage farmers to achieve greater environmental improvements (Sybertz *et al.*, 2017) by adapted management. However, most existing valuation approaches are either very complicated and time consuming, e.g. due to detailed field surveys, or they are adjusted to assess individual farms by advisory services which complicates comparisons across different farms (e.g. Targetti *et al.*, 2014). Moreover, biodiversity on the farm also depends on the landscape context (e.g. landscape heterogeneity, site characteristics) (e.g. Bredemeier *et al.*, 2015) that is mainly outside the farmer's control (Stoeckli *et al.*, 2017) and is not yet systematically taken into account. The objective of the presented research is thus, to develop and test indicator sets for modelling on-farm species diversity that are applicable for different geographic regions in Germany. The resulting species and habitat assessments should be automated and therefore repeatable over time as well as comparable between farms.

Materials and Methods

Easily recordable key indicators of typical habitat types of the agricultural landscape were determined on the basis of an extensive literature review. This comprised both management indicators and indicators dealing with the landscape context. On this basis, indicator models were developed for the habitat types arable field, hedge and field margins as well as for the species groups vascular plants, birds and butterflies.

To validate these models, comprehensive on-site surveys were conducted on seven farms in different typical landscapes in Germany covering coastal to mountainous landscapes. Based on the previously defined indicators, 282 study sites – thereof 135 arable fields, 77 hedges and 70 field margins – have been examined for their species diversity on organically and conventionally managed farms.

For each species group, a multiple linear regression model with forward stepwise selection was designed to predict species numbers. Cross-validation was used to identify variables that best predicted the species diversity of the respective habitat type and variables that were relevant only for single study sites.

Based thereon, final linear regression models were computed for each habitat type using variables with the highest predictive value. The resulting simplified models were integrated into the management software MANUELA (German acronym for "Management system for nature conservation and sustainable agriculture") to ensure proper application in practice. To meet the requirements of practicability, periodic user tests were carried out with farmers and farm advisors.

Results and Discussion

The models are highly significantly correlated with the numbers of typical species that were recorded in the on-site surveys. Based on the statistical analyses, the relevance of the combined indicators could be specified and, thus, the models could be enhanced and much more simplified. Thereby, the practicability of information gathering has been strongly enhanced considering the reduced number of necessary indicators, many of which can be provided through existing farm data. The user tests revealed good basic functionalities of MANUELA and its opportunities for visualization of management measures and their effects.

Conclusions

The results show that it is possible to accomplish a sufficiently reliable and quantified valuation of biodiversity services of farms based on easily recordable information. The farms' achievements and changes in biodiversity performance can be documented in a result-oriented way and could be remunerated with little effort on this basis. This way, food companies gain a tool to document biodiversity services of their supplier farms and can easily integrate the results into their business strategies.

Acknowledgements

We thank all participating farmers and the companies HIPP, Bionade, Neumarkter Lammsbräu and Märkisches Landbrot for their support. The study was funded by the Deutsche Bundesstiftung Umwelt (German Federal Environmental Foundation) [AZ 31112].

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Enhancing farmland ecosystem services, productivity, and resilience-building at landscape level on European arable crops

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Introduction

A large variety of ecological enhancement measures like providing foraging and nesting opportunities for birds, establishing flower strips or hedges are recommended for use on farmland to increase agricultural biodiversity. However, research on benefits of these measures to agricultural productivity is limited (Bommarco *et al.*, 2012). Here, we aim at identifying those measures, which also enhance productivity and call them Agri-Resilience Enhancement Measures, hereafter AREMs.

Methods

Based on an exhaustive study of Dicks *et al.,* (2013), we analyzed 62 measures specifically suited for implementation within large arable field crops using defined selection criteria e.g., practical and cost efficient for use by farmers, serving many ecosystem services/species. Then ecosystem services upon which farming depends were identified according to the Millennium Ecosystem Assessment: soil fertility, soil erosion, pest and water regulation, and pollination (MA, 2005). Subsequently, based on further literature and practitioners' experience, benefits, trade-offs and synergies were elaborated on in an attempt to making transparent productivity and biodiversity interrelationships of each AREM against priority ecosystem services.

Results and Discussion

Across publications, AREMs are given different names and vary considerably in terms of length of time applied, management type, size, crop or context used in. Thus, their effectiveness depends upon multiple aspects. Nevertheless out of all measures referenced, five categories of AREMs could be identified (see Table 1). Despite the lack of research on the productivity gains of AREMs, and the lack of pan-European data some conclusions can be drawn: by example AREM-1 contributes to an increase in pollinators like bees, butterflies and hoverflies, leading to optimized pollination. This has been suggested by some studies to increase yield and produce quality for oilseed rape and sunflowers. In addition to enhancing the flow of farmland ecosystem services AREM implementation could contribute to facilitated machinery use, reduced labor costs or input costs, thus provide potential economic benefits. While it remains difficult to generalize and quantify AREMs' productivity benefits as they are part of a hugely dynamic agricultural system, uncertain disturbances and changes through urban expansion, habitat loss, climate change, and invasive species, all suggest some benefits to productivity and biodiversity alike.

Table 1. **Aggregated terms per AREM category that combines the names given to various single measures for use in-field and best suited for large arable crops.**

AREMs	Aggregated term given	Single measure term used	Potentially benefiting ecosystem services
AREM-1	Flower areas in-field	Flower strips, flower enriching measures, a multitude of different wildflower seed mixtures exists	SF; SER; WR; POL; some NPR; CS
AREM-2	Uncropped areas in-field	Fallow areas, crop edges, conservation headlands, untreated areas	SF; SER; WR; POL; some NPR
AREM-3	Extensively cropped areas in-field	Cereals in wide rows, sparsely sown areas in fields, with or without under-sowing (clover and/or a seed mix to enhance soil fertility and/or pollinators)	SF; SER; WR; POL; some NPR, some CS
AREM-4	Managed margins in-field	Buffer strips, creation of grassland verges, random strips, margins bordering sensitive sites, unsprayed field edges and headlands – either as habitat creation or dedicated to specific sites	SF; SER; WR; some POL; some NPR, some CS
AREM-5	Stubble fields over autumn and winter	In-field habitat measure for autumn and winter, especially valuable for various birds, mammals and insects	Some WR; POL; some CS

Abbreviations for ecosystem services used: soil fertility: SF; soil erosion regulation: SER; water regulation: WR; pollination: POL; natural pest regulation: NPR; cultural, aesthetic/ecotourism services: CS

Conclusions

It was concluded that over time and scale local benefits of AREMs could also contribute to resilience-building at landscape-level; these efforts have to be complemented by off-field (semi-natural habitats), urban, industrial, and other land ecosystems enhancements and wildlife protection measures. Increasing promotion and simplifying communication of proven benefits of AREMs to farm productivity rather than only focusing on their ecological benefits would increase acceptance and uptake by farmers.

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Ecosystem services assessments on N cycling of China

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Introduction

The nitrogen (N) cycling has supported the basic material and food for the increasing population. But it also caused a range of ecological and environmental problems, such as: water eutrophication, soil acidification, biodiversity decreasing, and so on (Winiwarter *et al.,* 2010). In China as the developing of agriculture, a great amount N fertilizer has been used which caused very strong N pollutions (Cui *et al.,* 2013). The chemical N input amount in China reached to 35% of total global chemical N fertilizer (FAO, 2014; Liu *et al.,* 2013). This high input N is profoundly affecting the ecosystems. However, we could not neglect that the nitrogen cycle in China also bears the important mission of food security for the world's five per cent population. So, it is very important issue to evaluated N ecosystem services on N cycling in China.

Materials and Methods

To assess ecological services of Chinese N cycling, this study established a model by integrating biological processes models and social-economical models using a great amount of published work. Based on the model, Chinese N cycling ecological services have been evaluated that covered provisioning service and regulating service.

Results and Discussion

Firstly, for provisioning service, the production of agriculture, forestry, animal husbandry and fishery has been greatly improved, and the gross domestic product (GDP) increased 23, 34, 68, 197 times, respectively. The changed N cycling in China promoted national life from poor food into rich food.

Regarding regulating service, the damage capacities of terrestrial habitats, ground water quality, surface water quality and air quality have been employed. For the period of 1970's, it assumed the terrestrial habitats, ground water quality, surface water quality and air quality have not any damage due to little industry or chemical fertilizer used in China. But the current regulating services were facing a serious damage. In national scale, the damage index was 48%, 12%, 61% and 10% for terrestrial habitats, ground water, surface water and atmosphere, respectively. For the spatial distribution, the east area higher than west region, the coasts region higher than the inland area. Particularly in the surrounding areas of Bohai Region, Yangtze and Pearl River deltas, the damage index was much higher than other region.

The main N air pollution was from livestock and chemical fertilizer to stimulate ammonia vitalization as well as the burning of coal, diesel, crop straw and fire-wood for contribute to nitrogen oxides emission. The damage of terrestrial habitats would contributed by high N deposition, and the NH_x-N was higher than NO_x-N. Even the agriculture showed a big input N in water, but industry, domestic sewage and landfill were the significant point N pollution sources for both surface water and ground water.

In the future of China, population will continue increasing and national life will keeping improve. The anthropogenic reactive nitrogen input consequently would still increase. So, to mitigation N environmental pollution will be a long-term strategy for sustainable development.

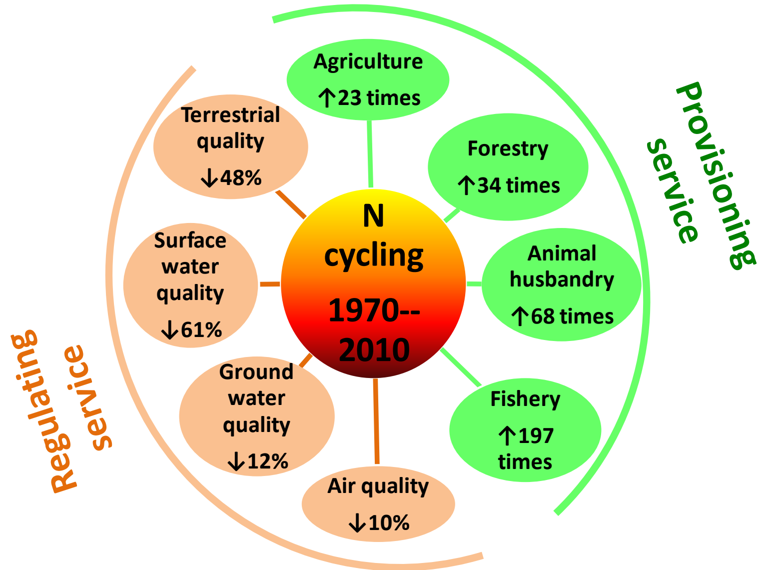

Figure 1. The changed N ecological services of China from 1970 to 2010.

Conclusions

The results showed that the ecological services of N cycling in China was significant changed since 1970's. The production of agriculture, forestry, animal husbandry and fishery has been greatly improved, and the gross domestic product (GDP) increased 23, 34, 68, 197 times, respectively. But the current regulating services were facing a serious damage. In national scale, the damage index was 48%, 12%, 61% and 10% for terrestrial habitats, ground water, surface water and atmosphere, respectively.

Acknowledgements

We would like to thanks professor Miao Chang from Tsinghua University for the valuable suggestions and all the members of professor Tianzhu Zhang lab for their economical technique help.

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Maximze the balance! – Optimizing trade-offs between ecosystem services and biodiversity in agricultural landscapes

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Introduction

Quantifying the impact of human land use on ecosystem services (ESS) and biodiversity is one of the main tasks in current environmental research. Most land use planning studies focus either on biodiversity conservation or agricultural production and other, i.e. water- and soil-related ESS. Only few studies look at the relationship between agricultural production and biodiversity. To fill this research gap, our study aims at identifying the optimal trade-offs between three different ESS and biodiversity in an agricultural area in the Lossa-Basin, which is part of the Mulde-Saale-Basin in Central Germany.

Materials and Methods

ESS trade-offs can be determined by solving a multi-objective optimization problem. In our case, the four objectives were to maximize agricultural production (crop yield), water quality (nutrients, sediments), water quantity (environmental flow) and biodiversity (birds, habitat structure). Agricultural production, water quality and quantity were modelled with the Soil and Water Assessment Tool (SWAT) (Arnold and Fohrer, 2005) (Figure 2); whereas biodiversity was represented by a bird indicator that was specifically developed for the project (Figure 1), and by considering linear elements in the landscape. During a stakeholder workshop we allocated different land uses according to three scenarios (business as usual, land sharing, land sparing). The results were partly used to define the decision space of the optimization problem. SWAT and the biodiversity model were then coupled with the optimization tool CoMOLA (Strauch *et al.*, 2017), which is based on the non-dominated sorting genetic algorithm II (NSGA-II) (Deb *et al.*, 2002), taking into account land use specific transition rules and total area rules.

Results and Discussion

We obtained a multi-dimensional Pareto frontier of optimal land use strategies which illustrates the best possible trade-offs between all objectives. Additionally, we compared the set of Pareto-optimal solutions to the three scenario solutions and thus identified potential solutions that improve the current as well as the different scenario land use configurations.

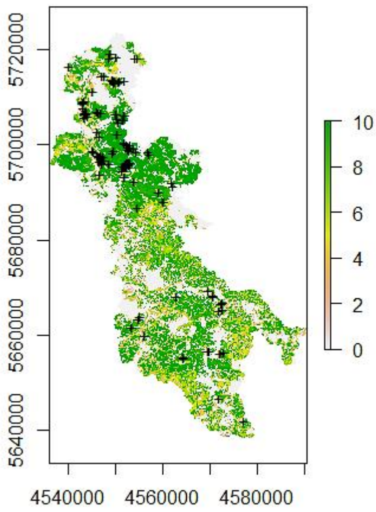

Figure 1. **The biodiversity indicator is based on suitable habitats within the study area for different bird species. As an example, the map shows the suitable habitats for the whinchat before the optimization.**

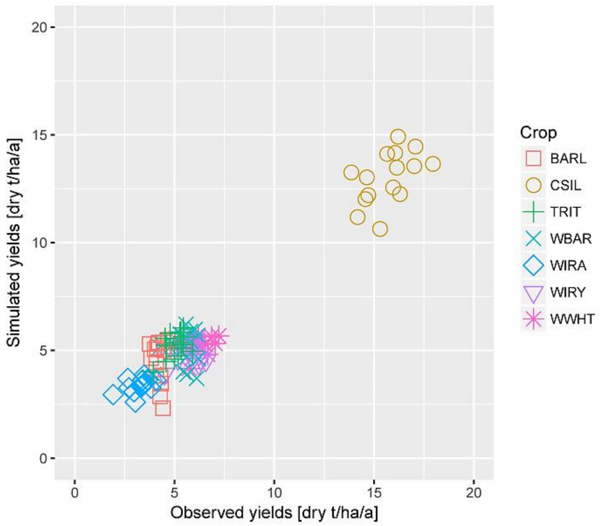

Figure 2. **SWAT modelling results for agricultural production showing observed and simulated yields of seven crops for 15 years (i.e., 15 points per crop). BAR – spring barley, CSIL – silage corn, TRIT – triticale, WBAR – winter barley, WIRA – winter rape, WIRY – winter rye, WWHT – winter wheat.**

Conclusions

Especially by including stakeholder knowledge and explicitly integrating biodiversity, this study supports decision makers in finding realistic solutions for sustainable landscape planning and agricultural management.

Acknowledgements

This research was funded through the 2013/2014 BiodivERsA/FACCE-JPI joint call, with the national funder BMBF – German Federal Ministry of Education and Research (Project "TALE – Towards multifunctional agricultural landscapes in Europe: Assessing and governing synergies between food production, biodiversity, and ecosystem services", grant 01 LC 1404 A).

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A model based assessment of the trade-offs between provision of agricultural commodities and other ecosystems services

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Introduction

Historically landscape management has focused on efficient production and the reduction of environmental pollution. Increasingly, however, farmers are minded to manage their fields to reduce the depletion of natural resources (such as soil carbon) and enhance the provision of wider ecosystem services such as biodiversity. Schemes to monitor or assess land for these factors are prohibitively expensive and complex, and yet there is a need to analyse modern agricultural systems for the purposes of policy, planning or management. Here computer simulation models have a role to play, for they can predict outcomes from a large range of scenarios and explicitly quantify important indicators.

We are developing a spatially explicit model that can simulate the essential processes of soil, water, crop growth and biodiversity for agricultural landscapes in the Northern Europe. The model can be used to explore important questions related to landscape management, such as whether a degree of co-operation between farmers within a landscape could result in better delivery of ecosystems services. We have used this model to understand the trade-off between ecosystems services (including production) and biodiversity. Here we report on a version of our model that integrates agricultural production, water movement, nutrient flow and weed species diversity in a landscape.

Materials and Methods

To model our landscape, we impose a grid where each field is represented by one or more grid cells. Within each cell we simulate crop (including most major cereal crops, potatoes, onions and sugar beet) and weed growth, the dynamics of soil water, soil organic carbon, changes in bulk density and nutrient flows. The weed simulation model takes a novel trait-based approach which allows us to parameterize the model to predict the dynamics of 138 annual weed species. This will allow us to model the effect of weed management within fields on higher trophic groups at landscape scale. Water and nutrients can move laterally between cells, as well as vertically though the soil profile. For more details see Coleman *et al.,* (2017) and Storkey *et al.,* (in preparation).

We coupled the simulation model with an optimisation algorithm to determine Pareto optimal fronts between multiple objectives defined in terms of outputs from the model, for example yield and nitrate leaching. The optimization combines non-dominated sorting (Deb *et al.*, 2002) with differential evolution (Storn and Price, 1997).

Results and Discussion

Figure 1 illustrates the use of the model to identify trade-offs between multiple objectives. The model allows us to explore trade-offs between production and environmental outcomes to determine strategies that could contribute to sustainable food production. It accounts for feedbacks in the system and so has the capacity to identify unintended consequences of land management.

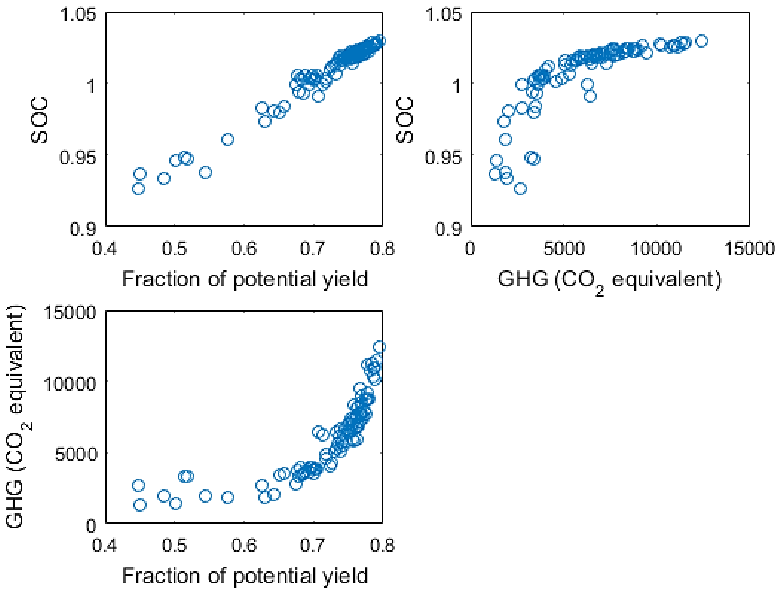

Figure 1. **Illustrative example of use of the model to identify trade-offs between multiple objectives such as maximising yield, minimising greenhouse gas emissions and maximising SOC.**

Acknowledgements

This research was funded by the Biotechnology and Biological Sciences Research Council (BBSRC) ISPG project quantifying sustainable systems and the Achieving Sustainable Agricultural Systems (NEC05829 LTS-M ASSIST) funded by BBSRC and NERC using facilities funded by the BBSRC and also partly by NERC grant NE/J011568/1

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Assessing ecosystem services trade-offs across agricultural landscapes in a mountain region

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Introduction

Multifunctionality of agricultural areas is at the core of policies promoting sustainability. Yet, assessing the potential benefits for biodiversity and understanding trade-offs among multiple ecosystem services (ES) remains hard. We develop an approach to assess the trade-offs and synergies in the ES associated with different agricultural production systems in mountain landscapes. Through case studies, we aim at providing empirical evidence to improve the limited understanding of ES trade-offs in mountainous landscapes. Our study evaluates the ES provided by seven study sites located in an Alpine region in northern Italy representing different types of mountain farming systems. Specifically, we addressed the following research questions: i) What are the main differences across the farming systems in the provision of (categories of) ES? ii) What are the trade-offs among individual (categories of) ES? iii) What are the spatial patterns of ES hotspots?

Materials and Methods

We performed a quantitative evaluation of 10 ES indicators (two related to provisioning services, 4 to regulating and 4 to cultural services) for the seven study areas, producing the relative thematic, and hotspots maps and synthesis tables. A thematic aggregation of the indicators and correlation analysis followed to gain a better understanding of the spatial and temporal ES trade-offs. Flower diagrams served to represent ES trade-offs and characterize the study areas.

Results and Discussion

The findings suggest that the transition to intensive forms of agricultural exploitation, in addition to habitat loss, involves a reduction in cultural and social services. This study showed that within five of the study areas there is a synergy between the supply of at least one service related to habitat maintenance and the supply of at least one cultural service (Figure 1). For two of these areas, there is synergy between habitat maintenance and provision of forage. The aggregated indicators substantiate hypotheses about expected dynamics and relationships between ES categories: provisioning and regulating ES are positively associated with cultural ES. The study can offer valuable and reliable references for local level landscape management and planning.

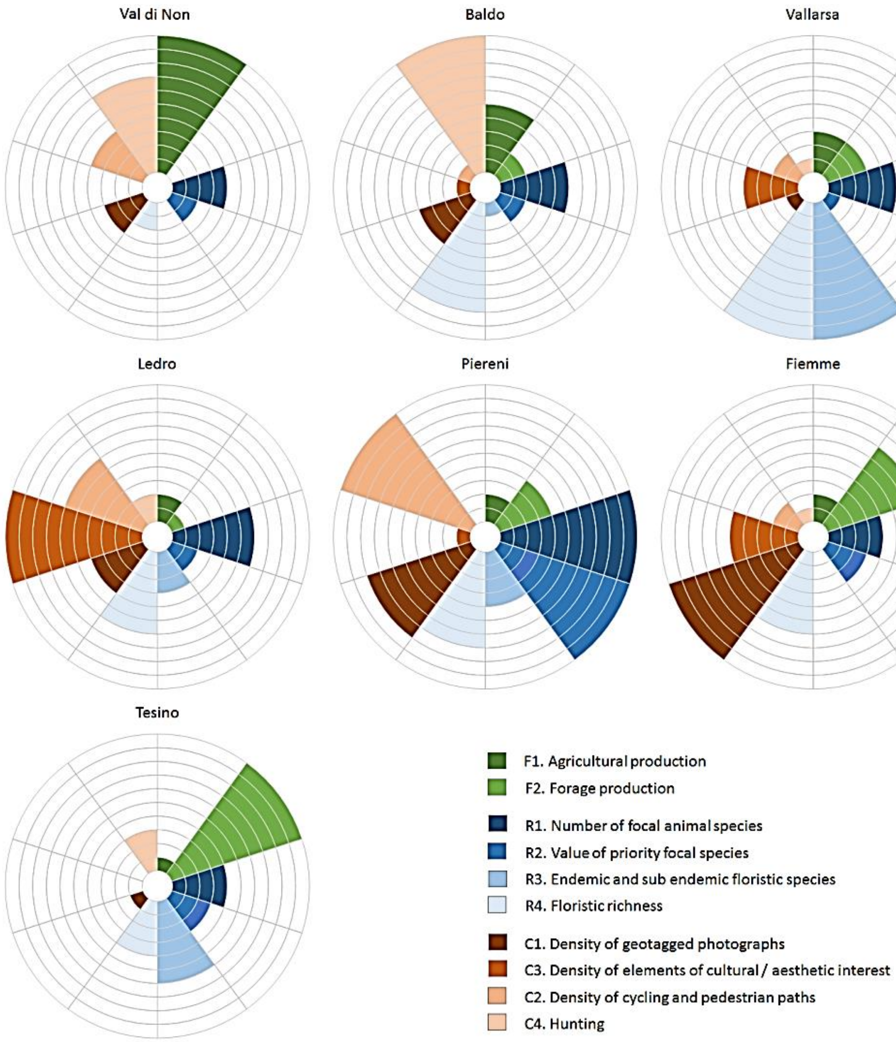

***Figure 1*. Comparison of the performance of the study areas with respect to 10 selected indicators of ESs.**

Conclusions

Due to the limited dataset, we cannot infer general trade-offs between the different patterns of crops and land uses, hence the correlations are to be considered as only illustrative. Nonetheless the study provides interesting information for the study areas: they can be ranked by individual indicators or by category of ESs, and characterized in terms of multi-functionality degree. Incorporating such information into spatial planning strategy may foster better synergies between mountain agriculture and multifunctional landscapes.

Integration of process-based and socio-ecological approaches for ecosystem service trade-off analysis in cultural landscapes

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Introduction

Species conservation, forage production and carbon stocks are important, yet conflicting components of sustainable grassland management. However, given the huge variety of agricultural landscapes and different habitat requirements of species, whether land modification leads to a decline or increase in species' numbers is not easily predicted. Therefore, recent studies have called for a theoretical understanding of the multiple relationships between drivers and ecosystem services. This requires a process-based approach, addressing structural and functional relationships between environment, ecosystem parameters and service outputs. Besides, environmental gradients have shown effects on key plant functional traits that subsequently explain ecosystem properties of several systems. However, little is known concerning how trade-offs and synergies between plant functional traits predict variation of ecosystem properties and services. Furthermore, few studies have used independently-measured final ecosystem services, which represent endpoints in the ecosystem services provision cascade. On the other hand, it has been argued that ecosystem service assessments should be carried out by stakeholders because they benefit from the services provided by ecosystems. The question then arises whether different stakeholder groups perceive a given ecosystem service in similar ways and how stakeholder assessments relate to measured ecosystem properties. We asked which relationships in a causal chain including biophysical parameters and land use determine trade-offs or synergies, specifically between sales of forage-based agricultural products and the habitat value to conserve endangered plant and breeding bird species. Additionally we tested if plant traits collected on a broad area responded to the environmental variation and explain combinations of these ecosystem services and associated processes at site level. Finally, a socio-ecological approach was used to determine to which degree stakeholder perceptions corresponded to the field-measured data.

Materials and Methods

Forty-six plots were established in salt marshes, reeds, extensively, and intensively-used grasslands in a coastal marsh landscape of East Frisia, Northwest Germany. On each plot, we recorded plants and breeding birds, mean groundwater level and salinity, available soil nutrients, soil texture, biomass removal by grazing and mowing, ANPP, and soil organic carbon. For each site with plots, plant and bird conservation values were calculated using Red Lists, and sales of forage-based agricultural products were assessed by interviewing farmers. We used a partial least square structural equation model to model effects between abiotic and biotic ecosystem properties, land use intensity, sales and conservation values. Additionally plant functional traits and stakeholder perceptions were collected to determine their ability to explain the system.

Results and Discussion

Co-varying groundwater depth and salinity, on the one hand, and land use intensity on the other hand, represented respectively the most relevant ultimate and proximate causes for the landscape-wide variation in sales and conservation value. Plant traits trade-offs significantly explained trade-offs between ecosystem properties and final services in response to the intensity gradient and environmental parameters variation.

We found significant differences between conservationists' and farmers' perceptions of given ecosystem services.

Conclusions

Identifying ultimate and proximate, direct and indirect causes of ecosystem service variation in landscapes allows targeting the most relevant determinants of provisioning and bequest services for better planning and management schemes. Our study points to segregation and integration as two alternative spatial strategies resolving trade-offs between services on the landscape scale. Besides, trade-offs and synergies between bundles of ecosystem services such as forage production, plants' nature conservation value and ecosystem carbon stocks might be explained by plant strategies indicated by plant functional traits collected at broad scales in response to environmental factors. Finally, we found that perceived notions and values of ecosystem services are strongly influenced by different social contexts, involving current livelihoods, professional interests and traditions.

Acknowledgements

This project was part of the collaborative research project "Sustainable coastal land management: Trade-offs in ecosystem services" (COMTESS), funded by the German Federal Ministry of Education and Research (grant 01LL0911).

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Impacts of land sharing and land sparing strategies on ecosystem services and biodiversity in an Austrian case study region

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Rural landscapes are dominated by agriculture and forestry in many parts of Europe. Due to competing private and societal demands on particular ecosystem services (ESS) and ecological functions, land use conflicts are ubiquitous. The two competing land use strategies of land sharing (LSH) and land sparing (LSP) have been defined in the scientific literature to increase total social well-being. LSH refers to extensive land use that shall provide both, provisioning services (i.e. biomass output) and high levels of biodiversity. On the contrary, LSP refers to intensive agricultural production on sites with favorable bio-physical production conditions in order to free land for nature conservation. Whether LSH or LSP is more favorable depends on the bio-physical production conditions, the habitat preferences of species, and on individual and social preferences. The latter not only includes provisioning services but regulating, supporting and cultural ecosystem services as well. Empirical case study evidence is required for developing LSH, LSP, or any other strategy in between (Merckx and Pereira, 2015). We present stakeholder driven land use scenarios for the Austrian Mostviertel region. This region is diverse in bio-physical production conditions, farm structure, and landscape complexity resulting in a high potential for biodiversity and competing interests for ecosystem services. The land use scenarios are applied in an Integrated Modelling Framework (IMF) to reveal synergies and trade-offs of ESS and biodiversity from competing land use strategies.

Materials and Methods

The IMF consists of the crop rotation model CropRota, the bio-physical process model EPIC, the regional bottom-up economic land use optimization model PASMAgrid, and several ESS and biodiversity indicators. Land use feeds into the IMF via three scenarios for a LSH, LSP, and a balanced land use strategy (LBA). The scenarios were defined in a stakeholder process at two hierarchical levels. The team in the TALE project (http://www.ufz.de/tale) derived three storylines for the agricultural sector at EU/national level. The storylines describe socio-economic framework conditions that can lead to LSH, LSP or LBA land use strategies. A stakeholder group of 12 agricultural sector experts defined spatially explicit land use scenarios at regional case study level. These scenarios are consistent with the EU/national storylines and represent plausible regional expressions from higher level socio-economic drivers for LSH, LSP, or LBA.

Results and Discussion

Figure 1 presents results for one exemplary ESS model output, i.e. yields of selected crops, to evaluate the land use scenarios. It shows the impacts of heterogeneous bio-physical production conditions and of alternative management intensities. For example, high fertilization is typical for a LSP strategy while low fertilization is a requirement for LSH.

Switching from high to low management intensity would increase vascular plant species richness by about one third in the Mostviertel region (Schönhart *et al.*, 2016).

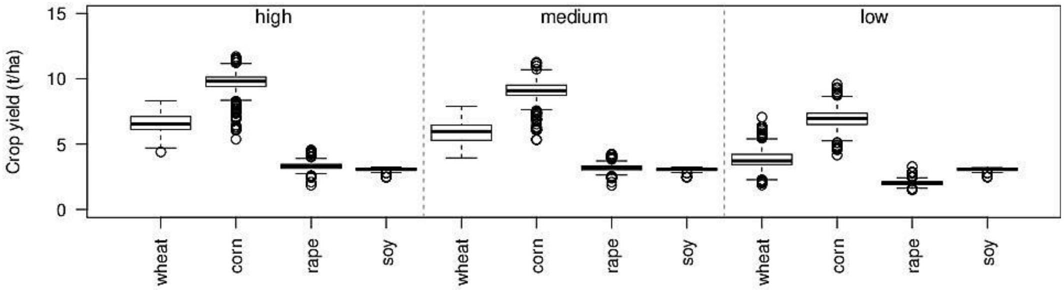

Figure 1. **Exemplary EPIC results for provisioning service "crop output": crop yields (t/ha) of winter wheat, corn, rape seed and soybean for a high, medium and low fertilization level and standard soil mechanization with plough. Data represents homogenous response units with a spatial resolution of 1km.**

Conclusions

Stakeholders anticipated a rather gloomy regional outcome of LSP driven by EU and national polices. Framework conditions under LSH were better aligned with their attitudes towards sustainable land use. The scenario on LSP results in agricultural production at high intensity levels in landscapes with favorable production conditions, mainly in the bottom valleys around cities. However, most parts of the Mostviertel would not be able to compete under such European socio-economic conditions according to the stakeholders. Consequently, preliminary results with the IMF indicate decreasing regional provisioning and cultural ecosystem services from LSP, while changes in regional biodiversity appear inconclusive due to an insufficient land use coverage of quantitative biodiversity indicators. Impacts from international telecouplings can only be considered qualitatively in this study.

Acknowledgements

This research is part of the project "Towards multifunctional agricultural landscapes in Europe (TALE)". It is funded through the 2013–2014 BiodivERsA/FACCE-JPI joint call for research proposals. The Austrian funds are provided by The Austrian Science Fund (FWF) under contract number I 2046-B25.

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Spatio-temporal characteristics of ecosystem services and governance in rural landscapes

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Introduction

Ecosystem services are often used at a different place and time than where they are produced; this can be considered as the spatio-temporal lags (or mismatch) in ecosystem service provision (Fremier *et al.*, 2013). Different types (classes) of spatial and temporal relationships between service provision and receipt can be identified, see Figure 1a and b for schematic overviews. Recognizing these relationships and their heterogeneity among ecosystem services can help to identify appropriate governance approaches for ecosystem service management (Fremier *et al.*, 2013).

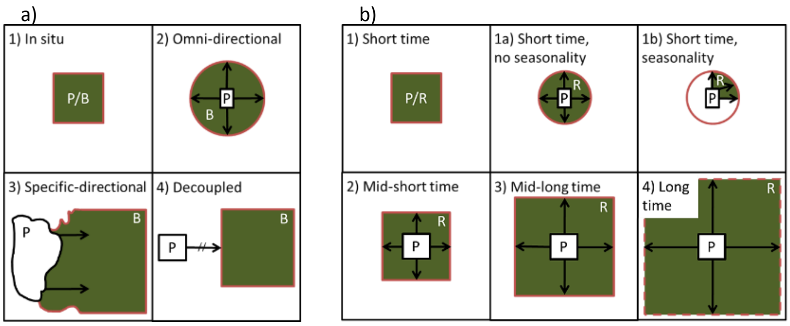

Figure 1a). **Possible spatial relationships between service production areas (P) and service benefit areas (B). In panel 1, both the service provision and benefit occur at the same location (e.g. soil formation, provision of raw materials). In panel 2 the service is provided omni-directionally and benefits the surrounding landscape (e.g. pollination, carbon sequestration). Panel 3 demonstrates services that have specific-directional benefits (e.g. storm and flood protection). Panel 4 indicates that a service providing area can be located (far) away from the benefiting area (e.g. food production). Adapted from: Fisher *et al.,* (2009).** ***Figure 1b).*** **Possible temporal relationships between the provision of service (P) and the receipt of the service (R). In panel 1, both the service provision and benefit occur at the approximately the same time (i.e. short time, e.g. regulation of air quality). Panel 1 has been split to indicate that a service can be provided and received year round (i.e. no seasonality, e.g. maintenance of genetic diversity) (panel 1a) or received in a specific season (i.e. seasonality, e.g. natural pest control) (panel 1b). In panel 2 the time between the service provision and receipt is mid-short-term (e.g. provisioning of drinking water), in panel 3 the time lag is mid-long-term (e.g. water flow regulation) and in panel 4 the time lag is long term (e.g. regulation of global climate).**

Only recently the interest in mapping and modelling the demand side of ecosystem services has increased. In these studies often the capacity or potential of an ecosystem to provide a service is mapped. More rarely also demand and location of the beneficiaries of the ecosystem service as well as the flow of the service are considered.

In this study we do both and also make the connection to governance. This is done by comparing the spatio-temporal relationships in ecosystem service provision and receipt, with the spatio-temporal characteristics of the governance approaches that are identified in three European case study areas. Thereby we hypothesize that collaborative governance approaches help to support the supply of ecosystem services because their spatio-temporal characteristics fit better with the spatio-temporal relationships of ecosystem services than for example the spatio-temporal characteristics of top-down governance approaches. This follows from the assumption that regional or local communities respond more effectively to local environmental problems because they are more aware of the context and local priorities and needs. Moreover, local stakeholders have the capacity to recruit local communities, resulting in possibly more efficient governance (Lane and Corbett, 2005).

Materials and Methods

For the most important ecosystem services in three case study areas (Spreewald, Germany, Jauerling-Wachau, Austria and Berg en Dal, the Netherlands) we 1) mapped the capacity, demand and actual use of these ecosystem services and 2) assessed their spatio-temporal relationships. In addition we made an inventory of the most important governance approaches in the case study areas. We especially focused on the spatio-temporal characteristics of these approaches, i.e. the locations and the length of time each governance is applied.

Per case study area we compared the spatio-temporal relationships of the ecosystem services with the characteristics of the governance approaches. Based on this comparison possible mismatches in spatio-temporal characteristics were identified. Moreover, we assessed with help of the developed ecosystem service maps if the governance approaches were targeting the right locations, i.e. did the governance approaches help to overcome the spatial mismatch between capacity and demand for ecosystem services?

Conclusions

Based on our results we assessed which type of collaborative governance approaches most optimally supported the supply of ecosystem services and assessed if the current spatial locations of capacity and demand for ecosystem services are aligned or if improvements are possible.

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Towards multifunctional agricultural landscapes: assessing and governing synergies between food production, biodiversity and ecosystem services

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Introduction

The increasing demand for agricultural products calls for an improved understanding of synergies between biodiversity, food and energy production and ecosystem services as well as for the development of policy measures to support these synergies. The BiodivERsA funded project TALE contributes to such an improved understanding by identifying and quantifying the trade-offs and synergies between food production, biodiversity and selected ecosystem services, developing scenarios on how future land use can look like under different policy priorities (land sharing, land sparing and balanced), identifying optimal land use strategies and analyzing existing policy measures to assess their effectiveness to support such strategies.

Materials and Methods

The studies were carried out in a set of representative agricultural landscapes in Germany, Switzerland, Austria, the Netherlands and Spain. The methodological steps of the project consist of i) designing and implementing a systematic stakeholder integration process (incorporation of expert knowledge) in all project phases to ensure practical relevance, ii) developing a set of land use scenarios and land use policies and iii) developing a framework that links biophysical and statistical models with optimization algorithms. Moreover, TALE provides an innovative online learning environment that is accessible both for experts, students and the general public.

Results and Discussion

Stakeholder guidelines were developed to initiate a bottom-up process for ensuring co-design of knowledge within the project. Figure 1 illustrates how the WPs are linked to steps of stakeholder engagement and underlines their fundamental role.

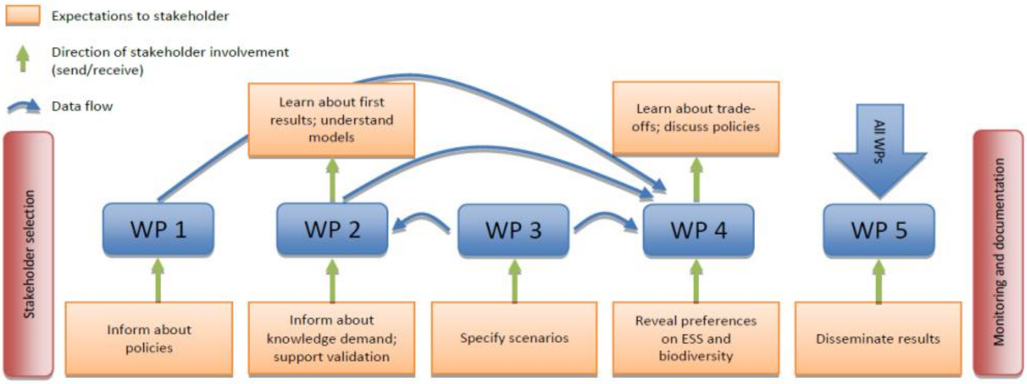

Figure 1. **Stakeholder engagement process.**

By using the stakeholder-defined scenarios as model input, we received information on their impact on selected ecosystem services and biodiversity. In addition, explorative modelling was carried out to explore limits but also further potential of providing several ecosystem services of a region. Combining the scenario simulations with the results of the explorative modelling indicates where, for instance, agro-environmental measures can be implemented most efficiently to approach the "optimum" (Seppelt *et al.*, 2013).

Conclusions

By analyzing policy instruments and combining stakeholder integration with scenario and explorative modelling the project helps to identify priority areas for land use systems, specific areas suitable for intensification or find the best locations for environmental measures. Thus, TALE contributes to solve multi-criteria problems to support landscape multifunctionality.

Acknowledgements

This research was funded through the 2013–2014 BiodivERsA/FACCE-JPI joint call for research proposals, with the national funders German Federal Ministry of Education and Research (BMBF), The Austrian Science Fund (FWF), Netherlands Organisation for Scientific Research (NOW), Spanish Ministry of Economy, Industry and Competitiveness and the Swiss National Science Foundation.

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Assessing the biotic and economic impacts of different greening rules for farms in three northern German cases study regions

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Introduction

The 2013 reform of the Common Agricultural Policy (CAP) of the EU introduced the 'Greening' as a new component with the ecological focus area (EFA) as a core measure to obtain ecosystem services and biodiversity. The effectiveness of the EFA has been questioned by scientists and practitioners since. Isermeyer *et al.,* (2014), argue that Greening is an expensive instrument with only marginal positive effects for biodiversity. Lakner *et al.,* (2013) argue that the Greening rules may affect farms quite differently depending on their specialization, raising fairness concerns. Taking up these arguments, the objective of this article is to analyse and compare the Greening rules currently implemented in Germany with the previous CAP and an alternative scenario of specific biodiversity oriented management practices in order to provide insights regarding the effectiveness of the Greening and to identify possible alternatives.

Materials and Methods

Three NUTS3 administrative regions located in a west to east transect in Northern Germany with different farm types, farm sizes and natural conditions were selected for this analysis. We compared three scenarios: a reference scenario representing the 2003 CAP reform ('Decoupling', REF), one representing the 2013 CAP reform with the newly introduced basic, redistribute and Greening payments (EFA) and an alternative scenario with alternative biodiversity-enhancing measures according to Berger and Pfeffer (2011) replacing the ecological focus area of the EFA scenario (BDIV). To simulate farmers decision behaviour in the different scenarios, the bio-economic whole farm model MODAM was used (Uthes *et al.*, 2010). The model takes a number of farm internal interactions into account: (i) crop rotational restrictions, (ii) feed production for livestock and (iii) substrate production for biogas plants and (iv) usage of organic manure and fermentation residues (digestate) from bioenergy plants within crop production. Biodiversity effects have been assessed by performing the habitat value model (Stachow *et al.*, 2002) using 7 farmland bird species as indicators (Glemnitz *et al.*, 2015).

Results and Discussion

On-farm compliance costs reflect the income forgone resulting from the adaptation of the model to changed framework conditions. Compliance costs per ha are presented in relation to the area of farm land covered by EFA or biodiversity-enhancing measures. The calculated compliance costs for implementation of the Greening rules in the EFA are relatively low. Highest costs occur in arable and pig producing farms in Diepholz followed by arable farms in Uelzen, while arable farms in Oder-Spree had the lowest costs, as poorer soil conditions limit the costs of setting area aside. Some farm types in Uelzen have zero compliance costs as, for example, irrigation-based potato and sugar beet-focused production systems are managed with a high share of intercrops.

In Diepholz the higher level of livestock and biogas plants causes higher compliance costs. For the scenario with biodiversity-enhancing measures the compliance costs are with about 200 €/ha lowest in Oder-Spree and with 680 €/ha highest in Diepholz, thus reflecting differences in site conditions, production orientation and farm types.

Biotic impacts are analysed using the Shannon index of crop diversity as well as field bird habitat value based indicators. Even small changes in the cropping structure can have positive effects on the target organisms. Above, even small areas with biodiversity measures are able to partly compensate limited habitat qualities of major cash crops.

Conclusions

Our study suggests that the current CAP may cause low or no compliance costs in many farms. The ecological focus area has only little impact in terms of area affected by land use changes and quality of the land use due to high windfall effects, which we even underestimated in our study as we did not take into account that many farms can declare semi-natural habitats within their farm area as ecological focus area. A higher ecological impact could be achieved at the same level of public costs if the Greening payment was used to finance more targeted biodiversity-enhancing measures, which would also serve biodiversity much better compared to the current CAP regulation as the impact on biodiversity is related to the diversity of cropping systems.

Acknowledgements

The case study work was funded by the BMBF project NaLaMa-nT (FKZ 033L029) while the further elaboration of the modelling approach was funded by the EU FACCE project MACSUR.

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Local visions of land-sparing and land-sharing – is there room for improving strategies to better maintain multiple agroecosystem services?

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Introduction

In an agricultural landscape, conflicts between provisioning services on the one hand and regulating ecosystem services on the other hand are common. The concept of land-sharing vs. land-sparing provides a framework for envisioning configurations of land-use and management to promote best possible synergies between different agroecosystem services. The question is if and under which conditions spatial segregation of agroecosystem services (land-sparing) or region-wide integration of services (land-sharing) allow for maintaining a better balance between agro-ecosystem services at the regional scale.

In Switzerland, agricultural policies have long favored developments towards the integration of services at the national scale, with regional differentiations according to elevation zones. Recent policy instruments include an increasing number of targeted measures focusing on particular geographical regions or land characteristics with the aim to increase the cost-effectiveness of the subsidy system.

The research question that was posed in this study is: How could deviations from the current development (pathway) towards more extreme visions of land-sharing vs. land-sparing be implemented in an agricultural catchment in South-Western Switzerland and how would implemented changes in land management affect key ecosystem service indicators (i.e. crop yield, soil loss, nitrate concentration at the catchment outlet and low flows).

Materials and Methods

Scenarios of land-sparing and land-sharing were developed in two stakeholder workshops with representatives of local producers, nature conservationists and members of agricultural and environmental authorities at cantonal level. For the evaluation of these scenarios in terms of their effects on ecosystem service indicators, the model SWAT was applied (Arnold *et al.,* 1998).

Results and Discussion

Outcomes from the stakeholder workshops include lists with specific options of land-use and management changes for each scenario (Table 1). In the land-sparing scenario, extensive pastures and meadows are converted to intensive pastures and meadows; in addition arable area with slopes higher than 7.5% is changed to intensive meadows. Within arable areas, the potato share is increased, and unlimited irrigation is applied to spring crops planted on slopes lower than 7.5%. Moreover, areas with low soil fertility are converted to forest.

In the land-sharing scenario, all areas with intensive pastures and meadows are turned to extensive pastures and meadows. Within arable areas, shares of field pea (representative of legumes or pulses) and leys are increased; no irrigation is applied.

Table 1. **Summary of land-use and management areas [ha] in each scenario.**

	Baseline	**Land sparing**	**Land sharing**
Intensive pasture and meadow areas	9184	20007	0
Extensive pasture and meadow areas	3678	0	12862
Total arable area	29576	20178	29576
Potato area	1506	2281	1252
Field pea area	1791	1143	3190
ley area	8254	5257	10219
Irrigated arable area	3989	18460	0
Forest area	14635	16889	14635

The model-based quantification of benefits and drawbacks of each scenario in terms of the selected ecosystem service indicators allows for deriving conclusions about which changes in land management would lead to an improvement in ecosystem service provision for one indicator and at what cost. Trade-offs and synergies between key ecosystem services indicators will be presented and discussed for each land management scenario in comparison to the baseline situation.

Acknowledgements

The presented study was conducted within the BiodivERsA/FACCE-JPI project TALE (Towards multifunctional agricultural landscapes in Europe: Assessing and governing synergies between food production, biodiversity, and ecosystem services) funded by the Swiss National Science Foundation.

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The acceptability of innovative strategies for sustainable valorisation of marginal wetlands in the Spreewald region (Germany)

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Introduction

The marginal wetlands are a core element of the cultural landscape (CL) in the Spreewald region, which is grown over the course of centuries. Nowadays, these wetlands are increasingly under threat of falling out of use due to economic and cultivation-related reasons. Their continual use is aimed at preserving biodiversity and providing an attractive landscape for tourism (Rogga *et al.*, 2017). Therefore, an innovative and systematic strategy for the sustainable valorization is under development using a transdisciplinary innovation process. One part of the innovative strategy consists of an alternative financing option for the development and maintenance measures, so called land pools (Froger *et al.*, 2015). However, this strategy has to be accepted by the affected actors in order to achieve a successful implementation. Accordingly, diverging interests have to be identified by the acceptance study, which in turn helps avoiding potential land use conflicts.

In this case study, we ask for factors that influence the acceptance decision of landowners and farmers in innovation processes for a sustainable use of marginal wetlands in the Spreewald region.

Materials and Methods

In order to address this research question we developed an acceptability framework that merges approaches from different disciplines and research fields (e.g., Lucke, 1995; Fournis and Fortin, 2017; Wolsink, 2012). It considers the social context of decisions, the process-oriented and interactive character of acceptability, and the existence of various degrees (ranging from non-acceptance to engagement). With this model, acceptability can be measured on the level of attitudes and values, the level of taking actions (behavior), and the level of long-term use.

To identify the acceptability factors for land pools in two example areas, we conducted 15 semi-structured interviews with land owners, land users, and regional authorities. The interviews were analyzed with MAXQDA using qualitative content analysis. A central element of the analysis is the profile matrix, which allows one case analysis and the analysis across cases.

Results and Discussion

The acceptability towards land pools differs between these two examples. The example without stakeholder involvement was seen more critically as the one with integrated participation process. Additionally, the dgree of acceptability differs among interviewees. There are actors with a high acceptance and with strong opposition in both example areas.

Results show that the acceptability of land pools on the level of attitudes is strongly connected with the individual value perception of these wetlands as element of the regional CL. In general, the appreciation of the CL is high or very high but this does not lead ”per se” to a positive acceptance of the land pool.

Reasons for this are the lack of shared values among actors and the existence of diverging opinions about the objective of land pools. Additional important acceptability factors on both levels are previous experiences, level of participation, and trust in actors or institutions. These factors are related with the issue of procedural and distributive justice observed in other studies with focus on the acceptability of land use changes (cf. Wolsink, 2012; Gross, 2007). However, to our knowledge, there are no acceptability studies that deal specifically with land pools.

Conclusions

The analysis of the case study showed that the discussion on values of all involved actors may support the identification of shared values. A clear problem description using maps and embedding the concept of land pools in a systemic strategy for regional development could enhance the acceptability. For the success of land pools it is crucial to design a fair innovation process with a transparent communication and active involvement of all actors. If possible, the concept should be modified to local and official framing conditions.

The framework supported an in-depth analysis including the linkages between values and arguments on different levels. It revealed a broad range of previously unknown factors. Furthermore, the case study showed that process-related factors should be highlighted as crucial element of the framework.

Acknowledgements

Funding from the Federal Ministry of Education and Research, Germany (BMBF) has supported this work (funding code FKZ 033L145D).

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Keynote: It's a bargain: better landscape-level outcomes for people and biodiversity at low cost

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Landscapes are the physical manifestation of regulation, governance, individual and communal decisions. The interplay of such decisions with the functioning of the concordant biophysical systems determine the nature of the services and benefits landscapes deliver to humans, as well as their habitability for non-human species. Using research from Borneo, China, sub-Saharan Africa and the United States, we illustrate three important dynamics that can have long-term, landscape-level impacts on the costs and benefits landscapes deliver. First, small, initial policy changes can have large positive effects on landscape level biodiversity with little additional private or social costs. Second, individual preferences for some land uses are highly malleable and often influenced by seemingly unimportant contextual manipulations with potentially large changes in landscape level processes. Third, managing the landscape matrix with a clear understanding of the spatio-temporal dynamics of well-functioning ecosystems can have clear impacts on human health and therefore societal welfare. These lessons add to the growing evidence base that we can greatly improve the landscape-level outcomes for people and nature at relatively low cost.

Dr. Brendan Fisher is an Associate Professor in the Environmental Program and the Gund Institute for Environment at the University of Vermont. His research and fieldwork lie at the nexus of conservation, development, natural resource economics and human behavior. He is the author of over 60 peer-reviewed articles on topics such as poverty, health, ecosystem services and biological conservation. He is the author of two books, *Valuing Ecosystem Services* (Earthscan, London, 2008) and *A Field Guide to Economics for Conservationists* (Roberts and Company, 2015). In 2013 he was a Rockefeller Foundation Bellagio Fellow. When he's not working he spends most of his time enjoying the Vermont outdoors with his wife and three children.

The ambivalent effects of climate insurance on land use practices

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Introduction

Innovative insurance programs, such as rain-index insurance, promise to mitigate impacts of climate change on agriculture. They are increasingly being offered to smallholding farmers in the Global South. Beyond short-term economic analyses, the implications of this innovation trend are largely unknown; studies on social and ecological consequences have produced inconclusive results. We have conducted a review of recent studies on the potential effects of such insurance programs and produced a systematic overview (Müller *et al.*, 2017). In this contribution, we address the question how the introduction of insurance can affect land use practices, specifically focusing on adverse social and ecological effects this may have. We also spell out strategies for designing insurance programs that support poor households, protect biodiversity, and promote sustainable landscape management.

Materials and Methods

Our review study compiles scientific knowledge gained in both developing and developed countries using various methodological approaches, including empirical observations, surveys, and analytical and simulation models. We produced an overview table which lists existing agricultural risk management strategies as well as potential beneficial and adverse effects of insurance introduction.

Results and Discussion

The introduction of insurance may trigger changes in land use practices. Although the benefits people obtain from ecosystems may be positively affected in the short term (high yield from monoculture of insured cash crops), they may deteriorate in the long term (lower pest control and disease resistance). Furthermore, land users with insurance may reconsider their engagement in informal risk-sharing networks.

New insurance options can lead to increased cultivation of cash crops (Cole *et al.*, 2017); though this transformation has been praised by economists, it comes at the expense of drought-resistant subsistence crops. Additionally, the financial security provided by insurance may disincentivize households from maintaining traditional drought mitigation practices – such as intercropping of crops with different drought tolerances or application of moisture conservation techniques. This may reduce the overall resilience of the ecological system by omitting positive effects of intercropping such as improved soil fertility, reduced pest incidence, and increased agrobio-diversity.

A further key concern is the effect of insurance on the extensive margin – the expansion of cultivated areas into environmentally sensitive marginal lands of lower agricultural value. Partly in response to this debate, the 2014 US Farm Bill re-linked crop insurance to conservation compliance for wetlands.

The extent to which the availability of climate insurance will lead to a change of land use practices is largely unknown. So far, the evidence from pilot studies, lab experiments, and simulation models has been mixed. While some studies have found a decreased use of chemical farm inputs such as pesticides and fertilizers, for instance, others have found an increase after the introduction of insurance. Consequently, there is an urgent need for long-term monitoring of insurance programs.

Six recommendations for the elaboration and design of future agricultural insurance programs follow from our analysis:

1. Evaluate priorities in an inclusive, participatory manner. Insurance is not necessarily the most appropriate tool to reduce vulnerability.
2. Encourage diversity. Insurance should be designed to maintain diversity (e.g. of crops, seeds, and strategies).
3. Adapt policies. Policy effects will typically differ from one location to another according to specific features of local environments.
4. Choose the right scale. To avoid a crowding out of social networks, insurance products may be offered on the village scale rather than for individual households.
5. Limit coverage to extremes. Insurance contracts should be consciously designed to avoid crowding out existing risk coping strategies and forms of 'natural insurance'.
6. Tie insurance to ecologically sound strategies. Premium subsidies could be granted only under the condition that ecologically beneficial land use strategies are adopted, such as practices promoting sustainable agriculture.

Conclusions

Climate insurance in agriculture has the potential to drastically transform land use dynamics in the Global South. Although evidence on the impacts of such novel insurance programs on landscape management is patchy and ambivalent, maladaptive and unsustainable outcomes have been observed and predicted. Therefore, international efforts are needed to increase the awareness of all actors involved in monitoring and designing future insurance programs.

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Modeling environmental decisions using cultural values: the water-land-environment nexus in the Central U.S. Great Plains

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Introduction

The Anthropogenic era emphasizes the importance of humans as agents of planetary modification (Ellis, 2011). In this era, there is a need for developing a science of coupled natural and human (CNH) systems to investigate the feedback loops from human decision-making to the environment, and to improve the sustainability of CNH systems. Agent-based models (ABMs) of CNH systems have contributed to our understanding of such systems, mostly based on economic rationale for human behavior (Rai and Henry, 2016; Filatova *et al.*, 2013; Ostrom, 2009). Economic reasoning is not the only decision-process humans employ though, especially when dealing with environmental issues (Caldas *et al.*, 2015). For instance, the Value-Belief-Norm (VBN) theoretical framework has been used to understand environmental decision-making (Stern *et al.*, 1999; Henry and Dietz, 2012; Sanderson *et al.*, 2017). However, the VBN framework has not been tested to incorporate feedbacks from the environment into humans' decisions in an ABM. We apply the VBN framework to agents' decisions of supporting an environmental policy, given environment feedbacks to agents' previous actions in a fragile landscape in the state of Kansas, U.S.

Materials and Methods

The study area is the Smoky Hill River Basin, an agricultural region in the state of Kansas. This region is experiencing increased competition for freshwater from rural and urban populations. We develop an ABM for this region to simulate and evaluate policies that may improve sustainability. To model policy support, we introduce the VBN framework into the ABM so that agents' decisions are the results of agents' beliefs that a valued object is threatened by certain behaviors. This belief can be further reinforced by evidence and other factors, leading the agent to adopt a new behavior norm to protect the valued object (Henry and Dietz, 2012; Sanderson *et al.*, 2017). The ABM integrates natural and human system processes and the feedback loops and interactions among the systems. The feedback from the natural system to the human system is mediated by a VBN-based decision rule, while the feedback from the human to the natural system is mediated by economic decision on land use, with land use/land use change impacting biodiversity and water. The human system model and the VBN decision rule were built using survey data collected with 790 community members in 2015. The questionnaire asked a series of questions on local knowledge of environmental issues, and respondents' values and beliefs related to biodiversity and the environment.

The natural systems models were developed using fieldwork data collected from 2014–2016 for fish, birds, and wildlife. The water system was simulated using ArcSWAT calibrated for the Smoky Hill River as described in (Gao *et al.*, 2017). The ABM for the Smoky Hill River is being developed and documented using the ODD+D protocol (Müller *et al.*, 2013).

Results and Discussion

Previous research demonstrated a causal pathway from values and beliefs of community members in Kansas to their support for environmental policy (Sanderson *et al.*, 2017). The framework for incorporating VBN into the human decision-making posits that adoption of an environmental policy would be the result of the presence of environmental evidence that resonates with agents' values and beliefs. We empirically test this framework.

Conclusions

No conclusions have been reached at this time.

Acknowledgements

This work was supported in part by the National Science Foundation, Dynamics of Coupled Natural and Human Systems Program, Award 1313815. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Searching for the instrumental value of equity in Payments for Ecosystem Services schemes: Evidence from behavioural field experiments in Vietnam

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Introduction

Ecosystem services governance like payments for ecosystem services (PES) influences rights and responsibilities of resource use in agricultural landscapes and is thus a highly normative undertaking. Studies find that recognizing the social equity implications of such policies can have an instrumental value in shaping environmental outcomes (Pascual *et al.,* 2014). Yet, to date, empirical studies with regard to the effects of equitable policy on the effectiveness to motivate behavioral change among primary resource users are very scarce (Loft *et al.,* 2017). In this work, we circumvent the empirical challenge of distinguishing between cause and effect inherent to survey and correlational research with an experimental design and implement it among land users from Dien Bien province, Vietnam, who participate in the national PES program. Importantly, previous research has shown that the study communities have strong opinions on the fairness of alternative payment modes which do not fully match with the policy currently in place.

Materials and Methods

We conducted a field experiment which borrows methodology from behavioral economics. In such an experimental setting, we can manipulate the payment scheme (input-based, output-based, egalitarian, random) between subjects to see if they influence the supply of labor for ecosystem services provision. The experiment consists of two incentivized stages: in a coordination game, we elicit the shared perceptions about the equity and appropriateness of different payment schemes (Krupka & Weber, 2013). Then, in a real effort task, we assign subjects to the different payment schemes and measure in a standardized setting the effort they put into the preparation of seedling bags for local afforestation, as a proxy for an activity yielding ecosystem services provision.

Results and Discussion

We find significant differences in the evaluation of payment methods in the coordination game. We also find that different payments induce different effort in the labor task. Specifically, participants who receive conditional payments (piece-rate for bag production) produce more seedling bags than their counterparts with unconditional payments (flat-rate). We find a suggestive tendency that besides this effect of monetary incentives, payments that match local perceptions of distributive equity (e.g. a flat-rate that is equal across individuals rather than variable) lead to higher conservation effort.

We discuss these and further findings in the local context and reflect on the suitability of experimental research for the design of effective and efficient ecosystem service governance for forest conservation.

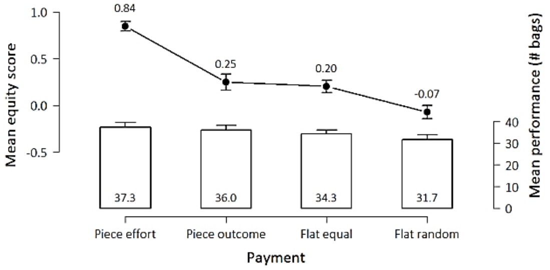

Figure 1. **Mean productivity in the real effort task and mean equity scores in the norm elicitation task by treatments, aggregated over all villages (error bars represent standard errors).**

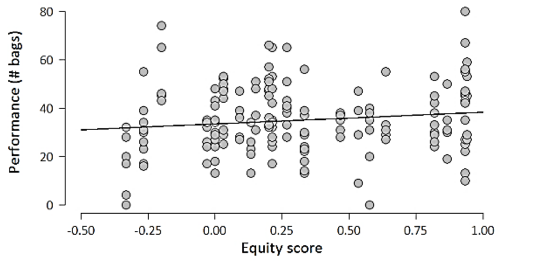

Figure 2. **Association of treatments' equity scores and productivity in the real effort task (Pearson's r = 0.14, p = 0.076), pooled across all villages.**

Conclusions

In implementing a policy, costs have to be evaluated against benefits. Input- and effort-based payments may be perceived as more equitable and may also induce higher conservation efforts. Although differences in perceived equity are rather large in our study, these translate only into small – albeit statistically significant – differences in effort. Arguably, the benefits of paying more equitably are, thus, limited. In other words, effort- and input-based payments are to be preferred especially in situations where they are easy and cheap to implement.

Acknowledgements

We would like to thank Prof. Dr. Klaus Müller his support for this study, which was essential for its realization. Further, we thank the local field team in Vietnam, led by Mrs. Ha.

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An online-marketplace for biodiversity and ecosystem services in Germany: attitudes of the private sector and the role of place-based payment options

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Introduction

In Germany, biodiversity and ecosystem services (BES) are especially threatened in agricultural landscapes (BfN, 2015). Besides command and control policies, economic incentive instruments such as agri-environmental measures are seen as vital to improve this situation. However, governmental programs in the framework and under the constraints of the Common Agricultural Policy are often not targeting specific conservation goals and not flexible enough to find place-based solutions. Furthermore, additional funds are needed to cover all costs of nature conservation in working landscapes. Thus, increased private sector investment is needed to achieve environmental goals (Fisher and Brown, 2015; van den Burg and Bogaardt, 2014). Against the background of a more fiercely contested donation market (Alscher and Priller, 2016), the concept of "ecosystem services" (ES) and associated market-based instruments have become increasingly widespread as one possible way to involve the private sector. Through identification of ES-beneficiaries and quantification of their benefits ES help to convert the typical "public good" character of nature's benefits to tradable services (Bull *et al.*, 2016; Matzdorf and Meyer, 2014) that can be sold in markets (Payments for Ecosystem Services, PES). But even though the ES concept has been developed with high hopes to generate more funding, the private sector perspective on markets for BES has rarely been explored as our literature review has shown. In our study we address this research gap by analyzing the attitudes of companies and private individuals towards a Germany-wide online-marketplace for BES, called "AgoraNatura".

Through this marketplace, buyers can voluntarily invest in German conservation projects that quantify the effects on BES. In the presentation we focus on the following research questions:

- Would private individuals and business actors be interested in such kind of market-place – are they willing to invest?
- Do they have preferences for certain BES, resp. for BES in agricultural landscapes?
- How important is the provision of BES in a specific landscape or regional context?

Materials and Methods

We have used a mixed method approach. Our results regarding private individuals are based on about 150 short interviews and questionnaires with people interested in conservation-related topics as well as 9 interviews with individuals, who already in-vested in German PES schemes. Regarding companies, our results are based on face-to face and telephone interviews with 10 experts as well as with 26 company representatives across sectors and regions in Germany.

Results and Discussion

Out of 26 interviewed companies, 15 stated a potential willingness to invest in BES through an online-marketplace. Numerous factors seemingly impact, whether or not a corporate actor is willing to invest in BES. These include the business sector, ownership type, customer type, access to land, as well as partnerships with conservation organisations.

Among the interviewed private individuals about 60% thought that the online -marketplace was a good idea and could imagine, that it would achieve an improvement of nature conservation investments. We could not identify clear preferences for single BES. Instead, most respondents asked for a wide range of BES types, with a certain focus on biodiversity-, water- and climate-related PES in agricultural landscapes. Additionally private individuals as well as experts and company representatives asked for specific, clearly located projects, high transparency regarding the project's provider and use of the funds with a focus on the project effects and low-level as well as co-investment opportunities. Strikingly, all data show that the provision of BES in a clear defined region or landscape plays a vital role: German companies prefer national projects often situated as close as possible to their headquarters or production locations, especially if the financial engagement in BES is not directly linked to their core business. For private individuals projects near their home, their working place or other places they are familiar with (e.g. due to vacation or family residence) are comparatively important. Often their thoughts about the best spatial scale of projects were accompanied by the wish to experience the project effects personally.

Conclusions

Our results indicate that place attachment not only relates to pro-environmental behavior in general (Gifford and Nilsson, 2014) but could be able to boost nature conservation investments by individuals and businesses. Building up on the suggestion of Reed *et al.*, 2017 to develop more place-based approaches of PES, we conclude that clearly located, small, regional BES-projects offered through a comprehensible, transparent online-marketplace can potentially increase private actors' financial support for nature conservation.

Acknowledgements

The work is done as part of the research and implementation project "AgoraNatura" (2015–2021), which is supported by the German joint funding initiative "Research for the Implementation of the National Biodiversity Strategy" by the BMBF and BMUB, as well as the BMUB's "Federal program on biological diversity".

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Towards an enhanced indication of provisioning ecosystem services in agro-ecosystems

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Introduction

Provisioning ecosystem services (ES) play a vital role in sustaining human well-being. Agro-ecosystems contribute a significant share of these services, besides food and fodder also fuel, fiber as well as regulating and cultural ES (Power, 2010; Balmford *et al.*, 2011; Huang *et al.*, 2015). Provisioning ES of agro-ecosystems have until now almost solely been indicated based on yields of agricultural products, quantified e.g. in t ha^{-1} per year. Such an indication is problematic due to several facts, including the disregarded role of significant anthropogenic contributions to ES generation (including fertilizer, pesticides, tillage), external environmental effects and strong dependence on site conditions (Zhang *et al.*, 2007). In order to consider ecosystems that are managed based on anthropogenic system inputs, a newer definition of ES is proposed, that considers 'the contributions of ecosystem structure and function – in combination with other inputs – to human well-being' (Burkhard *et al.*, 2012). The objective of this paper is to propose indicators that account for both, the share of anthropogenic inputs in provisioning ES and the environmental effects caused by anthropogenic inputs.

We test this in three case studies and argue for an enhanced indication of provisioning ES, focusing on six key aspects: 1) ES potential of natural ecosystems; 2) anthropogenic inputs; 3) realised ES flow from agro-ecosystems; 4) Environmental impacts of provisioning ES; 5) Demand and preferences for ES; and 6) Spatio-temporal ES aspects.

Materials and Methods

The conceptual base for such an indication has been made by prior publications, which have been analyzed in a literature review. Relevant points are taken up in the article, elucidated using a conceptual model and exemplarily tested based on data from a modelled land use scenario for three different case study regions in Germany. Yields of different crops were converted into grain units[1] to allow comparisons. Inputs and outputs were calculated using a farm model and data from statistics and interviews with farmers and experts. Based on that, recommendations for using the enhanced indicator set in different contexts are derived.

[1] https://www.bmel-statistik.de

Results and Discussion

The results showed different patterns in terms of production systems and intensities in the three case study regions. Varying input and output levels as well as environmental indicators can be explained by differences in natural conditions, farm structures and market access. The anthropogenic inputs in the three example regions show differences in labor, nutrient and water use caused by different production systems. These were resulting in considerable differences in yield levels – here indicated by grain units. Incomes per ha and per person are thereby highest at the medium input and output level, due to specialized production systems (Figure 1).

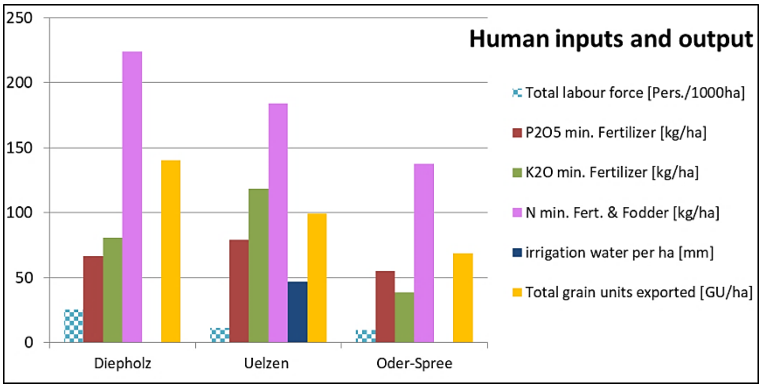

Figure 1. **Average anthropogenic inputs in terms of fertilizers, water and human labor as well as provisioning ecosystem service (grain units) outputs in the three case study areas.**

Conclusions

Uncertainties as well as pros and cons of the enhanced provisioning ES indication were elaborated. Finally, recommendations for an enhanced indication of provisioning ES in agro-ecosystems, that can help to integrate agricultural principles with ideas of sustainability and site-specific land use, are given.

Acknowledgements

The NaLaMa-nT project (the case study work) was funded by the BMBF (FKZ 033L029). We furthermore thank the participants of the Workshop „Ökosystemleistungen in Agrarlandschaften in Abhängigkeit von der landwirtschaftlichen Nutzung“ for fruitful discussions at ZALF Müncheberg in October 2015.

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Farmers' preferences for an agri-environmental measure designed for climate friendly peatland management

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Introduction

Across EU Member States in 2014, greenhouse gas emissions were the highest in Germany (21.9% of the EU-28). Germany is committed to reduce its greenhouse-gas (GHG) emissions by 40% by 2020 compared to 1990 and aims at cutting them by 80–95% by 2050. To reach those goals more effort needs to be made.

Drained and agriculturally used peatland areas are one major GHG source and make up 5% of overall German GHG emissions. These emissions are mainly driven by the water level and its respective land management. Currently, most peatlands are managed as grassland (53%) and about 20% as cropland. A reduction of GHG emissions from peatlands can be reached through a) improved water table management and water logging, as the emission is lowest with a water table just below the surface, and b) extensive management.

To compensate for profit loss and forgone income a new agri-environmental and climate protection measure for peatland protection through water logging (Moorschonende Stauhaltung) on grasslands was established. The aim is on the one hand to protect and re-establish peatlands and to keep water in the landscape system, but on the other hand to allow farmers to manage their land, and to maintain their business activities. Until now, only limited knowledge and experience is available about the measure uptake, effectiveness and optimal measure design.

With our study we try to answer, which factors influence the willingness of farmers to participate in an agri-environmental measure designed for climate friendly peatland management targeted at reducing GHG emissions and improving habitat quality. We further investigate how important cooperation, coordination and neighbouring effects are.

Materials and Methods

We apply a discrete choice experiment to access, which factors influence the willingness of farmers to participate in the agri-environmental measure for climate friendly peatland management.

The selection of attributes and the respective levels were based on the following steps. First, a list of attributes was collected from literature, several workshops and initial interviews with farmers that manage peatlands. Second, an online pre-test was conducted among people from the field of peatland farming, science, administration and other organisations. 12 attributes were presented and responds had to rank the attributes in their importance for the measure uptake. Third, the most important attributes were discussed with peatland farmers in cognitive interviews to set the levels.

In the final choice experiment five attributes are considered: contract length, support in the cooperation with neighbours, effort to register for the measure, acceptance of cut grass assured and financial compensation.

Each respondent faced 9 choice situations with two different measure designs and an opt-out (status quo) option. We used a mixed-method approach (pencil and online) to enhance participation. 3000 letters were sent to farmers North-Germany. And we additionally distributed the online link via farmers associations.

We collected empirical primary data with: discrete choices on the uptake of the measure with different design characteristics, socioeconomic information, self-assessment, and information on the influence of cooperation (already existing and future possible cooperation). We sampled in northern Germany in regions with a high share of peatlands (Mecklenburg-Vorpommern, Brandenburg, Schleswig Holstein, Niedersachsen and Sachsen-Anhalt) and received 150 responses of farmers managing peatland.

Results

We find that besides financial compensation, factors such as contract length and whether the acceptance of cut grass is assured are important for the willingness to participate in the measure. While more than 70% of respondents consider participating in the measure, about one out of four always chose the opt-out option. One reason is, e.g., that the incentive still cannot compete with the prices in very intense agricultural systems (especially in intense agricultural regions such as Niedersachsen). In-depth analyses are carried out. With our results the very new scheme targeted at climate protection could be adjusted and better tailored to different farm types.

A neglected debate in Europe: the need for wild areas

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Introduction

The increasing demand on land to support modern European societies with individualistic lifestyles requires land that is set aside, wild or is developing into a wilderness. Europe still exhibits some large areas free from infrastructure. These remaining wilderness areas are, however under threat, be it for tourism or for infrastructure projects. In context of today's European landscapes, wilderness lies at the top extreme on a continuous gradient of naturalness (ranging from pristine nature to wild areas and to highly modified urban areas). Beyond this unanimous defining character the meaning of the term 'wilderness' is very subjective and opinions on wilderness vary greatly depending on people's past experiences, encounters and expectations. Consequently a wide variety of definitions have been developed in different cultures and landscapes (Carver *et al.*, 2012).

Recent pan-European mapping of wilderness indicate that the European mountains may contain some significant remnants of wilderness areas. As Switzerland comprises a major central part of the European Alps, assessment of the wilderness quality of this area is essential. Moreover there is a distinct need for robust and suitable methods to evaluate and map wilderness, to identify remaining wilderness areas and to provide essential baseline information for wilderness monitoring, planning and protection.

The aims of this study are to (1) Develop a suitable and objective method, which accounts for varying wilderness perception and to quantify and map wilderness quality; (2) Implement this method to identify areas of current high wilderness quality in Switzerland and determine where such areas lie.

Materials and Methods

The wilderness quality of Switzerland was quantified based on four properties, here termed wilderness criteria, similar to studies of Carver *et al.*, (2012) and Müller *et al.*, (2015). The four wilderness criteria are: *naturalness*, *human impact, remoteness*, *ruggedness*. Ruggedness is a measure of the terrain and is relevant in mountainous landscapes. Wilderness was modelled using quantitative spatial data for these four criteria. The wilderness criteria (and their input data layers) may vary in their individual impacts on wilderness. This variation was accounted for through the combination of certain input data layers and wilderness criteria via weighted linear summation. Weights were applied according to expert opinions on the importance of these elements (data layers and criteria) for wilderness.

Results and Discussion

Results of this study identified areas of high wilderness quality in Switzerland, most of which were present at higher elevations in mountainous areas. When quantified according to collective expert opinion ca. 3800 km^2 of Switzerland (ca. 9% of the territory) lie within the top 25% wilderness quality and have patches > 3000ha (definition WildEurope, 2013).

The spatial distribution of wilderness concur with results of studies in topographically similar landscapes (Carver *et al.*, 2012) and studies addressing larger spatial scales (EEA, 2010; Kuiters *et al.*, 2013).

Conclusions

We demonstrate a suitable and adaptable method for quantifying wilderness quality at the *national scale*, which could *easily be applied in other countries*. Comparable data sets to those used in this study are available in most European countries (see Kuiters *et al.*, 2013). Moreover the method is flexible and allows the opinions of local experts and or local people to be implemented in future assessments to define the weighting of data elements and wilderness criteria. The involvement of local people is invaluable for promoting the acceptance of regional developments and protected areas (Blondet *et al.*, 2017).

Acknowledgements

Mountain Wilderness, the Bristol Stiftung and the Swiss Federal Institute for Forest, Snow and Landscape Research WSL provided financial support for the study. The study was embedded in a cooperative project with social scientists and the NGO Mountain Wilderness.

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II. Poster Elevator Pitch (Plenary)

Land Use and Governance

Managing Ecosystem Services and Biodiversity at the Landscape Scale

Authors alphabetical

Identification driving factors of land degradation/restoration in Mongolia plateau from 1975–2015: A case study from Xilingol, China

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Introduction

In many parts of the world, land-use and land-cover change (LUCC) has had various effects on natural systems and societies. Examples have been reported where LUCC has increased pressure on resource production, and influenced climate change, biodiversity and soil erosion, as well as threatening food security and even causing land degradation (Lambin *et al.*, 2003). Xilingol League, located in the centre of Inner Mongolia, Regional development in Xilingol has been strongly affected by national policy and regional strategies, some of which correlate with land-use type conversions.

Above all, The specific objectives of this study were to: (1) evaluate land degradation(LD), especially grassland degradation, on the basis of Land use land cover change analysis; (2) identify the causal factors effects the land degradation/restoration in this area; (3) state the relationship between these causal drivers.

Materials and Methods

The data present in this research were collected through four approaches: (1) remote sensing images (203 senses); (2) Inner Mongolia Statistical Yearbook, at a county level (there are 12 counties in Xilingol). (3) Climate data got from China Meteorological Bureau (4) distance measures collected from Landsat MSS/TM/ETM+/OLI. Thirteen drivers were collected in this analysis, all the drives group into four categories. Computer-assisted visual interpretation of satellite images was chosen as the approach to map LUCC due to its high degree of accuracy .

Results and Discussion

Two main LUCC processes and two distinct phases were identified (Figure 1): during Phase 1 (1975–2000), the LUCC pattern was dominated by land degradation, affecting 11.4% (22,937 km^2) of the total area. During Phase 2 (2000–2015), land restoration increased (12.0%, or 24,161 km^2) while degradation continued, resulting in a further 9.5% (19,124 km^2) of degraded land. The transition pattern changed accordingly. Our findings show that, in spite of notable restoration successes in the past, grassland degradation continues to be the main ecological and environmental problem in Xilingol, requiring the continued attention of decision-makers. Strategic land-use management has already had a significant influence on LUCC in this area, leading to the expectation that science-based land-use strategies can be developed to further reduce land degradation in Xilingol. Regional development in Xilingol has been strongly affected by national policy and regional strategies, some of which correlate with land-use type conversions. Overall, there have been four periods of area development strategies in Xilingol.

The first period was the "Cultural Revolution" before 1978; the second period, from 1978 to 1984, was called the "Livestock price, Families having and Families raising" period; the third period was the "Double Contract System" period (1984–2000); and the fourth period post-2000 has been called "Ecological Construction" (Li *et al.*, 2014).

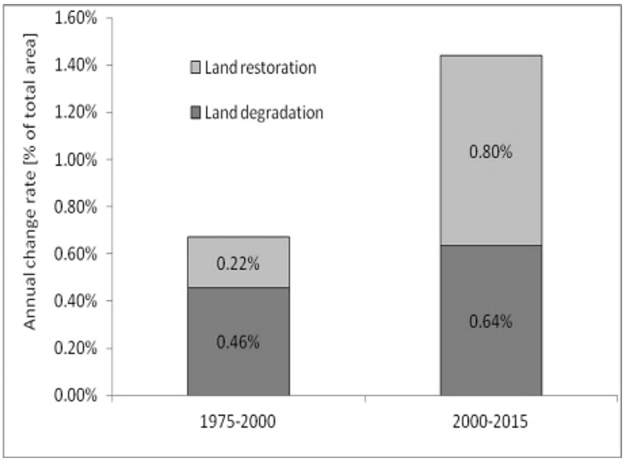

Figure 1. **Significant LUCC process rate in Xilingol from 1975 to 2015 as a percentage of total area.**

Xilingol as a typical area, not only for policy conversion, as well as the population increased, livestock fluctuation, economic development, climate change and other anthropogenic influences. Did these drivers result in the different LUCC process between the two phases? Which one is the important driver of the LD and LR. Thirteen drivers were collected from different years (1975, 2000, 2015), using them to analysis the difference between LD and LR, as well as the difference between different periods.

Logistic regression (LG) is widely use method to analyze the relationship between causal drivers and land use/land cover change. Four LG models were created in Xilingol, but the accuracy of these models was unsatisfactory. The shortage of the LG can't consider the spatial autocorrelation of LUCC. Additionally, LG also showed a high requirement of all the drivers. More models (Decision tree, Random forest tree, K-nearest neighbors, Support vector machine, Adaboost) should be tried in the future.

Conclusions

LUCC analysis reveals that human land use has increased considerably in recent decades. Land degradation, especially grassland degradation, remains a major ecological problem in this region.

Acknowledgements

We would like to thank the Chinese Scholarship Council (CSC) for funding this research and Florian Gollnow, Fabian Thiel, from the Department of Geography, Humboldt-Universität zu Berlin, Germany, for their valuable comments and suggestions.

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Natural and human derived capitals in ecosystem services delivery: A case study from peri-urban agricultural landscapes of Bangalore, South India

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Introduction

The role of ecosystem services in securing human wellbeing has been extensively studied in diverse geographical locations and landscapes across the globe. Most such studies consider people as beneficiaries of ecosystem services, but the role of humans in co-producing and delivering those services is often overlooked. We attempt to explore the stocks and flows of both natural and human derived capitals to highlight their significance in realising ecosystem services from a multifunctional agrarian landscape in peri-urban Bangalore. Our objective is to identify the variation in capital stocks and flows and consequent differences in realisation of ecosystem services along the rural-urban gradient. This is expected to contribute to sustainable management of these landscapes by enabling predictions of changes in ecosystem service delivery under different conditions of natural and human-derived capital stocks and flows.

Materials and Methods

We use the framework proposed by Jones *et al.,* (2016) that conceptualizes the amount of realised ecosystem service flow as a function of the amount of potential service that can be provided (potential supply), the number of beneficiaries and their service needs (user demand), and their efficiency of use of the service. To illustrate the framework we use examples of a provisioning service (production of food crop -finger millet), a regulating service (regulating irrigation water quality) and a cultural service (aesthetic value) from agricultural landscapes in the urban peripheries of Bangalore, India's third most populous city that is home to nearly 10 million inhabitants . Rapid urbanisation triggered by the Information Technology (IT) revolution and the resultant increase in commercial and residential construction, pollution, and landscape fragmentation in and around Bangalore has greatly transformed many ecosystems in former agricultural hinter lands (D'Souza and Nagendra, 2011; Nair, 2005).

The study area is spread across two transects in north and south directions from Bangalore city, covering an area of 250 and 300 km^2 respectively. The transects were divided into six strata using a composite index based on distance from city centre and percent built up space along the transect in the urban-rural gradient. 25% of villages (total 32 villages) were randomly sampled from each strata. Data collection was done in two phases with an initial exploratory phase of interactions with farmers for identifying crucial ecosystem services in the agricultural landscape. Further village level group discussions were conducted to garner detailed information on three important services: production of food crop (finger millet)- a provisioning service , maintaining water quality: a regulating service and aesthetic value: a cultural service. Biodiversity and use of the landscape in shooting movies served as proxies for aesthetic value.

Natural capital stocks and flows contributing to these services were estimated by collecting and analysing soil and water samples for physico-chemical parameters and observing floral and faunal diversity in the villages while data on rainfall and other climate related parameters and human produced capital such as farming inputs, labour, farm machinery, financial inputs, irrigation channels, road infrastructure, knowledge and information sharing network etc. were collected from group discussions as well as from secondary data collated by various government departments. The study extensively used data generated by various subprojects of the Indo-German collaborative project 'The Rural-Urban Interface of Bangalore: A Space of Transitions in Agriculture, Economics, and Society' on soil and water quality, biodiversity, crop production and farm household level socio-economic characteristics along the same gradient (http://www.uni-kassel.de/fb11agrar/) .

Results and Discussion

The preliminary results emerging from the study shows a clear gradient in potential ecosystem services, with the highest value in the strata farthest from the city to the lowest in the most urban strata for all the three services analysed. The stock and flow of capitals however indicates that realised services do not follow the same pattern due to the variation in human derived capitals including infrastructure, knowledge and financial capital. The data analysis is in progress and final results are expected to be ready by December 2017.

Acknowledgements

The authors acknowledge funding received from Department of Biotechnology, India as part of the project 'Ecosystem services, agricultural diversification and small farmers' livelihoods in rural-urban interfaces of Bangalore' that forms a component of the larger Indo-German collaborative project 'The Rural-Urban Interface of Bangalore: A Space of Transitions in Agriculture, Economics, and Society'. The German collaborators (University of Kassel and University of Gottingen) are thanked for sharing data on stratification index that facilitated selection of sampling sites for the study. The authors also sincerely thank the farmers in study sites who co-operated with the survey and discussions

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A Bayesian approach toward sustainable development of rice provisioning ecosystem services

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Introduction

The approach of Bayesian Belief Networks (BBN) has been become an increasingly popular method for simulating uncertain and complex issues through a Directed Acyclic Graph (DAG). BBN have regularly been used in agricultural development (Cain, 2001) and ecosystem service assessments (Burkhard and Maes, 2017). BBN were used in this study to predict and diagnose changes of rice provisioning ecosystem services through different options of farming practices and crop selection methods supporting related decision-making processes in a study area in northern Vietnam.

Materials and Methods

In this study, the focus was on three main components of ecosystem service (ES) provision including ES supply, demand and budget. Yields were used as indicator for rice provisioning ES supply, the number of beneficiaries using rice as main food was as indicator for demand of the service and based on supply and demand, respective ES budgets were calculated. The BBN network in this study was developed through various methods, including interviews, expert knowledge, geographical information systems and statistical models including the years from 2010 to 2015.

Results and Discussion

A fully worked-out BBN was developed to distinguish ecological structures and processes, ecosystem functions, additional anthropogenic system inputs and rice provisioning ecosystem services (generalized in Figure 1). Based on additional inputs by humans, different ecosystem functions can be optimized in order to increase the capacity of rice provisioning ES. Additional inputs from humans (including fertilizers, seeds and pesticides) were analyzed in the "farming practices" nodes, three types of ecosystem functions were defined including photosynthesis processes, water availability and nutrient availability. Through the three ecosystem functions, site selections for rice cultivation based on 21 "ecological integrity" nodes are indirectly affecting the rice provisioning ES supply capacities. Consequently, the probability of an ES supply-demand balance can be predicted if the evidences related to site selections for rice cultivation and the efficiency of farming practices are given.

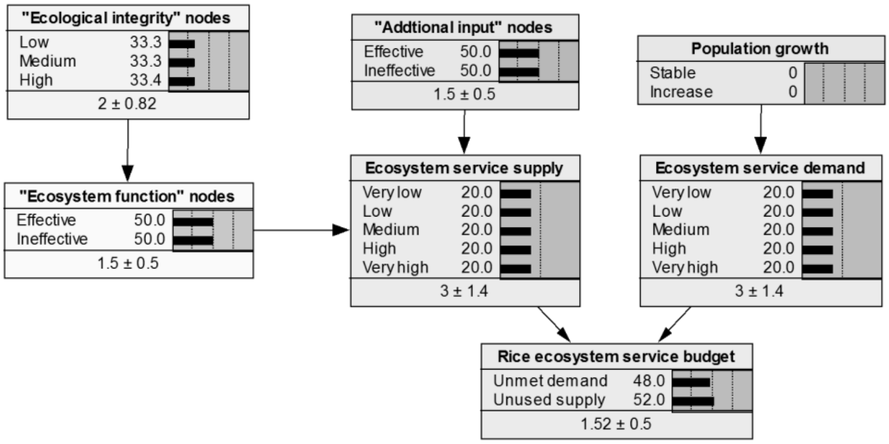

Figure 1. **Bayesian Belief Network structure for modelling rice provisioning ecosystem services.**

As a powerful application of the BBN approach, the authors made a diagnosis of crop suitability areas for rice cultivation in the Sapa region, Vietnam. The evidences related to the capacity of rice provisioning ES supply were inserted to find out the best conditions of the "ecological integrity" and "additional inputs" nodes. Finally, the suitability areas for rice cultivation were identified at Plinthic Acrisols soils, slopes from 13 to 18 degrees, altitudes lower than 1000 m, precipitation lower than 1800 mm per year, temperature from 22 to 24.5 degrees Celsius and strong solar radiation. Otherwise, the unsuitability areas for rice cultivation were proposed at Humic Acrisols soils, slope higher than 24 degrees, altitude higher than 1240 m, precipitation higher than 1930 mm per year, temperature less than 21.5 ^{0}C and weak solar radiation.

Conclusions

The use of the BBN approach for assessing rice provisioning ES demonstrated: (1) the chains of causal relations amongst environmental and socio-economic components with the rice ecosystems; (2) the emergence of ecosystem functions through biophysical structures of the environment; and rice provisioning services through the ecosystem functions and the additional inputs from humans in one network. The above information related that the effective/ineffective site selection is very important in generating a map of rice provisioning ES supply in the future.

Acknowledgements

The study is embedded in the LEGATO (Land-use intensity and Ecological EnGineering – Assessment Tools for risks and Opportunities in annual crop based production systems) project, funded by the German Ministry of Research and Education within their funding measure Sustainable Land Management; Funding No. 01LL0917. This study was co-financed by the Vietnamese Government Scholarship (911).

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Effect of soil tillage, crop rotation and irrigation on maize yield and its development from 2008–2016, in Müncheberg, Germany

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Introduction

Changes in land use (e.g., crop rotation) and soil management systems such as soil tillage and irrigation often create changes in soil quality and strongly influence soil properties *(*Kilic *et al.*, 2012) and thus crop yield. The study aims to assess the effects of land use management of tillage, irrigation and cropping system methods and their developments on maize biomass yield from a 9-year experiment from 2008–2016 at experimental ZALF station in Müncheberg, Germany.

Materials and Methods

The experimental field "V4" was a split-plot-site with 3 replications with 3 management factors. Tillage methods; no till and plough, Irrigation treatments; rainfed and irrigated. Crop rotation; monoculture and rotation. Monoculture with winter-rye (roundup) – Silage maize and a 4-year rotation: silage maize – winter rye/forage sorghum – winter triticale – Lucerne (Silage was harvested as whole plant). The study focuses on dry maize biomass yield, tillage methods, irrigation treatments and cropping systems. Generalized Estimating Equations (GEEs) as marginal models were mainly applied to explore the treatment effects, then Generalized Linear Models (GLMs) for their development on dry maize biomass yield.

Results and Discussion

Tillage significantly affected after 3 years and continuously lasted through year 9 (*Figure 1*). Unlike the study by Linden *et al.*, (2000), yield differences began to appear after 5 years and continued through year 13. Irrigation showed yearly significant effect on yield. The interaction effects between tillage and irrigation was insignificant.

Irrigation treatment had a significant effect on crop yield in the test region with high water stress *(Table 1).* The impact of tillage was not robust in scale of 9 years, showing significant effect only at 90% CI. The results disagree with the fact that tillage impact on crop yield was related to water and nutrient use efficiencies and ultimately the agronomic yield *(*Busari *et al.*, 2015*)*. Three-factorial analysis showed that 3 main effects were certainly significant through years. However, the interaction effects were sensitively changed under the uncertainty and changes of annual weather patterns.

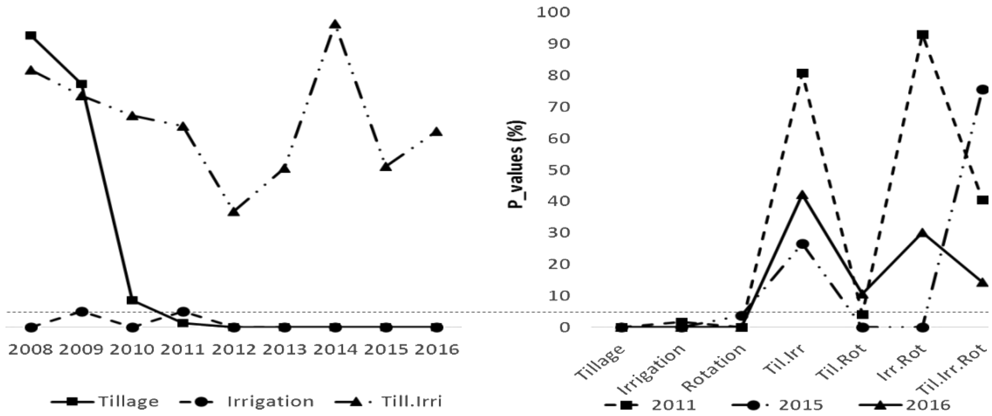

Figure 1. **Temporal effect developments of land use management on maize biomass yield from 2008-2016.**

Table 1. **LUM effects by 2 factorial analysis (9 years).**

2 factors	Df	X2	Pr (> |Chi|)
Tillage	1	3	.083.
Irrigation	1	243	<2e-16***
Till.:Irrig.	1	0	.995

Table 2. **LUM effects by 3 factorial analysis (3 years).**

3 factors	Df	X2	Pr (> |Chi|)
Tillage	1	6.6	.0101*
Irrigation	1	271.7	<2e-16***
Crop rotation	1	3.9	.0481*
Till.:Irrig.	1	1.7	.1867
Till.:Crop	1	15.5	8.3e-05***
Irrig.:Crop	1	6.7	.0096**
Till:Irrig.:Crop	1	1.8	.1779

Conclusions

In general, maize biomass yields were significant differences by tillage, irrigation and cropping system. However, irrigation and rotation immediately effected maize yield from the first year while tillage started to significantly effect from the fourth year.

Acknowledgements

The authors are grateful to G. Rosner and S. Ehlert as representatives of all those involved in data collection process and colleagues at ZALF Experimental Station for conducting the field experiments.

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Contrasting different methods to characterize outdoor recreation user groups: a typology of recreationists in the Kromme Rijn area, the Netherlands

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Introduction

Increasing urbanization accompanied by growing demand for recreational use of peri-urban green spaces is likely to cause land-use conflicts (Steiner, 2012; Von der Dunk *et al.*, 2011). The nature of these conflicts is subject to the heterogeneous preferences of outdoor recreationists (Bell *et al.*, 2007; Komossa *et al.*, 2017; Pröbstl *et al.*, 2010). Although the importance of differences between user group preferences has been acknowledged in the literature, a workable typology of outdoor recreation groups has yet to be defined. To describe variations among outdoor recreationists, three aspects – namely socio-demographic characteristics, visitation behavior and landscape preferences – frequently appear in the literature but are rarely taken into account all together. The present study forms a first attempt to develop an outdoor recreation user group typology based on all three aforementioned aspects through a case study in the Dutch Kromme Rijn area.

The paper is structured around the following research objectives: (1) to construct a typology of outdoor recreationists by contrasting two different methods; (2) to analyze differences between recreation user groups in terms of demographic profile, visitation behavior as well as preferences for specific landscape elements.

Materials and Methods

Literature shows a variety of methodological approaches to formulate outdoor recreation typologies. Each data-analysis method can provide different insights. Dissimilarities in results often relate to the confounding effects of the different input variables. In the present study, we use two different methods – a principal component factor analysis and a cluster analysis – to establish our typology. Data used to develop the typology originates from a structured questionnaire with a total of 200 respondents held in the Kromme Rijn area. A convenience sample of outdoor recreationists was used, focusing on the maximum of variety (e.g. gender, age, income, recreational activity) among respondents (Strauss *et al.*, 1996). The target population consisted of outdoor recreationists within the case study area, all age groups, level of education, both sexes, and all levels of recreational engagement in the outdoor environment. The study area was chosen because of its peri-urban, multifunctional character.

Results and Discussion

While the 'factor analysis'-based typology shows 5 outdoor recreation user groups, the 'cluster analysis'- based typology contains 3 user groups.

Comparing the results of both types of analysis, which support and complement each other, leads to the identification of three coherent but distinct outdoor recreation user groups. The first user group is focused on convenient, short-term close to home recreation. The second group showed clear preferences for one-day recreational activities and destinations. The last group was mainly defined through its strong interest in culture and nature. By comparing the results of the two methods, we obtained a deeper insight in the variation of user groups than would have been possible with a single method.

Conclusion

Our study identified large variations in outdoor recreation preferences and recreation needs. Understanding the heterogeneity of recreation preferences is essential to articulate effective landscape management strategies, targeted to ensure the multi-functional character of peri-urban landscapes while accounting for different types of users.

Acknowledgements

We acknowledge funding from the European Commission, through the project PROVIDE (Providing smart delivery of Public Goods by EU agriculture and forestry, http://www.provide-project.eu).

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What determines rural land transactions at household level in Sichuan, China?

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Introduction

Agricultural land use has altered fundamentally in China during the last 30 years. Rapid economic development pulled massive number of people from rural into urban areas and population control policies kept birth rates low. Combined, this caused a rapid decline and aging of the rural population and a sharp decrease of the agricultural labour force. However, legal constraints on transaction of agricultural land impeded adaptation of agricultural structures to the new economic and social circumstances. As a result, rural China is still dominated by very small farms that are operated by the rapidly aging and shrinking rural population. To respond to these challenges, the Chinese government experiments with land rights reforms to ease structural change in agriculture. Such reform potentially has profound impacts on agricultural development, including on farm size and productivity. We examine a land reform experiment in Sichuan province, a large province in South-West China with a national important agricultural sector, where we investigate the consequences of land market liberalization on household-level land use decisions.

Materials and Methods

We conducted a questionnaire-based household survey in four counties of Sichuan province. The counties are characterized by diverse topography, natural endowments, and distance to the market centers. Three of the counties are within the experimental zone of the rural land reform experiment and one county is located outside of this zone. This allows us to analysis the land transfer decision making under different land market policies.

We use the survey data to analyze the factors that determine if households are renting or selling some of their agricultural land. For the analysis, we used boosted regression trees (BRT) that are a non-parametric machine-learning tool that combine decision trees with boosting (Elith, Leathwick *et al.,* 2008). BRTs offer a number of advantages compared to conventional regression analysis: They are insensitive to outliers, missing data, and collinearity of predictors and they are robust against overfitting. Moreover, BRT can handle different types if input data, non-linear relationship among predictors, as well as interaction effects (Friedman, 2001; Elith, Leathwick *et al.,* 2008; Müller, Leitão *et al.,* 2013; Plieninger, Levers *et al.,* 2015).

Results and Discussion

To analyze the determinants of land transfer we carried out a two-step analysis: In a first step we model the decision to rent out land with the BRTs with data of all 410 households. 68% of all households rent out land and we observed that the share of irrigated plots contributed to 74,5% and the share of plots with land of good quality 7,3%.

In a second step, we analyzed the determinants of how much land farmers rent out. We used the data of the 68% (280 households) the total area of rented out per household as the target variable. The importance of the predictor variables are shown in Table 1. We observed that the share of off-farm income (from total household income), mean plot size per household, total area (given to HH under HRS) and the age dependency ratio contributed to more than 80%.

Table 1. **Relative contribution.**

Variable	Relative contribution (%)
Share of off-farm income	26.7
Mean plot size per household	23.6
Area under household responsibility system	15.4
Age dependency ratio	15.4
…	

Conclusions

The dominant influences for renting out agricultural land in rural Sichuan are plot characteristics, such as irrigation and quality of land. This is mainly driven by demand from agricultural companies, which rent in land for agricultural production at larger scale. Our results also show that households that received a large share of income from off-farm work tend to rent out more land while a smaller work force relative to the household size was associated with less land rented out because land in rural China continues to be an important social security. Yet, our results suggest that the existence of a land reform had no influence on the farmers decision to rent out land.

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Storylines for European agriculture to support integrated assessments

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Introduction

Integrated assessments of agricultural systems frequently require storylines to determine socio-economic framework assumptions such as input and output prices and agricultural policies. These storylines shall be consistent with the Representative Concentration Pathways (RCPs; Moss *et al.*, 2010) and the Shared Socioeconomic Pathways (SSPs; O'Neill *et al.*, 2015). SSPs are available at global to continental scales and describe major socio-economic developments to parameterize integrated assessment models. However, their spatial resolution and scope is insufficient for sectoral studies at regional to landscape levels, and the scientific community requires further detail how the SSPs shall be interpreted, e.g. with respect to agricultural technologies, markets and policies. Storylines at various spatial scales shall overcome this gap by suggesting plausible potential futures for the agricultural sector. The FACCE JPI knowledge hub MACSUR (http://www.macsur.eu) fostered an initiative to jointly develop storylines for European agriculture that are consistent with the RCP and SSP frameworks. Here, we present the research method to achieve such storylines.

Materials and Methods

We present a stylized research design for defining EU agricultural sector storylines (see Figure 1). It follows a nested approach from global to regional levels, as suggested by Rosenzweig *et al.*, (2016). Stakeholders from two groups are involved, i.e. scientists that shall apply the storylines and other agricultural sector stakeholders, e.g. from administration and policy making, that may apply the storylines but are mainly in charge of interpreting research results. Both groups advise the storyline definition process, e.g. by identifying and prioritizing storyline elements.

Results and Discussion

Global or EU-SSPs are the underlying pathways for agricultural sector storylines at global, EU, national and regional level. Some elements defined in the global SSPs immediately inform agricultural sector storylines and are not variable among continents, economic blocks or countries. Other elements drive EU-level processes. For example, the EU Common Agricultural Policy (CAP) has continuously been adjusted to changes in international market conditions, trade standards and societal concerns. Some CAP regulation (e.g. direct payment schemes), as well as other EU policies (e.g. environmental legislation) are similar in most member states. This is indicated by the second column of arrows from global SSPs to agricultural sector storylines. Other elements are different in the member states or in particular regions due to regional or local peculiarities.

This is indicated by the last two columns of arrows and includes, e.g. the uptake of emerging technologies and the speed of structural changes both being sensitive to cultural and geo-biophysical conditions. The first two columns contribute to the definition of EU agricultural sector storylines and are thus the focus of this joint research effort.

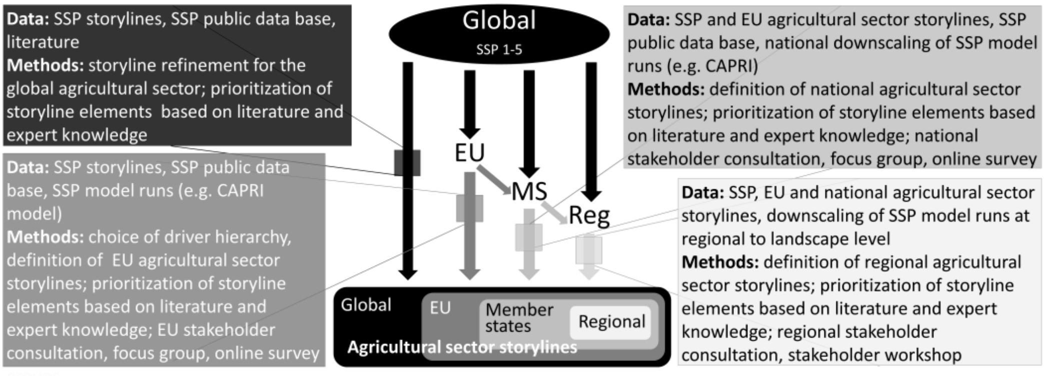

Figure 1. **Stylized research design (Schönhart *et al.*, 2017).**

Conclusions

For the agricultural sector, many drivers are effective at the European level. Therefore, a shared storyline definition of European developments can set the framework for storylines at national, regional and landscape level. This would increase comparability and consistency of integrated assessments at national, regional and landscape levels and can save resources in research processes. Furthermore, it shall facilitate a structured and target-oriented dialogue within the scientific community and beyond and shall prevent stakeholder fatigue from a large number of inconsistent storylines.

Acknowledgements

The work emerged from collaboration in FACCE MACSUR – Modelling European Agriculture with Climate Change for Food Security, a FACCE JPI knowledge hub. It is supported by the Austrian Climate and Energy Fund under the project RAPs.AT (KR15AC8K12675), the BonaRes – soil as a sustainable resource for the bioeconomy (031A608B) programme of the German Federal Ministry of Education and Research (BMBF) and the EU's Horizon 2020 research and innovation programme (grant agreement No 652615, project SUSTAg).

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Landscape appraoch to assess trade-offs in peri-urban agriculture – a case of Bangalore, Karnataka, South India

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Introduction

Peri-urban landscapes are characterized by complex interactions between natural and human agents. The interactions span over multiple sectors including farming, fishing, forestry, tourism, industries and housing and involve diverse stakeholders such as farmers, industrialists and tourism enterprises, often with conflicting needs, interests and values. Decision making in such contexts are extremely complicated and tricky and result in trade-offs between functions, sectors and stakeholders. Identifying such trade-offs to assess their impacts therefore becomes very crucial in sustainable landscape management.

Agrarian landscapes in peri-urban areas face multiple challenges acting at different scales. These could range from local and regional pressures in the form of growing demand for certain commodities, water and labour for the city to global challenge of changing climate. The trade-offs in response to such challenges happen at farm or household level, but aggregately are amplified at landscape level. Informed decision making by individual stakeholders may help mitigate the negative consequences of such trade-offs. This paper intends to identify trade-offs in peri-urban agrarian landscape of Bangalore, South India with the overall purpose of providing information that can guide various stakeholders in land-use decisions and landscape management.

Materials and Methods

Bangalore, the third most populous city in India, offers range of opportunities to both farm and nonfarm livelihoods in and around its periphery. Nevertheless, farmlands in the peripheries are continuously pressurized as source of food, water, housing and construction material and sink for liquid and solid waste from urban center. Due to the rapid transformation, peri-urban landscape of Bangalore witnesses fundamental shift in agrarian livelihoods, ecology, society and culture (Purushothaman *et al.,* 2013). Farmers respond to mounting urbanization pressures through varying choices about crops, inputs and other resources. We use integrated land-use approach (ILA) to understand the dynamics of farming generally triggered by trade-offs in selected locations.

Location for the study were selected from two transects in south and north directions along the peripheral growth of the city, covering 300 and 250 km^2 respectively. Thirty-two locations are selected based on an index computed using distance from the city core and percentage built-up area, and are divided into different strata of urbanisation. The study team prepared a list of important ecosystem services and livelihood options adopted based on group discussions with farmers in each location. These ecosystem services were assessed to arrive at the gradients within and between strata in each transect separately.

Further detailed ranking of ecosystem services and the temporal changes and drivers of important ecosystem services were elicited using participatory mapping exercises in selected locations within the gradients. The conceptual framework developed for the study highlights trade-offs within and between land use functions, stakeholders, and sectors. As questioned by Howe *et al.,* (2014), we intend to explore the possibilities of win-win despite the trade-offs in the real world.

Preliminary Results and Discussion

We discuss here the trade-offs between ecosystem services in peri-urban agrarian landscape along the lines of concepts of ILA that cover multiple dimensions and scales of function, stakeholder and sector. Figure below depicts the organization of trade-offs within and between dimensions. Scales of temporal and spatial overarch any possible trade-offs.

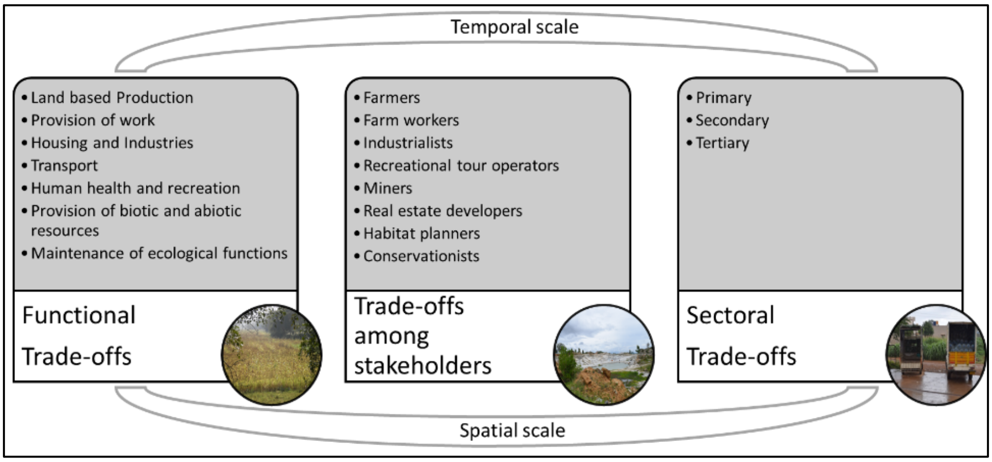

Figure 1. **Assessing trade-offs within agrarian landscape in peri-urban Bangalore.**

Discussion with farmer groups and other stakeholders revealed spatial gradient of important functions and embedded stakeholders and sectors within the selected locations across the strata. With changes in drivers like infrastructure, industries and resource availability over time and space; trade-offs also differ in its nature and intensity.

Conservation and efficient management of natural resources is as essential as expansion of cities and industries. Although, trade-offs are integral part of landscape management, knowing them beforehand and avoiding any potential negative impact is always advantageous. Operationalisation of Integrated Landscape Approach with focus on trade-offs can help improve the levels of sustainability of farm livelihoods in peri-urban areas.

Acknowledgements

Authors would like to acknowledge financial support for the study from Department of Biotechnology, Government of India. The study is a component of the larger Indo-German collaborative project 'The Rural-Urban Interface of Bangalore: A Space of Transitions in Agriculture, Economics, and Society'. The German collaborators (University of Kassel and University of Gottingen) are thanked for sharing data on stratification index that facilitated selection of sampling sites for the study. The authors also sincerely thank the farmers in the study sites who co-operated with the survey and discussions.

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Collaborative governance approaches as boundary organizations for improved landscape stewardship: A case study from Germany

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This paper uses the concept of boundary organizations (BOs) to examine if collaborative governance approaches – established by different governance actors for an improved landscape stewardship to enhance the delivery of ecosystem services and biodiversity at landscape level – display the typical characteristics of BOs. Thereby, we define collaborative governance as the vertical (across different scales) and horizontal (across different sectors) collaboration of multiple actors, involving partnerships between the public, private, and civil society sphere of society. BOs then are understood as governance arrangements which create strategic bridges between actors positioned on different sides of a 'boundary' (cf. Franks, 2010; Crona and Parker, 2012). Such a boundary often develops between actors who hold incompatible perspectives on a given issue or problem and have deviant underlying norms and values. Examples are existing boundaries along the divide in viewpoints between farmers and conservationists, governmental agencies and non-governmental organizations, scientists and policy makers, land managers and land planers, amongst others. For this paper we were specifically interested in the boundary that exists between actors, such as farmers or fishermen, who are primarily interested in producing provisioning ecosystem services ('food') and actors, such as environmental agencies or nature protection organizations, who are primarily interested in preserving regulating (e.g. water regulation), cultural (e.g. landscape aesthetics), or habitat ecosystem services (biodiversity) in agricultural landscapes.

Typical characteristics of BOs refer to a number of structural as well as procedural features (cf. Guston, 1999; Franks, 2010). Structural features relate to institutional aspects of the arrangements in view of: i) participation options, ii) adaptation mechanisms, iii) consolidation possibilities between individual and collective interests, iv) existing modes of accountability, and v) the durability of the arrangement. Procedural features relate to established routines in regard to: a) convening events to bring different actors together on a regular basis, b) translating between different types of knowledge these actors hold, c) allowing actors to collaborate by building trust and developing a mutual understanding, and d) mediating efforts between the various interests of stakeholders.

Against this backdrop, we address the following research question: Do collaborative governance approaches for improved landscape stewardship show the mentioned structural and procedural features and therefore qualify as BOs?

The analysis was based on empirical research conducted in a case study from Eastern Germany: the Biosphere reserve Spreewald in Germany. Altogether two collaborative governance approaches were analyzed and compared: a citizen foundation and a water management board. For data collection we used a mixed method approach, combining in-depth interviews (Boyce and Neale, 2006) and participant observation (Kawulich, 2005).

Data analysis was done based on context analysis (Mayring, 2000) of interview transcripts and notes taken during observations. All analyzed governance arrangements displayed at least some of the structural and procedural features typical for BOs. All approaches allowed actors situated on the different sides of the 'food and nature conservation boundary' (cf. Franks, 2010) to engage and negotiate common goals in favor of improved ecosystem service provision and biodiversity conservation, despite deviant individual interests. Through the established collaborative governance arrangements, actors could contribute and utilize specific knowledge and resources. Only through the pooling of knowledge and resources they were able to address a problematic issue at landscape scale, which they could not address individually. All approaches helped to create a forum for involved actors to engage into dialogues and deliberate different viewpoints while ensuring that actors could remain within their professional boundaries. Overall, the initial proposition that collaborative governance approaches for improved landscape stewardship can qualify as BOs could be supported.

Acknowledgements

Research leading to the presented results in this paper was conducted within the cp^3 project entitled 'civil-public-private-partnerships (cp^3): collaborative governance approaches for policy innovation to enhance biodiversity and ecosystem services delivery in agricultural landscapes' (http://www.cp3-project.eu). The cp^3 project is funded through the 2013–2014 BiodivERsA/FACCE-JPI joint call with the national funders BMBF (Germany), FWF (Austria), and NWO (Netherlands). We would like to thank all involved stakeholders from the case study for participating in the interviews, allowing us to participate in workshops and other local events and for sharing their knowledge and insights with us.

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Landscape context controls the biodiversity benefit of organic agriculture

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Introduction

Agricultural land use is the most important driver of biodiversity loss today – both through the conversion of natural habitats, as well as through the negative effects of intensive land management (Newbold *et al.*, 2015). To address the current biodiversity crisis, we therefore need to not only prevent the conversion of natural habitats but we also need to develop more wildlife-friendly agricultural practices. Organic farming has been shown to typically host higher biodiversity than conventional farming. But under what conditions is organic management most effective as a biodiversity conservation strategy? How does landscape context – an important driver of biodiversity – influence biodiversity in organic versus conventional fields? Here we carry out the most comprehensive meta-analysis to date examining the influence of landscape context on the effectiveness of organic management for species richness and organism abundance of a wide range of different taxa. Importantly (and differently than previous meta-analyses on the topic, e.g. Tuck *et al.*, 2014; Lichtenberg *et al.*, 2017), we tease apart landscape composition and landscape configurational effects to identify the specific landscape characteristics that influence the effectiveness of organic management.

Materials and Methods

We conducted a systematic review of the scientific literature for studies examining biodiversity in organically versus conventionally managed fields that provided details on study location, and site-level biodiversity data. We were able to include data from 92 studies and 290 study sites across North America and Europe. Unfortunately, no data from other regions could be included due to a lack of studies. We extracted landscape information for study sites at four different scales – 1, 2.5, 5 and 10km radius – using regional 250m resolution land cover datasets (CORINE for Europe and NALCMS for North America) with the software Fragstat v. 4 (McGarigal *et al.*, 2014), as well as using high-resolution imagery from Google Earth.

We examined linear and quadratic relationships between compositional and configurational variables, and used the residuals of this relationship to isolate the configurational effect that is independent from composition (Villard *et al.*, 1999). We examined the influence of landscape variables on the natural logarithm of the response ratio (Hedges *et al.*, 1999) using linear mixed models, based on multi-model inference (Burnham and Anderson, 2002).

Results and Discussion

Our meta-analysis across 17 countries and 2 continents shows persistent influence of landscape context on the effectiveness of organic management. Despite a large variability in patterns between studies, we find clear signals across studies and regions. Plants and arthropods benefit most from organic management in both compositionally and configurationally homogeneous landscapes (Figure 1). For soil organisms, instead, organic management is most effective in heterogeneous and for birds in more forested landscapes. We hypothesize that these patterns are driven by a general pattern where organic management increases biodiversity most strongly in situations where the background levels of biodiversity are lower. Whereas in situations where biodiversity is already high (e.g. plant and arthropod biodiversity in heterogeneous landscapes or farmland bird biodiversity in non-forested landscapes) organic management does not appear to provide an additional benefit for wildlife. We also show – for the first time for agricultural landscapes – that landscape configuration influences biodiversity in agricultural fields independently from landscape composition (Figure 1).

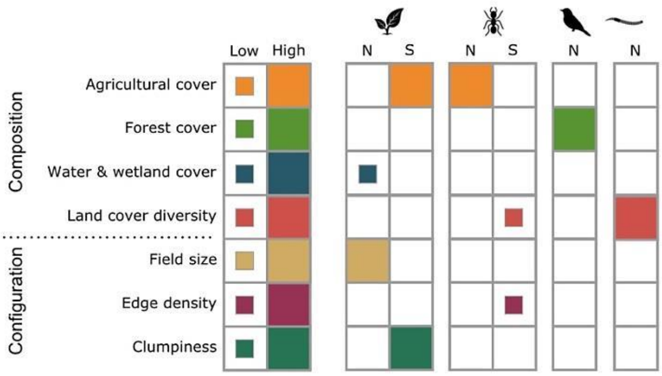

***Figure 1*. Landscape context in which organic management is most effective at increasing organism abundance (N) or species richness (S) of plants, arthropods, birds and soil organisms. Empty cells indicate that variable did not have an influence.**

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Reality check for the governance of a multifunctional landscape: Lessons from stakeholders in the German East Frisian Peninsula

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Introduction

The German East Frisian Peninsula is a globally significant site for biodiversity and as a cultural landscape, as shown by its dense network of protected areas of Natura 2000 sites, a National Park and an UNESCO Biosphere Reserve. Major parts of this cultural landscape are reclaimed from the Wadden Sea and without constant human activity, the sea would recapture the area. This century-old relationship between humans and nature created a strong local identity with an agrarian heritage. At the same time, it is a critical area for biodiversity, where up to 10 million migratory birds pass the area annually and the surrounding Wadden Sea builds the largest inter-tidal system in the world. Besides agriculture and nature conservation, tourism and more recently renewable energy, especially wind, have increased their economic importance for the area. This has lead to many competing demands on the land and the question how to best govern the landscape as a whole rather than the individual parts.

A multitude of regulations and laws apply to the landscape from standards to maintain the title of UNESCO Biosphere Reserve, EU environmental and agricultural policies, to state and local economic development and spatial planning. While the Peninsula represents one cultural landscape, there are various current and historical political units with varying boundaries affecting the governance of the landscape. Thus, a complex web of formal and informal rules with different spatial and temporal levels and effects characterizes the governance situation. Therefore, I turn to the actors governing the landscape and research how the UNESCO Biosphere Reserve can serve as a model region for sustainable development of the landscape integrating multiple demands.

Materials and Methods

I approach my research in two ways: I examine 1) the historical and current situation of administration of the UNESCO Biosphere Reserve and 2) the current relevant stakeholder groups of the landscape and their relationships. For 1), I conducted semistructured interviews with four heads of administration of three different areas in Germany that all are or were simultaneously both UNESCO Biosphere Reserves and National Parks. With help of the interviews, I gained an understanding of how the designation of the areas happened, the current status of the area, and how they see their cooperation with stakeholder groups.

For 2), using NetMap, a participatory social network mapping method, I conducted 20 interviews with stakeholders on the East Frisian Peninsula. Stakeholders were selected using snowball sampling and included representatives of e.g., farming, tourism, nature conservation and administration. I asked them who they perceived was influencing the current landscape development on the peninsula. In a further step, I asked interview partners to differentiate levels of power the stakeholders have to influence the current landscape development.

Results and Discussion

I found that the designation as large-scale protected areas all happened in a top-down manner about 30 years ago. The heads of the administrations observed that people in their areas perceive the UNESCO Biosphere Reserves as pure conservation areas and fear additional restrictions. However, in fact Biosphere Reserves allow a high degree of human activities including economic development, but the administrators are not able to work with individuals to counteract those perceptions.

With the NetMap method, I could identify up to 25 different stakeholder groups that interviewees mentioned influencing the landscape of the East Frisian Peninsula. Interview partners named municipalities and the agricultural sector as the most influential stakeholder groups for the development of the area. Almost all interviewees perceived themselves as having only very little influence, while assigning influence to other stakeholder groups. While relationships exist between different stakeholders, they are mainly between stakeholders in the same group (i.e., farmers know farmers). Relationships among different groups and across political boundaries are limited. There are some connections between agricultural and nature conservation representatives, but there is no platform for a large set of stakeholders to exchange ideas and work on common governance of the landscape.

Conclusions

The limited knowledge and information about the UNESCO Biosphere Reserve creates fear and mistrust among local stakeholders, and undermines the conservation and development goals of the designation. There is a need to link the different stakeholder groups and create a space for exchange in order to develop a shared strategy for a sustainable future of the landscape. The UNESCO Biosphere Reserve could serve as such a platform because it is suppose to function as a region of sustainable development. Without this common strategy, stakeholders' views remain limited to their own concerns and a bigger vision for the governance of the landscape will not exist.

Acknowledgements

This research is part of the Research Training "Interdisciplinary approach to functional biodiversity research" (IBR) at Carl-von-Ossietzky-University, Oldenburg funded by the Ministry of Science and Culture of Lower Saxony (MWK).

Cropping structures become increasingly clustered and concentrated in China since 1980

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Introduction

During the course of economic development, agricultural structures often become more homogenous and many countries experience a trend towards a concentration of crop production in specific regions. While specialization and spatial clustering of production has manifold economic advantages (Brülhart and Traeger, 2005; Fujita and Thisse, 2009), increasing concentration on fewer crops and on fewer places of production also infringe on domestic food security, brings higher production risks, and affects environmental conditions (Khoury *et al.*, 2014). Assessing the changes in spatial clustering and concentration of crop production can reveal such processes.

China is a particularly interesting case in that respect because its farming structures have fundamentally altered since the land reforms that were initiated in 1978 and transferred farmland management from collective to private hands. The demand for agricultural products have also increased tremendously in China due to rapid population growth and changing diets. As a result, national food security is still a paramount challenge for the Chinese government even though grain production has doubled during the past 40 years, particularly by shifting to higher-yielding crops, increasing livestock production, and higher production intensity in the country's main agricultural areas. However, the patterns of cropland distribution and production intensity, and how these patterns changed across China differ between regions. In this paper, we use Moran's I to quantify and visualize spatial clusters and their changes across all of China. In addition, we employ a generalized entropy index to measure the concentration of crop structures, and how these varied over time and regions. Together, these two concepts allow obtaining an improved understanding of the evolution of spatial concentration of cropping patterns in China.

Materials and Methods

We focus our analysis on the five main crops in terms of area cultivated in China, i.e., maize, wheat, rice, soybean, and potato. For these, we use annual county level data for entire China from 1980 to 2011. Using these data, we mapped the local Moran's I (Anselin, 1995) to show changes in the spatial clustering of the five crops and of the total farmland area. To quantify the concentration, we employed the general entropy index (Shorrocks and Wan, 2005) that we calculated for every year of the study period to reveal the changes in the concentration of crops across the seven agricultural regions of China (Northeast, North, Northwest, Center, Southeast, South and Southwest).

Results and Discussion

The area planted with each of the five crops tend to become more clustered over time, albeit only slightly so (Figure 1 left). Maize shows the highest increase in spatial clustering since 1980. Figure 1 (right) shows how maize cultivation was particularly clustered toward the North and Northeast in 2011.

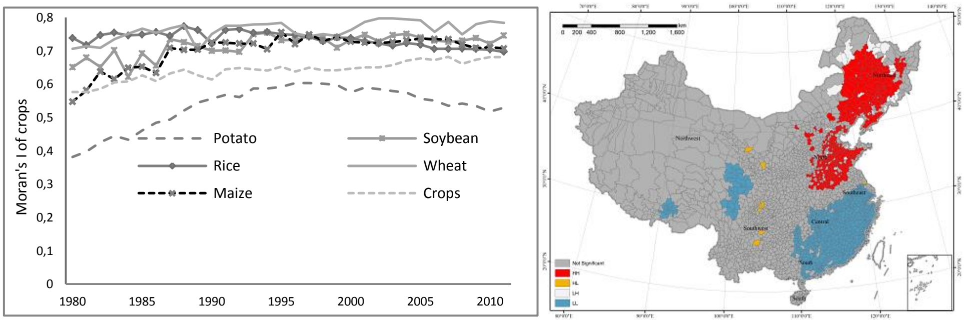

Figure 1. **Moran's I of crops from 1980 to 2011 (left) and spatial clustering of maize area in 2011 (right).**

In terms of concentration (not shown here), soybean is most unequally distributed crop in China since around 2000, followed by potato, maize, wheat, and rice. Rice and wheat account for more than 60% of the concentration before 2000, while the share of maize in total crop concentration increased from 11% to 36%.

Conclusions

We find increasing spatial clustering of the major crops planted in China, especially in the center and south of China. Moreover, these crops are also increasingly concentrated in fewer counties, suggesting a more homogenous cropping structure. Such trends may have beneficial economic effects but may also adversely influence national food security and have negative environmental outcomes.

Acknowledgements

We are grateful to Prof. Yongguang Zhang of Nanjing University for the great support in preparation. The first author is supported by the Chinese Scholarship Council (CSC) from the Ministry of Education in China.

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Biodiversity and land use – a comparative approach

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Introduction

The protection and optimal utilization of available agro-ecosystems is a major challenge. Here, we present a comparative approach focusing on European and African ecosystems to assess and better understand the effects of land use on biodiversity. Natural ecosystems in Africa are considered as "relict" case scenarios providing a reference frame for the original situation in Europe. At the same time, highly transformed European ecosystems contribute to assess impacts of a gradual intensification of specific land use forms on biodiversity in Africa. The central question is, whether or not comparative investigations of response patterns under different ecological conditions lead to a better understanding of common mechanisms between land use and biodiversity on a transnational or even global scale (Zeller *et al.*, 2017).

Materials and Methods

The study combines a variety of conceptual designs and methodological approaches: case studies on terrestrial small mammals and bats as bioindicators include the assessment of species richness, composition and abundance by means of trapping, mist-netting, acoustic monitoring and radio telemetry. Case studies on human-wildlife conflicts and the effects of reintroductions of large herbivores include assessments on spatial and temporal behavior of selected species via camera traps and radio telemetry. Data on organismic responses to land use are complemented by socioecological investigations (e.g. stakeholder interviews).

Results and Discussion

Strong focus is on the applicability of terrestrial small mammals and bats as ecological indicators for land use effects on biodiversity in primary savannas (Africa) and cultural landscapes (Europe). Owing to organismic abilities and limitations (Zeller *et al.*, 2007; Ferner *et al.*, 2014; Ferner *et al.*, in press.), small mammals can indicate habitat suitability on a small scale and enable the assessment of agricultural practices (e.g. agricultural intensification in Europe and cattle overstocking in Africa). We show that specific taxa (or ecological guilds) react to particular environmental conditions with changes in their occurrence and abundance (Vohland *et al.*, 2005; Muck and Zeller, 2006; Hoffmann *et al.*, 2010; Bengsch *et al.*, 2011; Starik and Zeller, 2013; Starik *et al.*, 2014).

Our approach further includes a comparison of rewilding concepts in Europe and Africa with special regard to reintroductions of megaherbivores for the restoration of ecosystem functions (Göttert *et al.*, 2010; Schwabe *et al.*, 2015). Using the example of carnivore-livestock conflicts, we furthermore apply comparative investigations of a common phenomenon under different ecological conditions to clearly differentiate between case-specificity and common applicability of mitigation strategies (Dannenberg *et al.*, 2013; Zeller *et al.*, 2016).

These data on biodiversity response patterns to land use changes are complemented by data on stakeholder perspectives and resource governance in order to develop effective strategies for the integration of existing protected areas into broader conservation landscapes (Göttert and Zeller, 2008; Mannetti *et al.*, 2015; Mannetti *et al.*, in press). Only on this basis, the ecological and socioeconomic/sociopolitical potential of agricultural landscapes as integral parts of protected area networks can be fully appreciated.

Conclusions

In contrast to the common practice of a well-applied North-South transfer of various European concepts to Africa, the comparative approach emphasizes the significance of natural ecosystems in Africa to promote innovative approaches for developing future nature conservation concepts in Europe.

Acknowledgements

This paper was possible as part of the research project "Land Use Contrasts and Edge Effects – a Comparative Approach", which is associated with Humboldt-Universität zu Berlin. We like to express our gratitude to the Zwillenberg-Tietz Stiftung for funding this project (Project-No. 2111460399).

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II. Poster Session

Land Use and Governance

Managing Ecosystem Services and Biodiversity at the Landscape Scale

Authors alphabetical

RESI – River Ecosystem Service Index

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Introduction

Rivers and floodplains are among the most complex and dynamic ecosystems in Europe that in some places still represent hotspots for biodiversity. However, in the last 200 years most of those areas have also been intensely modified e.g. through the construction of dams. Today, stakeholders have to deal with multiple legal frameworks and political objectives such as the Water Framework Directive, Natura 2000, Floods directive etc., that at the same time need to be aligned with socio-economic interests of e.g. tourism or agricultural sector. In order to establish a basis for cross-sectoral decision making, the project RESI – River Ecosystem Service Index – develops an integrated approach quantifying multiple ecosystem services (ES) to enable the comparison of management options.

Materials and Methods

The ES concept was adapted for the application in river and floodplain systems, including the definition of key terms, the classification of ES and the development of methods for quantification. We distinguish between the offered and the used (flow) ES, taking the human influence (input, pressure, modification) into account (von Haaren *et al.*, 2014; Burkhard *et al.*, 2014; Albert *et al.*, 2015). For the assessment, data from various sources were analyzed, thereby integrating methods from several scientific disciplines. The first practical application of the RESI was conducted for an 80 km section of the Bavarian Danube.

Results and Discussion

The results show maps of 1km river-floodplain-sections for the variety of ES all scaled from 1 to 5, which could also be subdivided into the river, the active and the non-active floodplain (see Figure 1). To ensure a transparent reporting of the methods used a standardized indicator-factsheet was developed. The comprehensive assessment of 15 ES enabled to identify hotspots and coldspots of ES supply.

Conclusions

The ES concept can serve as a common language for inter- and transdisciplinary communication, as it 1) fosters the integration of methods of different scientific disciplines, 2) enhances the science-practice knowledge exchange in terms of data and results and 3) forms a basis for the cooperation of stakeholders from various sectors, enabling a cross-sectoral approach for the management of riverine landscapes.

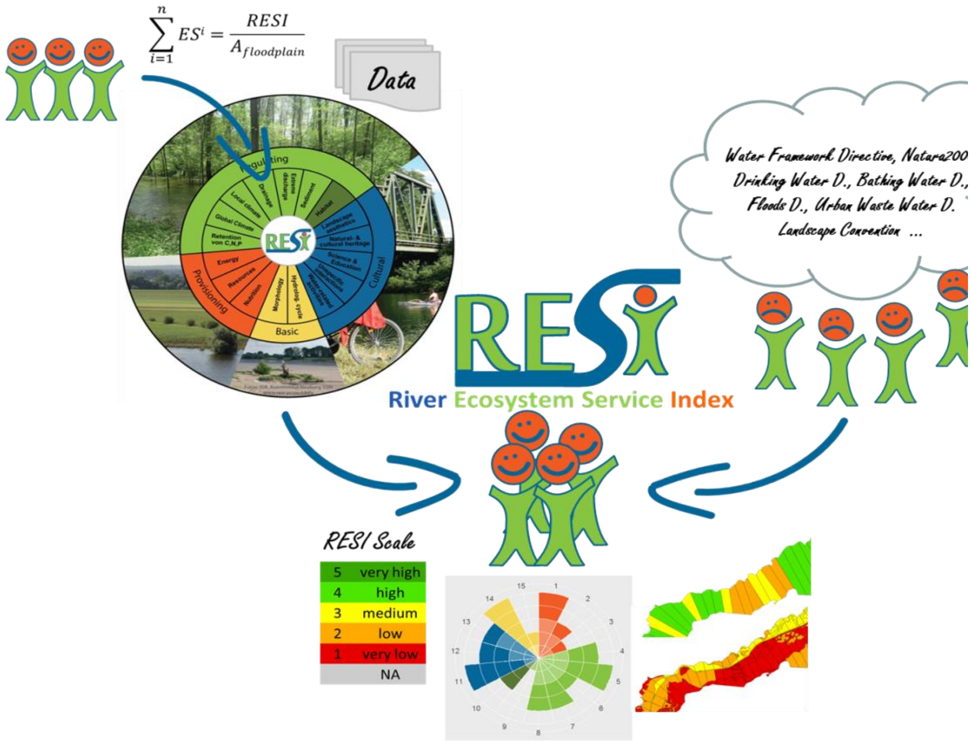

Figure 1. **Graphical abstract RESI – River Ecosystem Service Index.**

Acknowledgements

The project RESI (http://www.resi-project.info/en) was supported by the German Federal Ministry of Education and Research (BMBF) as part of the funding measure ReWaM in the BMBF funding priority NaWaM in the program FONA³.

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An analytical framework to link governance, agricultural production and ecosystem services in agricultural landscapes

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Introduction

Agricultural landscapes dominate much of Europe and other regions. Agro-ecosystems provide more than food, fodder, bioenergy, and livestock products as mainly marketed services (e.g. Swinton *et al.*, 2007). They contribute also to non-marketed regulating, supporting/habitat services and cultural services, like clean water, soil fertility, mitigation of greenhouse gases, wildlife conservation, landscape aesthetics, and recreation (e.g. Swinton *et al.*, 2006; Robertson *et al.*, 2014). The provision of these ecosystem services depends largely on the activities of the farmers in a region (Firbank *et al.*, 2013; Koschke *et al.*, 2013). Concerns about the long term sustainability of agricultural systems (Tilman *et al.,* 2002) and the provision of related ecosystem services demanded for governance approaches, which allow integrating agricultural activities of farmers and the frame conditions of farming. Based on the Agricultural location theory, we aim to develop an analytical framework with specific regard to agricultural activities, derive types of governance approaches according to their different types of pathway from the "input" (governance) to the "output (ES) via a detailed description of agricultural activities and their frame conditions and apply it to three European case study regions.

Materials and Methods

1. Development of an analytical framework.
2. Deriving governance types which link governance approaches and the provision of ecosystem services via the agricultural activities in a region.
3. Testing and application of the framework in three European case study regions: Berg en Dal in the Netherlands, the Biosphere Reserve Spreewald in Germany, and Jauerling-Wachau in Austria, which all differ in the regional agricultural activities, the natural site conditions, the agricultural products and the applied land use intensity, by describing the agricultural land use in detail, assigning existing regional governance approaches to the derived governance types (see above) and describing the impacted spatio-temporal scales.

Results and Discussion

We selected regional relevant governance approaches, which comprise hierarchical, market- and community based approaches (Natura 2000, Agri-environment and climate measures (AECM) and regional collaborative approaches, which includes foundations, regional associations and working groups). These approaches were assigned to seven basic pathways how governance may affect ESs via the main components of the Agricultural location theory, i.e. site conditions, farm conditions, land use program, and land use intensity. Our extension to include specific governance approaches and ES helps to make transparent the mechanisms between the types of governance approaches and the impact on ES on the landscape scale.

Conclusions

The analytical framework can help to link governance, agricultural activities and ecosystem in a comprehensive way and to integrate a detailed consideration of agricultural activities and their frame conditions. The application to the case study regions shows that community based, more collaborative approaches can target specifically those ecosystem services which are relevant to a specific region.

Acknowledgements

This work was supported by the Federal Ministry of Education and Research (BMBF) in the European program BioDiversa/Facce.

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Ecological enhancement of agricultural land in the Upper Rhine Plain

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Introduction

This project aims to find a broadly and simple maintainable way to increase biodiversity, especially to promote and support wild pollinators and honey bees in intensively used agricultural landscapes. A variety of different ecological enhancement measures like flower strips/fields or bee banks were implemented to increase species richness and populations of pollinators and other farmland wildlife.

Methods

Over a time period of eight years (2010–2017) changes in landscape structure, pollinator biodiversity and ecological parameters of arable fields were recorded. It is intended to continue this field study until 2019. After a baseline survey in 2010, flower strips and flower fields are cultivated on 10% of arable land within 50 ha study areas on two farms since 2011, which are complemented by unmodified control areas of the same size (Figure 1). Wild bees and butterflies were sampled on flowering in the enhancement areas and on flower-rich structures in the control areas. Autumn and spring sowing was carried out and the seed mixtures were adapted year by year according to the results obtained regarding an overall good variability of plant species and flowering periods, their attractiveness for pollinators, their ability to suppress undesired weeds, and their affordability.

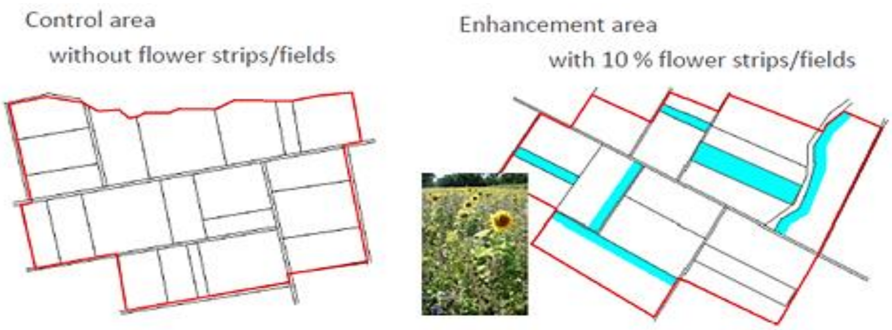

Figure 1. **Enhancement area (right, the gray plots indicating the flower strips) and the control area (left).**

Results and Discussion

Over the investigation period since 2010 species richness and abundances as well as the occurrence of specialist and endangered species have considerably increased (Figure 2). The abundances of wild bees in control areas increased slightly from on average 16 individuals per sampled subplot in 2010 to 26–60 in in the years 2014–2016.

Meanwhile, in the enhancement areas an enormous increase in abundances from an average of 14 individuals per sampled subplot in 2010 to 270 to >500 individuals in the years 2014 to 2016 was recorded.

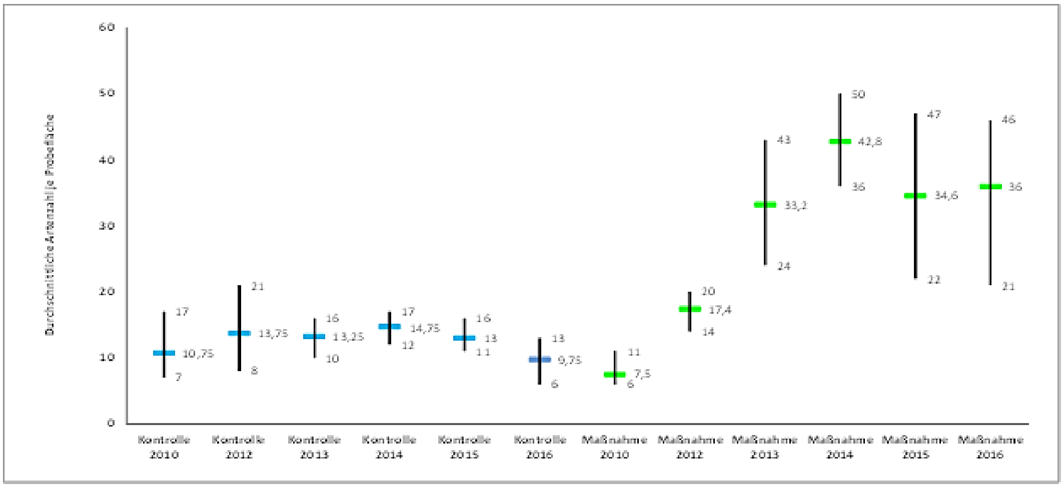

Figure 2. **Wild bee species: numbers control area -left- and enhancement area -right-.**

Further results regarding species composition, effects on butterflies, seed mix composition and management options as shown and discussed in [Lüdemann *et al.*, 2016, 2017] will be presented.

Conclusions

In conclusion, the project approach effectively promoted and supported pollinator diversity and population sizes in an intensively used arable region. Further insights from the ongoing project can help to manifest this conclusion and reveal if stable populations over a longer time period can be achieved. As the results of this study show, the combination of the established ecological enhancement measures is able to increase agro-biodiversity and to effectively promote and support pollinator diversity and abundance in an intensively used arable region.

Acknowledgement

The authors thank the two involved farmers Mr. Bolz and Mr. Graf for their continuous cooperation and Bayer Crop Science for the continuous support of the project.

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Targeted subfield switchgrass integration could improve the farm economy, water quality, and bioenergy feedstock production

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Introduction

Progress on reducing nutrient loss from annual croplands has been hampered by perceived conflicts between short-term profitability and long-term stewardship, but these may be overcome through strategic integration of perennial crops. Perennial biomass crops like switchgrass can mitigate nitrate-nitrogen (NO_3-N) leaching, address bioenergy feedstock targets, and – as a lower-cost management alternative to annual crops (i.e., corn, soybeans) – may also improve farm profitability. While focusing on the US "Corn Belt" state of Iowa, where substantial portions of cropland were unprofitable with corn and soybeans in the recent past (Brandes *et al.*, 2016), the suggested approach can be transferred to other agricultural regions world-wide.

Materials and Methods

We analyzed publicly available environmental, agronomic, and economic data with two integrated models: a subfield agroecosystem management model, Landscape Environmental Assessment Framework (LEAF), and a process-based biogeochemical model, DeNitrification-DeComposition (DNDC; Brandes *et al.,* 2017). We constructed a factorial combination of profitability and NO_3-N leaching thresholds and simulated targeted switchgrass integration into corn/soybean cropland in the agricultural state of Iowa, USA. For each combination, we modeled (i) area converted to switchgrass, (ii) switchgrass biomass production, and (iii) NO_3-N leaching reduction. We spatially analyzed two scenarios: converting to switchgrass corn/soybean cropland losing >US$ 100 ha^{-1} and leaching >50 kg ha^{-1} ('conservative' scenario) or losing >US$ 0 ha^{-1} and leaching >20 kg ha^{-1} ('nutrient reduction' scenario).

Results and Discussion

Compared to baseline, the 'conservative' scenario resulted in 12% of cropland converted to switchgrass, which produced 11 million Mg of biomass and reduced leached NO3-N 18% statewide. The 'nutrient reduction' scenario converted 37% of cropland to switchgrass, producing 34 million Mg biomass and reducing leached NO3-N 38% statewide. The opportunity to meet joint goals was greatest within watersheds with undulating topography and lower corn/soybean productivity. Our approach bridges the scales at which NO_3-N loss and profitability are usually considered, and is informed by both mechanistic and empirical understanding.

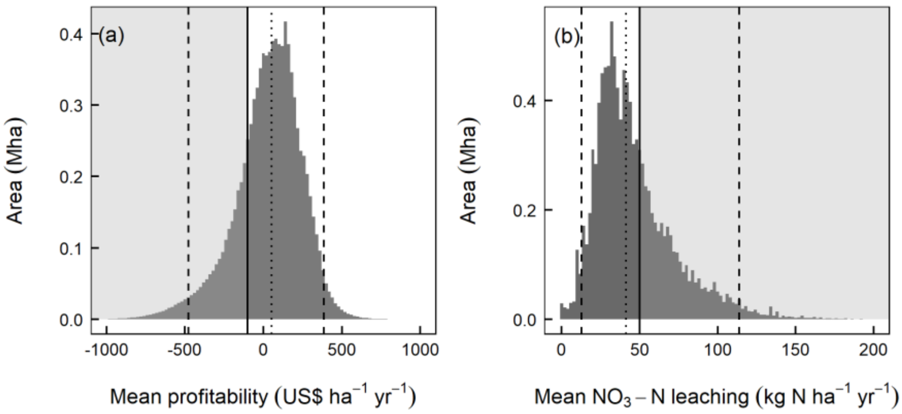

***Figure 1*. Baseline distributions of mean profitability (a) and mean NO3-N leaching (b) on Iowa cropland in corn and soybean production between 2012 and 2015. The grey shaded boxes include the areas below the US$ −100 ha−1 profitability threshold (a) or above the 50 kg ha−1 leaching threshold (b) used in the 'conservative' scenario. The dashed lines mark the lowest and highest 2.5% of values. The dotted lines mark the medians.**

***Table 1.* Ecosystem service outcomes from two switchgrass integration scenarios. 'Conservative scenario': converting to switchgrass corn/soybean cropland losing >US$ 100 ha^{-1} and leaching >50 kg ha^{-1}, 'nutrient reduction scenario': converting to switchgrass corn/soybean cropland losing >US$ 0 ha^{-1} and leaching >20 kg ha^{-1}.**

Scenario	Cropland in switchgrass	Biomass produced	NO_3-N leaching reduction
'conservative'	12%	11 million Mg	18%
'nutrient reduction'	37%	34 million Mg	38%

Conclusions

Though approximated, our analysis supports development of farm-level tools that can identify locations where both farm profitability and water quality improvement can be achieved through the strategic integration of perennial vegetation. This management change could also be adopted in some European regions characterized by highly simplified agricultural systems, where diffuse NO_3 sources cause ground and surface water pollution that threatens ecosystems and human health (Hiscock *et al.*, 2007).

Acknowledgements

This project was funded by the Iowa State University Department of Agronomy Anonymous Endowment, the Iowa Nutrient Research Center, and the USDA National Institute of Food and Agriculture, Hatch project 221195.

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A framework to assess linkages between river hydromorphology and ecosystem services: the HyMoCARES approach

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Introduction

Alpine rivers and river corridors provide several important ecosystem services (ES hereafter). Due to their high population density, Alpine valleys are often intensely used, and most rivers have been profoundly modified. In addition, climate change is deeply modifying the hydrological cycle of these rivers. The alteration of the hydromorphological processes has a relevant impact on riverine habitat, with possible consequences on the provisioning of ES to the society. The request to mitigate environmental impacts on river habitat, to include ES in the decision process, and the need for an improvement of the communication among stakeholders in rivers and related floodplain, have raised the need for governance instruments to implement these goals in policy. Hence, the HyMoCARES project aims to define the functional linkages between fluvial hydromorphology and the ES provisioning, and to depict how management measures may influence those linkages. HyMoCARES is a project funded by the EU Interreg Alpine Space which involves thirteen partners from six different countries, with eight case studies. Here, we present a list of hydromorphological functions of Alpine rivers, a list of riverine ES relevant for the Alpine region and a set of standard management actions. Finally, we developed a conceptual network linking management actions and ES.

Materials and Methods

We considered functions as a subset of the interactions between ecosystem structure, biotic and abiotic processes that influence the capacity of an ecosystem to provide goods and services. In total we identified nine fundamental functions, eighteen ES and three usages of abiotic natural capital. We selected twelve management actions typical of the Alpine area. The definition of the linkages among management actions, functions and ES also involved the application of a modified version of the expert-based matrix method proposed by Burkard *et al.,* (2009). To reduce the uncertainties that expert opinion unavoidably introduces, we applied bootstrapping techniques to calculate mean and standard error (Campagne *et al.*, 2017).

Results and conclusions

The result of the analysis is a matrix of uncertainty-corrected expert opinion scores. The scores were applied to produce a visualization framework (Figure 1). The aim of the visualization is to provide an interactive tool which can be used by the stakeholders to identify qualitatively the effects of a management action on river ES. Alternatively, if the objective is to optimize a specific ES, the network may also be applied to identify which management action maximize the specific ES. The network will be validated through its application to several case studies in different river catchments in the Alps. The case studies have been selected mainly because they have been or they will be subjected to river restoration projects.

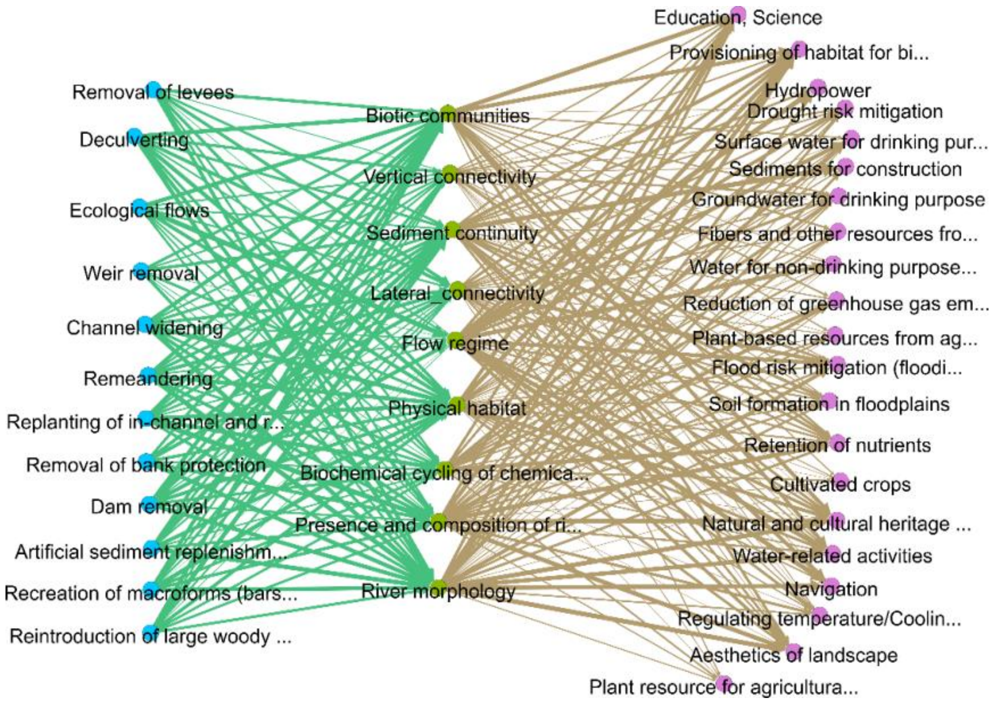

***Figure 1*. Network based on the analysis of the expert-opinion scores. We divided the framework in three groups: management actions on the left, functions in the center and ES on the right. Linkages are based on the statistical analysis of expert opinions and their thickness depend on mean and standard error.**

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Evaluation of the quality and land use in the irrigated area of low service Doukkala Morroco

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The Doukkala-Abda region covers an area of about 13.285 km² representing 1.87% of the total area of the Kingdom. The density of the population is close to 150.5 inhabitants per km² in 1997, more than four times that recorded nationally.

The agricultural area is 428 000 ha of which 96 000 ha of large irrigation schemes, 8,250 ha of private irrigation in coastal areas and 327 800 ha of rainfed agriculture. The large irrigation perimeters Doukkala are:

- The perimeter Bas-Service with an area of 61,000 ha with between 1930 and 1980.
- The scope High Service with an area of 35,000 ha within the 1990s.

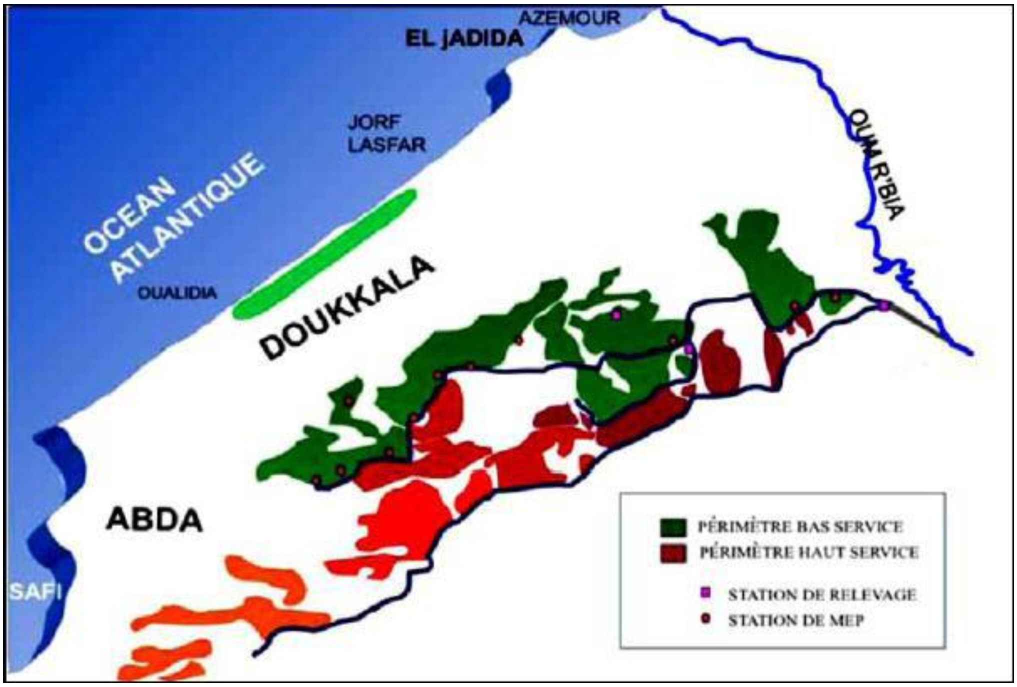

Figure 1. **Map of the irrigated perimeter of Doukkala (ORMVAD).**

Since the implementation of irrigation perimeter down service Doukkala, he experienced an imbalance both in the ground as the water table.

At first, the state of the quality of soil Doukkala not seem to be alarming. However, observation and comparison of test results between Bour soil and irrigated soils leaves seem a significant impact on the evolution of soil quality parameters under intensive farming practices.

In general, soil Doukkala:

- Present specific problems of salinity and sodicity despite the high salinity of irrigation water
- Are the poor to very poor in organic matter
- Are stable to moderately stable vis-à-vis the water share
- Are little draining and low permeability
- Are highly compacted and compacted to have a plow pan

Practical measures for rehabilitation and prevention are to be taken immediately in order to identify these problems and prevent them from degeneration. The methodology for the realization of this work consists of:

- Sampling, measurements in situ and analysis of soil quality parameters and groundwater,
- Treatment of results analysis and thematic mapping using GIS tool.

This must first go through the practice of a culture of conservation supported by a system of monitoring and surveillance of the quality of soil and water.

Keywords:

Low service imbalance, irrigation, degeneration

Effect of mixing black medic and alsike clover at different seed densities and proportions on germination rate, biomass production and weed suppression

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Introduction

Numerous studies have demonstrated that crop mixtures may be more effective than monocultures in terms of biomass yield and weed suppression. Legume species are considered as a key component in many mixtures because of their essential role in fixing nitrogen (Döring *et al.*, 2013), which is an important ecosystem service. Optimizing mixtures of only-legume for a particular farming situation depends on determining appropriate seed densities and species proportions in the mixture. Our research questions were (1) which seed density and proportion is the most productive and suppresses weeds most efficiently; and (2) how mixture effects and weed suppression are dependent on harvest time and variable environmental conditions.

Materials and Methods

A field experiment (plot size 3 m x 9 m, randomized complete block design, 3 replicates) was conducted in 2016 and repeated in 2017. Sowing dates were 29 April 2016 and 25 April 2017. The selected species were black medick (B, *Medicago lupulina*, cv. Ekola) and Alsike clover (A, *Trifolium hybridum*, cv. Dawn). Monocultures of both species and 3 mixture proportions (50A:50B, 67A:33B and 33A:67B) were grown at three different sowing densities (50%, 100% and 150% of recommended density). In both experiments, seed germination and biomass production were determined by counting and separating all growing plants (A, B and weeds) in a number of selected 0.5 m long rows (8 (2016) and 12 (2017) rows per plot. Besides, the above-ground biomass was harvested 2 times at the same plant growth stage by calculating the growing degree days of Black medic at 670±100 (40±9 DAS), 1100±100 °Cd (64±9 DAS). Relative mixture effect, transgressive overyielding and the land equivalent ratio were calculated at each harvest for the mixture that showed positive effects.

Results and Discussion

In the 2 years, germination rate was significantly decreased by increasing seed density in all treatments (Figure. 1). In 2017, germination rates were significantly ($p<0.001$, almost 20%) higher in all the treatments in comparison to 2016. In the first harvest of both years, B showed higher biomass in monoculture than A and in mixtures at each density demonstrating the same growth dynamics at the very early stage of plant growth (Figure 2). In the 2nd harvest of 2016, a positive mixture effect was observed at high density (150%) at the 50:50 proportions, demonstrating that interaction of the species in the mixture was time-dependent.

In 2017, at the 2nd harvest, the biomass in all the treatments was significantly decreased ($p<0.001$) despite showing a higher percent of germination this year. Weed suppression was significantly time-dependent ($p< 0.001$) and slightly higher in the presence of black medic. Weed suppression did not significantly change in the 2-years despite the significant reduction in the biomass production in the 2nd harvest in 2017.

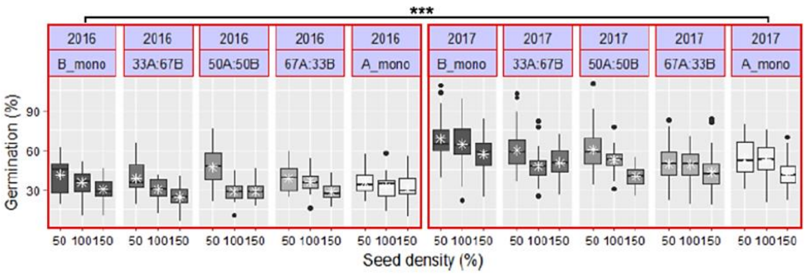

Figure 1. **Germination rate of Black medic and Alsike clover in monoculture and 3 mixture proportions. Asterisks indicate significance based on ANOVA.**

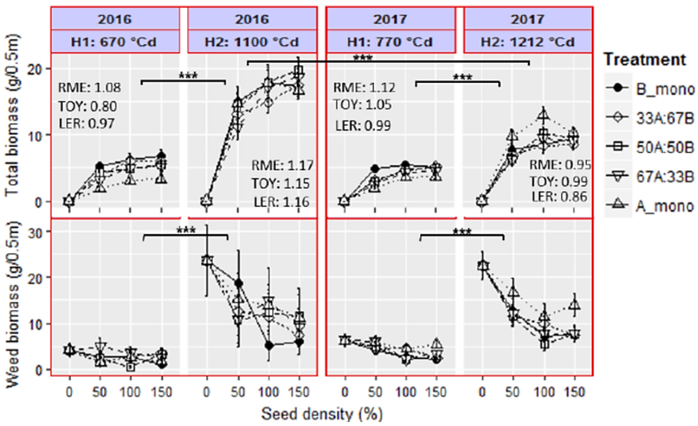

Figure 2. **Total biomass of Black medic and Alsike clover and Weed biomass at different deed densities and proportions at two harvest times (H1 and H2). RME (relative mix. effect, TOY (transgressive overyielding and LER (land equivalent ratio of the mix (50A:50B) at density 150%. Asterisks indicate significance based on ANOVA.**

Conclusions

An only-legume mixture of Black medic and Alsike clover showed higher biomass than the respective monocultures, but weed control was more dependent on seed density than on mixing. Further research is required to assess the potential of legume-only mixtures in environmental engineering and landscape management.

Acknowledgements

This research is supported by Yousef Jameel Scholarship Fund at Humboldt University of Berlin. We thank the staff at the university research station in Dahlem for technical support.

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Land-use changes and its impact on the social and environmental fabric of the rural urban interface of Bangalore, India

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Introduction

The growth of urban population exerts pressure on its peripheries in terms of land use change, water, labour, and other building material. Land use changes in these regions occur due to the demand of land for housing, industries, infrastructure, and other non-agriculture activities, which is facilitated by the acquisition of commons such as water bodies, grazing land, forests as well as private agriculture land.

Urban growth of Bangalore municipality during 2001 to 2011 is largely attributed to migration and jurisdictional changes, with the vast migrant population settling in its peri urban areas. The neighbouring areas of the city also houses industrial areas established since the 1980's. Chemically contaminated waste water flows from Bengaluru, is used for irrigation by farmers located along its path. In this context, the study examines changes in key land uses and its impact on the social and environmental fabric of the rural urban interface of Bangalore.

Materials and Methods

The study area is spread across two transects – one to the north of the city covering an area of 250 sq. kms and another to the south covering an area 300 sq. kms. The transects have 6 stratifications its value varying from 1 to 6, computed based on 1) distance from Bangalore and 2) percent of built up area within a 1 sq km area of the settlement, to indicate the degree of urban-ness, with 1 being more urban. Land use data from Census of India for the years 1991, 2001 and 2011 was used to understand changes in land use between transects and within transects. Further, spatial data from LANDSAT (30 meter resolution) images were also used to identify 7 land use classes – Built up, Water bodies, Forests, Plantations, Crop Land, Fallow and Others, for the 3 years 1991, 2001 and 2011. The corresponding changes and its influence on the social (agriculture and allied activities) and environmental (water availability and quality, and soil quality) fabric was examined.

Results and Discussion

Census data on land use shows that north transect had more area under agriculture than south in 1991 and 2001, while it declined in 2011. Within the transects north has more agri in S3 while it was more in the south in S6, during all the 3 periods 1991, 2001 and 2011. In both transects, Agri in S3 has been increasing over the years, more for south during 1991–2001 and north during 2001 – 2011. South also had increase in agri in S6 during 1991–2001.

Area under irrigation has also witnessed changes in both the transects. Irri increased from 1991 to 2001, but decreased during 2001 to 2011, the decline being more in the north transect. In 1991, ST Irr was slightly > NT Irr; while in 2001 the trend reversed with ST Irr < NT Irr, and in 2011 ST Irr > NT Irr.

Table 1. **Percent of land use in North and South transect during 1991, 2001 and 2011 Source: Census of India 1991, 2001 and 2011.**

	Year	**Forest: LU1**	**Cult_Waste: LU2**	**NA_Cult: LU3**	**Agriculture: LU4**	**Irrigation (Sub of Agri)**
North Transect	1991	0.00	11.52	12.65	75.83	12.43
	2001	0.09	10.46	12.69	76.76	26.96
	2011	0.00	11.10	15.83	73.07	10.24
South Transect	1991	1.35	15.37	16.90	66.38	14.00
	2001	1.04	17.14	10.85	70.97	22.31
	2011	1.32	12.69	11.73	74.26	19.36
Total	1991	0.68	13.46	14.79	71.06	13.22
	2001	0.57	13.87	11.75	73.81	24.59
	2011	0.66	11.89	13.79	73.66	14.79

Results of the spatial analysis which had finer land use classes, indicates an increase in built up area, with a corresponding decrease in area under crops in certain regions of the transect. This has intern had implications on the economic nature of the region, with a majority of the population being engaged in non-farm activities. Moreover, loss of commons including water bodies indicated a decline in access to fodder for livestock, has led to changes in the livestock population. Nevertheless, regions in the south that receive waste water from Bangalore didn't show a significant decline in cropped area, neither in the livestock numbers. Though, these regions report bad quality water which has affected health of the population and has also reported declining soil fertility.

Conclusions

The influence of urban growth in the form of land use changes, has significant influences on the social and environmental conditions of its neighbouring peripheries. The demand for land resulting in the loss of commons and private land as well as discharge of city's waste water that is used for irrigating agriculture crops, has had negative and positive implications on farming and livestock production. The positive influences nevertheless result in trade-offs on health of people and animals, water and soil quality. This study subtly brings out the threat to sustainability of the agricultural landscape in the urban peripheries of Bangalore.

Acknowledgements

Authors would like to acknowledge financial support for the study from Department of Biotechnology, Government of India. The study is a component of the larger Indo-German collaborative project 'The Rural-Urban Interface of Bangalore: A Space of Transitions in Agriculture, Economics, and Society'. The German collaborators (University of Kassel and University of Gottingen) are thanked for sharing data on stratification index that facilitated selection of sampling sites for the study. The authors also sincerely thank the farmers in the study sites who co-operated with the survey and discussions.

A zero-inflated Poisson mixtrue model to analyze spread and abundance of the Western Corn Rootwoorm in Austria

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Introduction

The Western Corn Rootworm (WCR) (*Diabrotica virgifera virgifera*) has become one of the main maize pests in Europe over the last years and can shift further north if it becomes warmer (Aragón *et al.*, 2010; Bernardi, 2001). Climate change can improve survival conditions of pests like WCR especially in cooler regions with high precipitation, for example in Austria`s Alpine foothills (Aragón *et al.*, 2010; APCC, 2014). In recent years different modelling techniques have been used to quantify the distribution of WCR under climate change. Aragón *et al.,* (2010) developed a risk map by defining its climatic favorable regions. Hemerik *et al.,* (2004) estimated the mean rate of expansion and the potential of WCR to establish in certain regions. WCR monitoring has become an important tool for projecting the distribution potential and thus determining the impact of WCR pressure on agriculture. Maize monocultures favor the survival of WCR and the percentage of cropland under continuous maize might be one of the most important factors for successful infestation (Meinke *et al.*, 2009). Hence, crop rotations are seen as an important measure to slow down the distribution rate. We have developed a zero-inflated Poisson mixture model by using annual WCR count data from 2002 to 2015 as well as climate and land use data for simulating spread an abundance of WCR in Austria. The model is used for predictive purposes using climate change and land use scenarios.

Materials and Methods

The zero-inflated Poisson mixture model (ZIP) takes into account the over-dispersion of count data, resulting in excess zeros (Diggle and Ribeiro Jr., 2010). Observed zeros may be either due to (i) the absence of infestation in a certain region or (ii) the lack of WCR caught despite infestation (McElreath, 2016). A ZIP model combines two probability distributions that model both zero-generating processes via generalized linear models (Bernoulli and Poisson, respectively). Different sets of covariates have been defined for these two regression models. The probability of WCR occurrence (Bernoulli part) is influenced by (i) its natural spread, represented by latitude and longitude and (ii) the maize share in a particular region. In case of infestation its extent is assumed to be influenced also by climate variables. The spatial auto-correlation is taken into account via kriging, and the resulting spatial ZIP model is used to make predictions for Austrian cropland. The performance of the model has been assessed by cross-validation.

Results and Discussion

Estimating regression parameters for both, the Bernoulli and the Poisson model, results in two sets of regression coefficients, i.e. 'zero-inflated model coefficients' for the Bernoulli part, and 'count model coefficients' for the Poisson part. The effect of the maize share is significantly different from zero in both parts.

That confirms its influence on the probability and number of WCR occurrence. The abundance maps in Figure 1 show a high infestation risk in eastern Austria for two precipitation scenarios and assuming 66% maize in the crop rotation. Probability maps and WCR abundance maps further reveal that a lower maize share can reduce the risk of WCR infestation.

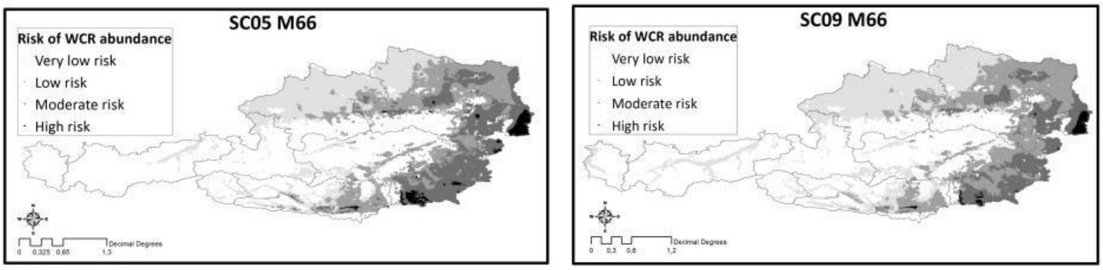

Figure 1. **WCR abundance maps for precipitation scenarios SC05 (+20% daily precipitation, compared to past observations) and SC09 (-20% daily precipitation, compared to past observations) with 66% maize in crop rotation (1 out of 3 years maize). Especially the 'Moderate risk'-area is larger with higher precipitation. (Details for precipitation scenarios: Strauss *et al.*, 2013).**

Conclusions

Current results show that maize share and thus crop rotation have an influence on prevalence and number of WCR. Abundance maps also show different results under different precipitation scenarios. Policy makers can use such analysis to establish information systems and legal (crop rotation) regulations. Further, the results may inform farmers' adaptation decision for maintaining successful maize production.

Acknowledgements

The presented results are derived from the project 'COMBIned weather related RISK assessment monitor for tailoring climate change adaptation in Austrian crop production' (COMBIRISK, KR15AC8K12614). The project is funded within the Austrian Climate Research Program (ACRP) of the Climate and Energy Fund.

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Improved national-scale agricultural mapping using intra-annual time series from sentinel-2 and landsat

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Introduction

With the recent increase in quality and quantity of high-resolution optical remote sensing data, agricultural mapping applications will greatly improve, moving satellite-borne analyses closer to a characterization of land use rather than land cover only. The European Sentinel-2 twin platform constellation provides unprecedented observation frequency at high resolution, new spectral bands and improved spatial resolution. Nevertheless, cloud cover can still render large parts of the growing season to remain unobserved. Integrating additional observations of similar nature, such as those of the Landsat mission, can further improve observation frequency.

Materials and Methods

We processed all available imagery over a time period of 15 months that was acquired by Sentinel-2a Multispectral Imager (MSI) and Landsat-8 OLI over Germany and integrated observations into composites. The data was preprocessed through the Harmonized Landsat-Sentinel (HLS) program, which includes subpixel co-registration, spectral bandpass adjustments and normalization of bi-directionality. Our processing approach includes generating proxy values for Landsat OLI in the Sentinel-2 MSI red edge bands and temporal gap filling on the 10-day time-series. We then derived a national scale crop type and land cover map based on machine learning models. These models were parameterized using reference data from the Land Parcel Information System (LPIS), which was available for three federal German states. Grassland use intensity was determined using a polynomial fit to the vegetation index time series.

Results and Discussion

Spatial patterns of land-use are well preserved in the map (Figure 1). The main centers of crop production in Germany become apparent; the crop lands as characterized here mirror the spatial distribution of high to medium agricultural yield potentials as identified by Soil Quality Rating (BGR, 2014). The main grassland areas are also well captured. The overall accuracy was assessed as 81% and the estimate of the mapped grassland area compared well with the census data, while cereals the area is slightly underestimated for some states with large cultivation areas.

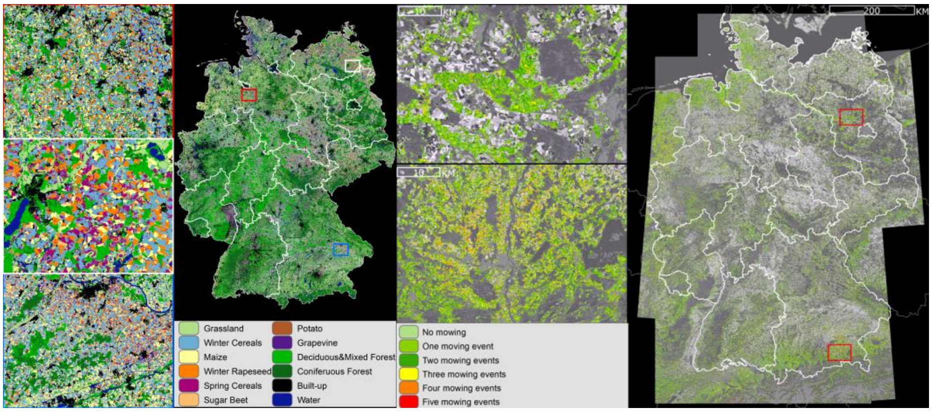

Figure 1. **Crop and land-cover map derived for Germany in 2016 (left) and the number of detetcted moving events in grassland (right).**

Conclusions

Combining optical remote sensing observations from sensors with similar observational characteristics can improve observation frequency and thus allow for the entire phenology to be captured. Having optimized processing algorithms at hand allows for large area processing and mapping of land surface dynamics. With regard to crop mapping, many classes can be well mapped with rather limited training data. Grassland use dynamics cannot readily be classified using spectral data. Here the explicit utilization of phenological profiles allows assessments of agricultural land-use that extend beyond conventional mapping.

Acknowledgements

This research is funded though the ESA Living Fellowship Program (ESA Contract No. 4000112795/14/I-SBo) and Humboldt-University Berlin. We thank NASA for the HLS data and for including Germany as one of the test sites. We thank the Federal States of Brandenburg, Mecklenburg-Vorpommern and Bavaria for the provision of the 2016 IACS (InVeKoS) data set. This research contributes to the Landsat Science Team and the Global Land Program.

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Participatory scenario development of land sparing and land sharing strategies in European landscapes

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Introduction

Scenarios are a common tool in land use science to support decision making. Quantitative modelling of trade-offs resulting from alternative land management often requires scenarios on alternative land use futures. The integration of stakeholders can thereby increase the quality, legitimacy, and dissemination of results. A carefully planned stakeholder process is required to govern the integration process and ensure a proper representation of stakeholder perspectives.

We present results of a standardized participatory scenario development process in the five case study regions (AT, CH, DE, NL, ES) of the TALE project (http://ufz.de/tale). The research framing in TALE is distinct from most scenario processes so far due to its consideration of the ongoing debate on land sharing (LSH) and land sparing (LSP) (e.g. Fischer *et al.*, 2014). This debate has emerged as a response to the vivid discussion on how to make global food systems more sustainable.

Materials and Methods

The scenario process designed for TALE follows a clear hierarchical order with respect to spatial scales and working steps. The TALE team drafted three EU/national level storylines consistent with one global storyline based on the middle of the road shared socioeconomic pathway (SSP; O'Neill *et al.*, 2017). The storylines on LSH and LSP are complemented by an intermediate balanced storyline (LBA). The latter follows current trends with respect to land use and agricultural sector developments at EU level. The TALE storylines form a mixture of an explorative and normative approach and framed the stakeholder processes, i.e. workshops and bilateral discussions, in the project regions. It resulted in three contrasting semi-quantitative spatially explicit land use scenarios.

Results and Discussion

Besides storylines, the process resulted in three land use scenarios in each of the five case study regions. They are described by narratives, maps, and tables displaying the changes of land use parameters under the categories land use and land management.

For example, Figure 1 presents mapped results from the Austrian case study for the LSH and LSP scenarios. Surveys among stakeholders and researchers were conducted following the scenario workshops to assess the appropriateness of the approach for defining scenarios. The results show that stakeholders as well as research gained from the exercise.

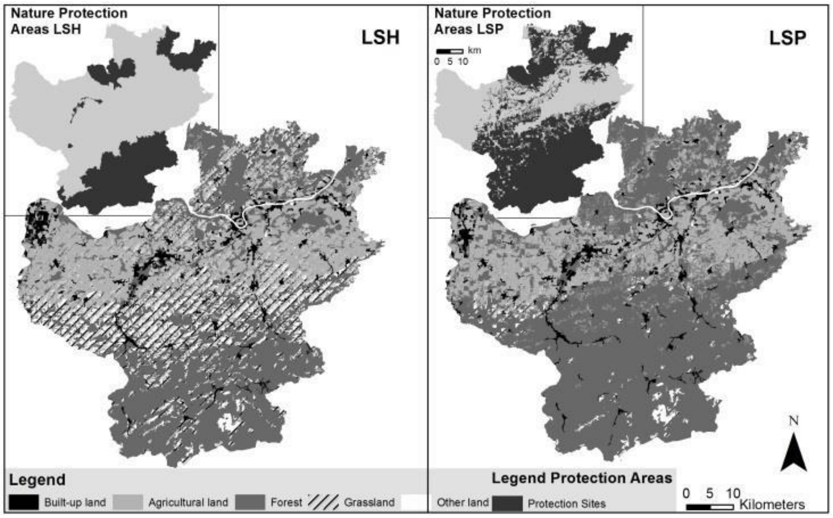

Figure 1. **Land Sharing and Land Sparing scenario results for the Austrian "Mostviertel" case study.**

Conclusions

A well-structured and harmonized process resulted in semi-quantitative participative scenarios on two rather theoretical science driven concepts, i.e. LSH and LSP. The process eases comparability of the scenarios and scenario results among the case studies and allows for regional specific planning recommendations. The use of an established global storyline improves comparability with existing scientific literature.

Acknowledgements

This research was funded through the 2013–2014 BiodivERsA/FACCE-JPI joint call for research proposals, with the national funders German Federal Ministry of Education and Research (BMBF), The Austrian Science Fund (FWF), Netherlands Organisation for Scientific Research (NOW), Spanish Ministry of Economy, Industry and Competitiveness and the Swiss National Science Foundation.

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Viability of double cropping systems in the Southern Amazon, Brazil, under climate change

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Introduction

The Southern Amazon is Brazil´s largest internal producer of cotton, maize and soybean (CONAB, 2017) and much of its productivity is related to an adaptation of intensive agricultural practices such as double-cropping to local climatic conditions (Arvor *et al.*, 2014). Between 2001 and 2011 the area under double-cropping in Mato Grosso increased from 0.5 million hectare to 2.9 million hectare (Spera *et al.*, 2014). However, climate change is posing an increasing challenge to rain-fed double-cropping systems in the Southern Amazon. The objective of this study is to analyze the viability of double-cropping systems in the Southern Amazon under climate change.

Materials and Methods

Climate change effects on crops yields in the Southern Amazon were simulated using the Model for Nitrogen and Carbon dynamics in Agro-ecosystems (MONICA; Nendel *et al.*, 2011) and two different sets of climate data ranging from 2001 to 2040 and 2013 to 2040, respectively. Climate projections are based on the IPCC SRES A1B and were generated with the Weather Research and Forecasting (WRF) model and the Statistical Regional Model (STAR) in a high resolution (900x900m), allotting the study area into more than 2.5 million raster points. Double-cropping systems were simulated as a rotation of soybean grown in the rainy season and followed by maize or cotton (Arvor *et al.*, 2014). Sowing dates for soybean were set to the onset of the rainy season, which was estimated following the approach proposed by Liebmann and Marengo (2001) and Dunning *et al.*, (2016).

Results and Discussion

Simulation results show that double-cropping systems in the Southern Amazon will be negatively affected by climate change both in the WRF and STAR climate forecasts. Under STAR climate predictions, soybean, maize and cotton yields decreased by 10%, 31% and 28%, respectively, between 2015–2019 and 2035–2040 (Figure 1). In the WRF simulations soybean yields increased by 9%, whereas maize and cotton yields decreased by 6% and 5%. Such results put in question future economic viability of double-cropping system in the Southern Amazon.

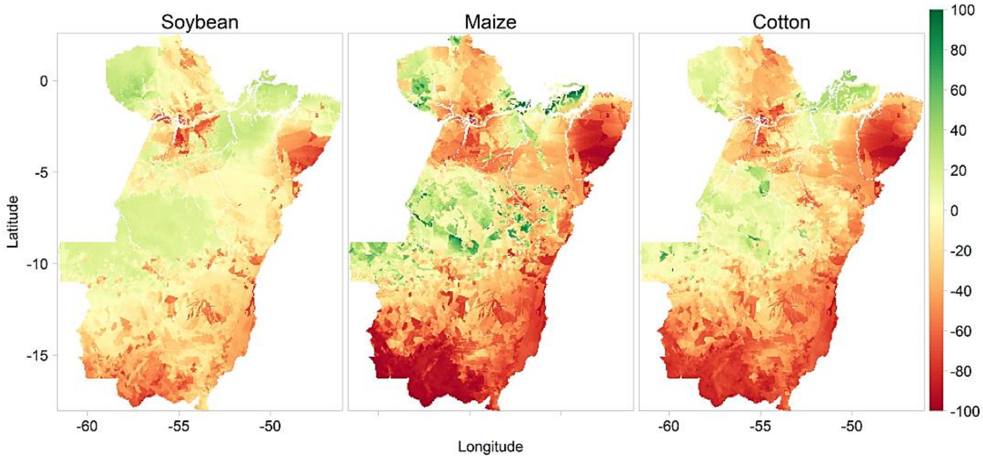

Figure 1. **Soybean, maize and cotton yield change (%) due to climate change between 2015–2019 and 2035–2040 period, using climate data from STAR model based on IPCC SRES A1B scenario.**

Conclusions

Future viability of double-cropping systems in the Southern Amazon is endangered through ongoing climate change, even under adaptation of sowing dates. However, alternative cropping systems including soybean varieties of different maturity groups may be more resilient to climate change.

Acknowledgements

We thankfully acknowledge the scholarship awarded to one of the authors of this paper by the Heinrich-Böll Foundation. The study was carried out in the framework of the integrated project *Carbiocial* funded by the German Ministry of education and Research (BMBF).

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Why grassland conversion matters: A regionalized analysis of decisive factors for Bavaria and their impacts on selected ecosystem services

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Introduction

More than 10% of permanent grassland area has been lost in Germany since the 1990s (BMEL, 2015). In Bavaria, grassland conversion was made subject to approval in 2014 after the conversion limit according to EU legislations was exceeded (Bavarian Official Gazette, 2014). Grassland areas, especially if managed extensively, play a key role in providing ecosystem services (Röder *et al.*, 2016). Increased biogas production and changes in livestock farming were found to correlate with grassland conversion in Germany, however strong regional differences were found (Laggner *et al.*, 2014). To design effective policy measures, different regional drivers and hotspots have to be identified and well understood. This study is contributing twofold to the improvement of future policy measures: Our aim is to increase the understanding of drivers of grassland conversion and to quantify lost ecosystem services in terms of greenhouse gas (GHG) and soil nutrient retention by preforming a regionalized analysis of high resolution data for Bavaria and couple the results with the biogeochemical process model LandscapeDNDC (Haas *et al.*, 2012).

Materials and Methods

The analysis is based on the spatially explicit land parcel data of the Integrated Administration and Control System (IACS) of Bavaria for the years 2005–2015. The correlation of different factors with grassland conversion is tested with a simultaneous autoregressive model (SAR). Agricultural and general statistics, locations of biogas plants as well as spatial datasets on environmental conditions, administrative borders and legal constraints are explicitly taken into account. For converted land parcels, altered soil processes for C and N including GHG exchange is modeled with LandscapeDNDC. Derived net changes in provided ecosystem services are summarized in spatial units.

Results and Discussion

First analyses show strong differences in magnitude and characteristics of grassland conversion for two selected case study regions within Bavaria (Figure 1).

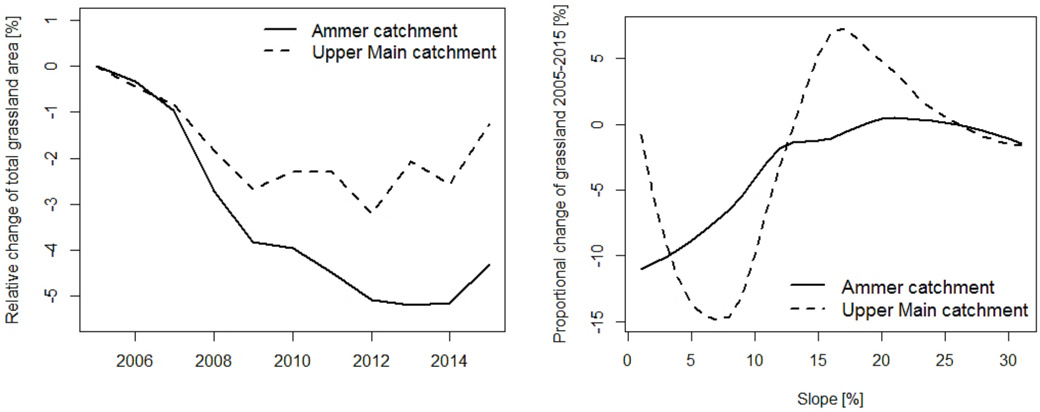

Figure 1. **The two study regions show distinctive patterns both for the relative change of total grassland area in relation to 2005 (left) and the proportional change of grassland area (2005–2015) related to slope (right).**

From further analyses we expect to find positive correlations of increased biogas production, lower regional livestock density and higher livestock numbers per farm with higher grassland conversion rates. We assume relative losses of ecosystem services to be high in regions with a moderate share of grassland but high conversion rates as well as in areas sensitive to change.

Conclusions

Our region-specific analyses of grassland conversion, serves as example how available high resolution data allows decision makers to identify areas with need for action. Besides the insights based on empirical data analysis, the results of this study will provide the parametrization of an agent-based land-use change decision model designed for the comparison of alternative policy scenarios. This tool will enhance informed decision-making to improve future policies.

Acknowledgements

The project AgentDNDC within the framework of the BioTip Programme was made possible through the funds of the German Federal Ministry of Education and Research.

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Regrowing forests contribution to law compliance in private properties of the Brazilian Amazon

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Introduction

Recent international commitments signed by Brazil on climate change mitigation depend on the success of national public policies related to deforestation, reforestation and forest and biodiversity conservation (Brancalion *et al.*, 2016). Chief among those is the implementation of the recently revised Brazilian Forest Code (BFC), regulating the conservation of native vegetation inside rural private properties (Law N. 12.651, 2012). Noncompliance to the BFC created a demand for forest restoration, which, if fulfilled, could support climate change mitigation (Aguiar *et al.*, 2016). Recent studies have calculated the BFC balance (e.g. a quantification of the forest debts and surplus, including an estimate of the amount of the debt eligible to be offset via compensation and/or restoration) (Soares-Filho *et al.*, 2014; Nunes *et al.*, 2016; Martini *et al.*, 2015). However, less attention has been given to the potential of current recovering forest areas to law compliance achievement. In this study, the importance of regrowing forests to reduce BFC incompliance in the Brazilian Legal Amazon was quantified, as well as the demand for additional forest restoration, according to the BFC.

Materials and Methods

A rule-based model was developed to quantify, based on the amount of forest in private lands, the forest debts and forest surpluses, on a property level. Based on the BFC's rules, the model differentiates between forest surplus (i) eligible (ii) non-eligible for compensation schemes and (iii) deforestable forest surplus, as well as the forest debts (eligible to be legalized via compensation in forest markets and or forest restoration). Next, the contribution of current regenerating forests to offset debts and or surplus increase was calculated. A collection of high-resolution datasets, resampled to a 100x100 meters cell size was used, including forest and land use cover and individual properties from a digital cadaster (SICAR, 2017) (over 250,000 properties).

Results and Discussion

Native vegetation cover inside this study selected properties amounted to 36.3 million ha when only primary forests (PF) mapped were included in the balance calculation and to 43.2 million ha when we added secondary vegetation areas (SV). SV areas in properties are mainly concentrated in states with higher forest debts. Most PF is not apt for compensation under the BFC (24.5 million ha considering only PFs and 27.5 million ha considering PFs and SV areas) (Figure 1). We estimate that regrowing forests could reduce 3.2 million ha of forests debts to be regenerated (reduced from 9.2 million ha considering only PFs to 5.9 million ha including secondary vegetation areas). This would represent a 35% reduction of restoration and/or compensation requirements by private properties analyzed by this study. Likewise, forest surpluses eligible for compensation increased by 3.35 million ha when we included SV in calculations, totaling 12 million ha (Figure 1).

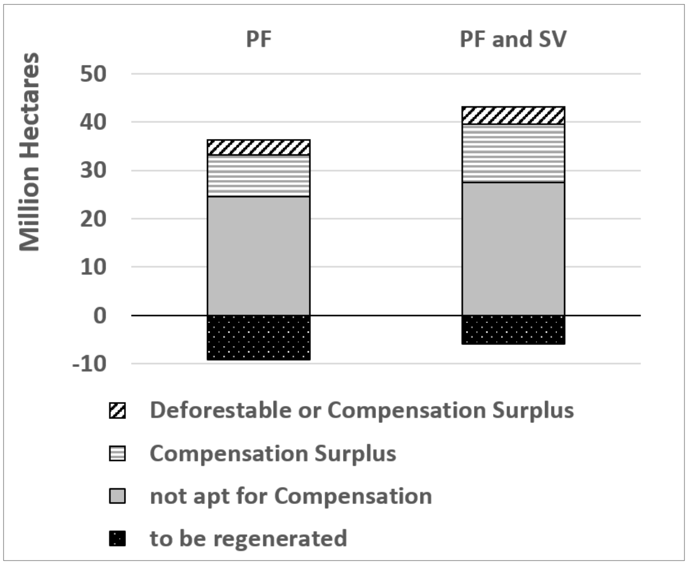

Figure 1. **Forest Balance for the analyzed properties in the Brazilian Legal Amazon.**

Conclusions

This study found that current regrowing secondary forests hold a large potential to offset forest debts in the Brazilian Legal Amazon. Therefore, passive regrowth could represent an alternative solution for a large share of farmers to comply with the BFC. However, given that there are no legal instruments to guarantee the protection of secondary vegetation the fate of these areas is at high risk, given the increasing demands of land for agricultural expansion.

Acknowledgements

Leticia Hissa acknowledges the financial support from CAPES/Science Without Borders program. BEX 104713-2. This work has been supported by the Brazilian-German cooperation project CarBioCial and financed by the German Ministry of Research and Education (BMBF, Project No. 01LL0902).

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Peri-urban agriculture in Istanbul: An analysis of ten family-based urban gardens

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Introduction

Even though the benefits of urban agriculture have been widely acknowledged, promoting urban agriculture in Istanbul has been hampered by rapid urbanisation and the lack of understanding of the economic, social and ecological roles within the larger urban system. In order to propose solutions for this challenge, it is necessary to understand the perceptions and practices of gardeners and relevant stakeholders in the city. This study investigated gardening practices in ten urban gardens in Istanbul. The study aimed to describe the socio-physical characteristics of the gardens and to examine the association between gardeners' socio-demographic backgrounds and their perceptions, motivations and farming practices.

Materials and Methods

This study focuses on the experiences of urban gardeners in Istanbul and aims to: (1) describe the bio-physical characteristics of ten garden projects (i.e., the gardens' facilities and types of plants grown) and understand the pressures affecting gardeners' activities; (2) examine the association between gardeners' socio-demographic backgrounds (i.e., age, gender, migrant background) and gardening practices with a view to understand if knowledge carried from the past affects current gardening activities; (3) understand gardeners' perceptions and motivations to gardening, including its positive and negative aspects. A case-study methodology has been used in this study. Case studies explore and investigate contemporary real-life phenomenon through detailed contextual analysis of a limited number of events or conditions, and their relationships (Yin, 1994). Our case study areas consist of 10 urban gardens located on the Asian side of the city (see Figure 1).

Figure 1. **study area and location of sample urban gardens**

The gardens were selected from different parts of the city, which included the densest zones of the inner city, the transition zone (from core to periphery) and the edge of the urban periphery.

The selected gardens also have a strong relationship with the urbanisation infrastructure around them, such as roads, new housing areas and urban renovation sites. The overarching goal was to achieve understanding the real problems through observing a diverse set of community gardens.

Gardeners were interviewed regarding their experiences, asked to describe their gardening practices and to evaluate the extent to which these practices are rooted in past knowledge transmitted from past generations. In-depth interviews also addressed social ties and the role of women, youngsters and older adults in gardening practices, self-reported health implications, and the main benefits and barriers related to peri-urban agriculture. Qualitative content analysis was used to categorise the interviews and data from the meetings with gardeners into meaningful themes. An inductive approach was used to code the interviews by creating categories and organising them into themes. present the main themes that arose in the content analysis of the interviews: Kinship ties and collective memory, gardening activities, role of women and older adults, social capital and health-related aspects of gardening, and benefits and barriers to peri-urban agriculture as experienced by gardeners.

Results and Discussion

Qualitative analysis showed that urban gardeners' production systems in Istanbul are much dependent on family kinship. Most gardeners are migrants who have maintained traditional practices. Even though the leader of each garden is the oldest man of the family, in practice a large proportion of urban gardeners are composed of women. The majority of gardeners had concerns about the availability of land and if they would manage to continue their activities in the future. The results shed new light on the dynamics of peri-urban agriculture in Istanbul and consider how policy might be developed to urban agriculture projects among different stakeholders.

Conclusions

Our findings illustrate the multifaceted nature of urban agriculture in Istanbul. The sustainable management of UA involves the interplay of physical and social aspects. In terms of physical aspects, UA represents an important source of food security and resilience as it improves economic growth for the urban farmers (Akin, 2011).

In relation to social aspects, UA in Istanbul provides historical continuity as urban gardening helps maintain ancient practices and knowledge. Our results demonstrated that UA in Istanbul is a main source of experiential knowledge (Barthel, Folke and Colding, 2010). This experiential knowledge acts as a 'library of information' (Berkes, Colding and Folke, 2000) and a 'store of agroecological knowledge' (Kaldjian, 2003) which contributes to the resilience of the city.

Acknowledgements

Thanks to the students of Landscape, Design, Health Class at Okan University, Department of Architecture for helping to the researchers during the site visits and interviews with the gardeners.

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Analysing future agricultural production under water restrictions at landscape scale: an Austrian case study

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Introduction

Sustainable land use assessments require to consider interactions within and among socio-ecological systems. Climate change, for instance, has direct impacts on agricultural production and other ecosystem services (ES) triggering indirect effects in socio-ecological systems (Iglesias and Garrote, 2015). The aim of this investigation is to assess the impact of future climate change scenarios on agricultural production and groundwater availability in the Austrian case study region Seewinkel. The Seewinkel is characterized by multiple, competing demands for land and water. Agriculture, with crop, forage and wine production, is the main user of both resources. The area is partly under nature protection and several saltine lakes exist, which form a unique biotope. These lakes require a certain level of the groundwater aquifer to ensure the capillary uptake of the salts. In the area, irrigation is a potential agricultural adaptation measure to avoid yield losses in dry years. However, the renewal of the groundwater aquifer and hence water availability also depends on future climate. The risk of maladaptation to future climate scenarios is high, especially due to uncertainties in future precipitation sums and patterns (APCC, 2014). Maladaptation can reinforce trade-offs between ES in the agricultural, water, and biodiversity sectors. A landscape scale consideration is important in this assessment in order to account for spatial effects of irrigation water withdrawal and capillary uptake of the salts at particular sites.

Materials and Methods

An integrated modelling framework is applied to the case study region consisting of i) the regional statistical climate model ACLiReM (Strauss *et al.*, 2013), ii) the crop rotation model CropRota (Schönhart *et al.*, 2011), iii) the bio physical process model EPIC (Williams, 1995), and iv) the economic land use optimization model BiomAT (Stürmer *et al.*, 2013; Mitter *et al.*, 2015). The optimization model is extended by a groundwater balance equation to integrate water restrictions on agricultural production at landscape level. The impacts on land and water use of three different climate scenarios until 2040 are assessed including a scenario *similar* with almost same precipitation volumes as in the past period 1975–2005, a scenario *wet* with +20% and a scenario *dry* with -20% precipitation volumes as in the past period. A temperature increase of +1.5°C is considered in all three scenarios until 2040. Maladaptation due to inaccurate or unavailable climate information is assessed for following cases: i) adaptation to a different climate scenario for the entire period, and ii) adaptation to a single year within a climate scenario for the entire period. Annual variability of precipitation is considered and impacts caused by maladaptation on some ES in the agricultural, water, and biodiversity sectors.

Results and Discussion

Table 1 shows economic and environmental results in the case study area for optimal adaptation to the climate scenarios at landscape scale.

In scenario *similar*, net-benefits increase due to a larger vineyard area. In scenario *wet*, higher yields and an even larger increase in vineyards can be achieved with more irrigation. In *dry*, the area of vineyards remains constant but net-benefits still decrease due to lower yields from limited irrigation water availability. The assessment of maladaptation shows that having information about the drier climate scenarios and extreme years results in groundwater extraction and lower agricultural production.

Table 1. **Economic and environmental results for the period of 2010–2040 and each climate scenario.**

Scenario	**Net benefit in Mil. €**	**Irrigation in Mil. m³**	**Cropland in ha**	**Intensive Grassland in ha**	**Extensive Grassland in ha**	**Vineyards in ha**	**Other land in ha**
Past	16.4	26.5	25,146	784	2,627	3,017	13,256
Similar	27.7	21.7	23,925	730	2,930	5,139	12,376
Wet	40.6	39.5	25,256	734	2,433	6,031	10,647
Dry	10.6	6.9	22,246	717	2,501	3,019	16,617

Conclusions

The landscape approach allows assessing the impact of future climate scenarios on agricultural land use and management while considering the interactions between land and water ES in the case study area. This analysis shows that sustainable land and water use are strongly driven by irrigation water availability in this semi-arid case study. Maladaptation, i.e. ineffective adaptation to a climate provokes trade-offs between ES such as water provision for competing demands.

Acknowledgements

This article was prepared within the BiodivERsA/FACCE-JPI project “Towards multifunctional agricultural landscapes in Europe (TALE)” funded by the Austrian Science Fund (FWF): [I 2046-B25]

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Modeling the spread of the invasive Asian bush mosquito *Aedes japonicus japonicus* in Germany

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Introduction

The Asian bush mosquito was found for the first time in Germany in 2008 on the border with Switzerland (Schaffner *et al.*, 2009) and since than it has spread widely in western Germany (Kampen *et al.*, 2016). As the species is a potential vector of many human and animal pathogens like the West-Nile virus and the Japanese enzephalitis virus, it is of the utmost importance to model the potential distribution areas of the species. The occurrence of the Asian bush mosquito is dependent on climate and land use. Therefore, we built a combination of two submodels to predict its recent and future potential distribution: One that determined the climatic niche and one that determined the ecological niche of the species dependent on land use factors.

Materials and Methods

To analyse the climatically suitable areas, we have built up a model that is suitable for a small number of presence only data of the invasive species. We used additional occurrence data from three native mosquito species to compensate for the lack of absence data and trained a support vector machine (Pedregosa *et al.,* 2011), which delimits the climate habitats of the target species from the habitats of the selected native species. Monitoring data from 2011 to 2014 were used for training the model and occurrence data from 2015 for the validation. Using the model results for the recent climate conditions and different IPCC climate change scenarios, we were able to predict the occurrence of the species until the year of 2080. The landscape model is, as opposed to the climate model, implemented with a white box approach. Many different large and small scale land use parameters were taken into account. Using the fuzzy-modelling technique, we evaluated the survival and colonization potential of the species and its external impact for each parameter.

Results and Discussion

Our climate model approach appears to be suitable for predicting the distribution area of the Asian bush mosquito in newly invaded areas. We reached a high selectivity and the model output matched very well with the presence data from 2015. We predicted a massive increase of *Ae. j. japonicus* future distribution areas in Germany over the next 70 years (Figure 1), presumably due to changing precipitation. However, with increased warming, the process is likely to reverse as the species is known to be adapted to temperate and cold temperate climates, and temperatures above 34°C inhibit larval development (Scott, 2003).

The application of the fuzzy model and the fine adjustment of the parameters have not yet been completed. The first results will be presented at the conference.

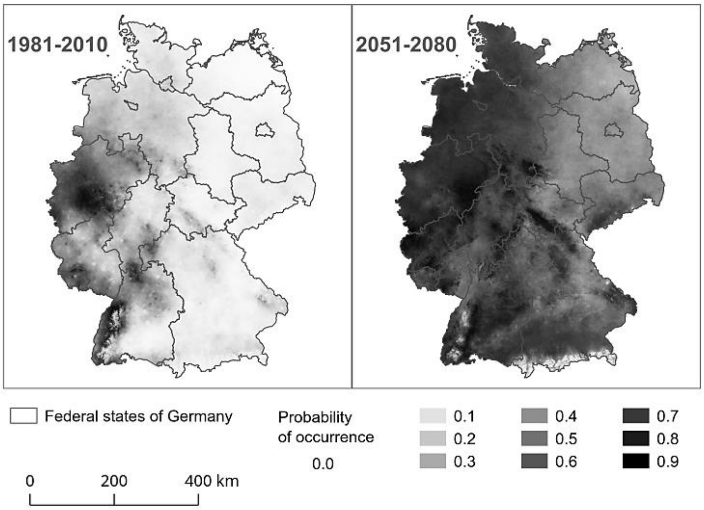

***Figure 1*. Calculated occurrence probabilities of the Asian bush mosquito in Germany under recent (left) and probable future climate conditions (right).**

Conclusion and Outlook

We have built a model for analysing the species climatic ecological niche and are still in progress on building a follow-up model based on landscape factors. The result will provide a map showing the possible hotspots, propagation barriers, and step-stones for the species. Based on the results of both models, we are going to implement process-based spread models in the future.

Acknowledgements

Our project was funded by the Federal Ministry of Food and Agriculture (BMEL, grant no. 2819105315) and the Ministry of Science, Research and Culture of the Federal State of Brandenburg (MWFK), Germany. JMJ was financially supported by the Deutsche Forschungsgemeinschaft (DFG; JE 288/9-1).

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Human-wildlife conflicts in agricultural landscapes: combining ecological field data with participatory stakeholder approaches

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Human wildlife interactions have long been debated controversially among different interest groups. While conservationists often argue that the dramatic losses of habitat and biodiversity threatens the survival of many species on the one hand; land users, on the other hand, who directly experience economic losses by wildlife damages argue that losses should be compensated, effective prevention measures subsidized and wildlife management be adapted.

However, in many cases, interactions and related conflict pattern between human and wildlife are often not known. Research-based evidence to support sound decision making for adapted land management, the design and implementation of damage prevention measures is yet rarely considered. Therefore, we propose the use of an integrated framework that combines participatory approaches with ecological field data and spatially explicit indicator-systems to address this challenge. Methodological aspects as well as practical outputs for wildlife management in human-dominated landscapes will be discussed.

Keywords:

wildlife, migration, damage prevention, conservation biology, impact assessment

Sustainable land-use and conservation agriculture to overcome agricultural crisis in Kerala

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Introduction

In the tropical state of Kerala in India, demands in food are rising with growing population, whereas availability of reliable water and farm land are fast decreasing. The state with heavy rainfall and fertile soil depends on neighbouring states for rice and vegetables. Land management and conservation agriculture becomes highly significant to maintain food security. More than 50% of the paddy fields was lost in the past three decades by encroachment for residential complexes, economic expansion zones, roads and mining. Implementation of environmental laws fails due to vested political interests and high levels of corruption. Survey showed that 80% farmers have already left the agricultural sector since 1950 because of Land Reforms Act that limited the area of land ownership, financial issues, non-availability of machineries in time and delay in the procurement of products by the marketing agencies (CEREM, 2013).

Materials and Methods

This paper analyzes various socio-economic and environmental issues associated with agriculture, especially in rice farming in Kerala and examines the possibility of conservation agriculture in overcoming the crisis. Impacts of climate change, environmental degradation and the changing government policies have been assessed. Data and information for the study have been collected from various national institutes, government departments, agricultural universities and NGOs. Changes in land-use and rainfall characteristics have been statistically analysed. Change in water availability under an altered climate has been assessed using hydrological model.

Results and Discussion

Extremes in climate have become a major threat to agriculture. There is an increasing trend in the development of convective clouds in the eastern hills where all rivers in the state originate. Large rain drops and intense rain erode topsoil which is already degraded due to deforestation, which is then deposited in rivers, adding to water scarcity and creating floods. Another trend in rainfall is the increasing seasonality that makes the dry season longer. Loss of soil moisture adds to the fall in production. Changing rainfall characteristics, droughts, floods and untimely rainfall during the harvesting period cause tremendous loss in agriculture. Vagaries in monsoons and rise in temperature affects the crop cycle and yield. Though the state receives an annual rainfall of more than 3000 mm, it experiences seasonal water shortage because of typical topography and improper management. Groundwater level is receding at an alarming rate of 1 metre per decade because of increasing rainfall seasonality, land-use chnage and unsustainable extraction. Model study predicts a considerable fall in water availability in near future. Recent hike in food price and shortage of cereals and vegetables have created interest in land and water conservation and conservation agriculture. Implementation of conservation agriculture, though in developing stage has produced expected results of more production with small investment.

The state needs a comprehensive policy for agriculture, water resources, environment and climate change adaptation and a strong mechanism for its implementation. Traditional, low cost methodologies in soil and water conservation, pest control, weed control and production of bio fertilizers are to be encouraged from the level of farmers holding small farm area. Special economic package and technical assistance should be provided to small and marginal farmers. Better storage facilities for seeds and grains, timely procurement of products and emergency assistance during crop failure due to extreme climates are necessary. Proper public awareness can help minimising the intensity of protests during the introduction of new varieties and new policies. Encouraging conservation agriculture may attract a new and young generation of farmers and control the internal migration as employment opportunities are decreasing. New crop varieties and crop calendar is necessary to cope with environmental changes and to reduce GHG emissions. Certain initiatives such as cooperative farming and incentives for farmers have been taken to rescue agriculture. But the progress is slow because of the typical bureaucratic and political set-up. Development of an appropriate policy is possible with the cooperation of scientists, representatives from the agricultural community, NGOs and the technicians and officials from the government departments.

Conclusions

Measures for land and water conservation and the introduction of conservation agriculture has proved the sustainability, economic benefits and increase in production, especially in rice farming (Ajith and Nair, 2012) in Kerala. Low cost, locally available traditional technologies in soil and water conservation were successful. Government has made agreements with banks for agricultural loans with low interest and with liberalised formalities. Promoting agriculture through self help groups (SHGs, mostly women), schemes for land protection and agriculture through rural employment schemes, arrangement subsidised supply for seeds and fertilizers produced good results. Recently, environmental protection has been adequately included in the curriculum. Modern agricultural technologies that minimises the use of water and new concept of utilising inexpensive biofertilizers are being popularised.

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Permanence of efa landscape elements in an intensively cultivated Hungarian agricultural landscape

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Introduction

In the member states of the European Union, the Common Agricultural Policy fundamentally defines changes in agricultural landscapes. In the 2014 reform, special attention was given to protection of biodiversity and landscape mosaics. In my PhD research, I examine the potential effect of the agricultural policy on the landscape structure. In this summary, I present the conclusions of analysing the photo documentation created on field surveys in the first two years (2016 and 2017).

Materials and Methods

The main objective of greening is to protect the quality of the water and soil, as well as to protect the biodiversity and the rural landscapes. Among the long-term objectives are mitigating climate change and adapting our agriculture to it (eea.europe). In the greening procedure, farmers have to meet the requirements in three various aspects to receive subsidies. These are: (1) maintaining permanent grasslands, (2) crop diversification, and (3) dedicating 5% of arable lands to 'ecologically beneficial elements' ('ecological focus areas', or EFAs in short) (Ministry of Agriculture of Hungary, resolution No. 10 of 2015 (III. 13.))

In my previous researches I have concluded that landscape elements in greening can be suitable for maintaining the structural stability of a landscape (Máté, 2016).

The study area is a 120 km^2 large conventional agricultural region. Its speciality is a highly protected grassland mosaic woven into intensively cultivated arable fields, which is a significant bird habitat both nationally and internationally. (It incorporates important habitats for species like the eastern imperial eagle (*Aquila heliaca)*, the great bustard (*Otis tarda),* or the Red-footed falcon (*Falco vespertinus*).

In Hungary, greening legislations are in effect since 2016, therefore I started an annual field survey in that year. The first field survey was conducted between 12 July and 13 August 2016, while the second from 8 to 10 September 2017. Among the preliminarily selected landscape elements, there are both EFA and non-EFA elements. Unfortunately, in the definition of which landscape elements are eligible for subsidies, ecological aspects have not been among the most important ones (Máté, 2017).

I created a photo documentation of the selected landscape elements so that changes from one year to the other can be illustrated with a series of pictures. I also noted attributes related to extension, composition of species and condition. In total, I performed a monitoring of 48 landscape elements.

Results and Discussion

Based on the field survey, it can be stated there is no significant difference in the ecological values of EFA and non-EFA landscape elements. In the tree and bush groups, plant communities of the invasive species black locust (also known as false acacia, *Robinia pseudoacacia*) can be found in both categories. Unfortunately, in case of small lakes, precious habitats cannot be accounted as greening elements, while hollows (former borrow pits) with no ecological values – ploughed in most cases – are part of the subsidy system as EFA elements.

Regarding alleys, the examined area can be considered as disadvantaged, as due to the strict legislation, there is not a single alley in the entire 120 km^2 area that could be officially accounted, even though I identified numerous alleys consisting of native species on my field survey. The most saddening changes are in permanent, not sensitive grasslands functioning as margins of arable fields: in most cases, they disappeared already after the first year, as the farmers have ploughed them.

Conclusions

After two years, it can be concluded that greening landscape elements do not guarantee the preservation of biodiversity in agricultural landscapes. With the spread of the subsidy system, farmers see more and more the financial opportunities in landscapes which otherwise would be critical in the protection of biodiversity and landscape mosaics.

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Supported by the ÚNKP-17-3 New national excellence program of the Ministry of Human Capacities.

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Environment protection through community participation: interventions in Rajasthan, India

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Abstract

Conservation involves social dimensions which are directly connected to the local ecological setup of the region through their culture. The concept of 'Aranya Samskruti' (Forest Culture) deeply embedded in the rituals and conventions of the Indians depict the picture of its eco-centric approach. The Indian customs describes the symbiotic relationship of human and nature through its traditional principle of 'Prakruti Purush' (nature and man). Based on the traditional conservation practices, the community manages its natural heritage. There are diversity of customs and traditions which result into vividness in the conservation practices. Thus, the socio-ecological systems could be used for site-specific conservation programs and the policies.

The present investigation reviewed the traditional knowledge and the customary actions of different communities of India, in general and Rajasthan, in particular. The primary aim of this investigation was to document the conservation practices inherited in the culture of different communities and to discuss the modern relevance of such actions towards conserving the local natural heritage. Further, using the cultural ethos, the authors prepared site-specific models from the outcome of the extensive scientific and social research carried out at Abu Hills (Sirohi) and Bharatpur from 2006 to 2017. The models represented the cultural and traditional linkages of community with components of nature. These linkages were used for livelihood generation of the local people. Further, a green lanscaping was undertaken in rural environs around World Heritage & Ramsar Site – Keoladeo National Park (Bharatpur), to present the eco-centric approach of cultural traits in India.

Abu model of livelihood from birding was focused on the conservation of habitats and the avifaunal species of global interest, i.e., Green Munia (Amandava formosa). Chak Ramnagar model of livelihood from artifact production was focused on the eco-restoration of the sites around Keoladeo National Park (Bharatpur).

It was observed that modern conservation actions overlook indigenous eco-centric customs and traditional values, rendering the followers to break up the inter-relationship with their natural set up. Thus, it is the tie to respect the customary and indigenous traditions to revive the symbiotic bond of "Man and Nature".

Crop residue energy potentials: what role for sustainable intensification?

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Introduction

The use of agricultural residues for energy purposes is seen as increasingly appealing due to its potential to contribute to climate change mitigation without jeopardizing food security. However, the attainable energy potentials and their associated contribution to climate change mitigation may be constrained by other socio-economic or environmental concerns, such as residue requirements for other economic uses or preservation of soil organic carbon (SOC). Sustainable intensification (SI) measures, as for example tailoring residue removal rates to SOC levels, can increase energy potentials while at the same time enhancing the socio-economic and environmental sustainability of agro-ecosystems.

This study investigates the extent to which SI allows increasing the potential of crop residues, while respecting other environmental objectives and competing demands. It presents the spatially explicit assessment of the theoretical, technical, environmental, socio-economic, sustainable, and implementation potentials of crop residues (see Batidzirai *et al.*, 2012 for a definition of potentials) under different SI measures. These measures include a) the adoption of varieties with enhanced crop-to-residue ratios, b) precision fertilization, c) tailoring residue removal rates to soil organic matter concentration in the soil, and d) full soil winter cover. The assessment focuses on the case-study of North Rhine-Westphalia in Germany, a highly productive and intensively cultivated region, and employs a novel methodology combining stakeholder interviews, crop modelling, economic modelling and estimation of residue potentials.

Materials and Methods

The methodology is based on the spatially explicit estimation of residue potentials with input from stakeholder interviews, agro-ecosystem modelling and economic modelling. Via the stakeholder interviews, we identified promising options for the SI of the crop residue supply chain. The different SI options have been simulated by the agro-ecosystem MONICA model (Nendel *et al.*, 2011) to estimate crop residue yields, as well as environmental variables (SOC, run off, nitrate leaching). The CAPRI model (Britz and Witzke, 2005) provided information on land use, energy prices, residue production costs, and residue demand.

The production, environmental, and economic information derived from the two models was integrated into the calculations for the spatially explicit estimation of the different crop residue potentials.

Results and Discussion

Our analysis allowed quantifying production and environmental variables such as residue potentials, residue yields, soil organic matter topsoil concentration, and nitrogen leaching (Figure 1) and identifying three distinct effects on potentials:

a) a significant reduction in potentials when considering socio-economic and environmental constraints (changes between theoretical to sustainable potentials)
b) a positive effect of SI due to the adoption of management-related measures (changes due to cultivars, fertilization, residue removal and cover crop practices)
c) a change in potentials over time, due to changing demand, and cumulative effects on variables such as SOC (changes between 2010, 2030 and 2050).

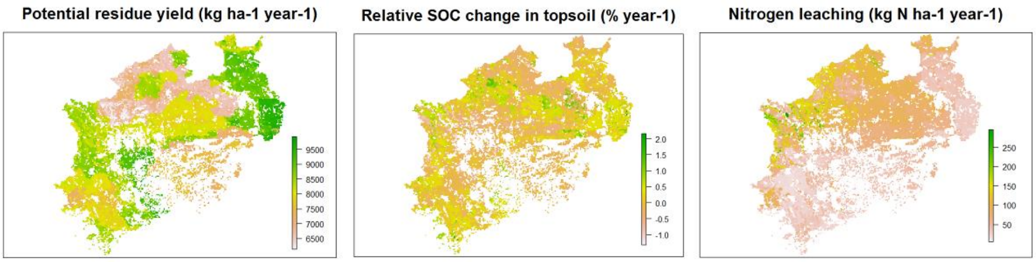

Figure 1**. Averages of residue yield potential, change in topsoil soil organic carbon, and nitrogen leaching in the period 2006–2030 for RCP 2.6.**

Conclusions

This study presented a novel methodology for the spatially explicit quantification of the effect of SI on crop residue potentials, as well as differences across different types of potentials and over time. Results indicate that SI can play a significant role in increasing potentials while respecting socio-economic and environmental constraints.

Acknowledgements

This research is part of the SUSTAg project, that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 652615.

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Governing synergies between ecosystem services on agricultural land: a policy analysis of five European case studies

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Introduction

Recognition of Ecosystem Services (ESS) and biodiversity in policies increases but is still moderate (Bouwma *et al.*, 2017). When looking at soil ESS, for example, only few policy measures are linked to the protection of soils (Turpin *et al.,* 2017). The paper applies a case study approach based on five European landscapes for delivering insights into the characteristics, design and application of agri-environmental policy instruments and policy measures considering different land use types, targeted policy fields, mechanisms of supporting or prescribing certain ways of land management and regarding governance structures. Moreover, the paper describes and assesses the governance structures which shape the concrete implementation of policy measures to provide recommendations for improving the integration of ESS.

Materials and Methods

Comparable information on policy settings and governance in the case study regions were gathered based on templates specifying the information needed and potential sources. Information was provided on strategies and obligations concerning agricultural land use and its environmental impacts, national and/or regional implementation and specifications of the CAP and of the Swiss agricultural policy, relevant environmental regulation and actors and governance. Sources of information were public documents and legislative texts but also expert interviews with representatives of the agricultural or environmental administration, farmers' organisations and NGOs or feedback from regional stakeholder meetings.

Results and Discussion

The analysis shows that besides sectoral legislation setting the mandatory baseline for land management, agricultural policies contain various incentive-based measures supporting environmentally sound management in particular via direct payments with attached environmental conditions and agri-environment climate measures (AECM) and comparable payments in Switzerland. AECM allow for adapting management within measure to local conditions by offering a number of sub-measures (e.g. different mowing regimes), defining concrete requirements in consultation with nature conservation administration, or result-oriented approaches. The majority of those measures aims at biodiversity protection and is often targeted to defined areas e.g. certain biotope grassland, habitat types, steep slopes or alpine meadows.

Moreover, we identified some rather innovative approaches, such as collective action and result-oriented schemes, for which we found several examples in the case study regions. They often require high commitment from farmers and willingness to communicate and to learn and are thus bound to have lasting effects on environmental awareness.

However, these measures need to be complemented by information and advice to become effective in biodiversity conservation and ESS protection in agriculture.

Conclusions

The analysis shows that the EU member states and Switzerland have developed elaborate systems of policy instruments aiming taking account of ESS and biodiversity on agricultural land. Mandatory baselines with effective enforcement are crucial for securing minimum standards but incentive-based measures are important for targeting especially regional specificities. In order to increase the effectiveness and efficiency of measures at a regional and local level, the transferability of good practice has to be supported and extended.

Acknowledgements

We greatly acknowledge the contributions by Annelie Holzkämper, Marta Nieto Romero, Martin Schönhart, Emma van der Zanden, Bárbara Willaarts and Žana Mehić.

This research was funded through the 2013–2014 BiodivERsA/FACCE-JPI joint call for research proposals, with the national funders German Federal Ministry of Education and Research (BMBF), The Austrian Science Fund (FWF), Netherlands Organisation for Scientific Research (NOW), Spanish Ministry of Economy, Industry and Competitiveness and the Swiss National Science Foundation.

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Stability of grain legume yields is a matter of scaling

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Introduction

One of the greatest challenges of this century is to meet the global demand for protein to feed an increasing world population, while reducing negative environmental impacts of current production systems (Henchion *et al.,* 2017; Tilman and Clark, 2014). Grain legumes produce high quality protein for food and feed, and provide ecosystem services contributing to sustainable cropping systems (Watson *et al.,* 2017; Reckling *et al.,* 2016). Nevertheless, yield instability is perceived to be high, resulting in low adoption by farmers (Zander *et al.,* 2016), especially in Europe, where grain legumes were only cultivated on 1.5% of the arable land in 2014 (Eurostat, 2016). The objective of this study is to assess whether yields of grain legumes are more or less stable than those of other crop species using data from long-term field experiments (LTE) in different agricultural landscapes in a northern European context and by accounting for yield differences between crops by applying Taylor's Power Law (TPL).

Materials and Methods

The data set used for the analysis of yield stability is based on 3768 site-year combinations from five LTEs conducted in the United Kingdom, Sweden and Germany. Sub-sets of data were generated in order to calculate the mean (μ) and temporal variance (σ^2) over eight consecutive years representing the typical rotation length, resulting in 471 observations. For the analysis of temporal yield stability, a corrected coefficient of variation (cCV) was introduced that is based on the power law residuals (Döring *et al.,* 2015), i.e. the residuals of the linear relationship between $\log(\sigma^2)$ and $\log(\mu)$ for the crop yield observations.

Results and Discussion

Our results showed that TPL, a widely verified quantitative pattern in ecology and other sciences (Eisler *et al.,* 2008) can be used effectively to quantify yield stability of different crop species grown in LTEs (Figure 1, A). Using the log-linear relationship between yield and variance in a cCV and data from LTEs changed the ranking of yield stabilities of crop groups compared to previous research (e.g. Cernay *et al.,* 2015). Yield instability of grain legumes (30%) was higher than that of autumn-sown cereals (19%), but lower than that of other spring-sown broad-leaved crops (35%), and only slightly greater than spring-sown cereals (27%) (Figure 1, B). By using the cCV that accounts for the differences of mean yields between crops following TPL, we estimated a 21% higher yield stability for grain legumes compared to a standard stability measure.

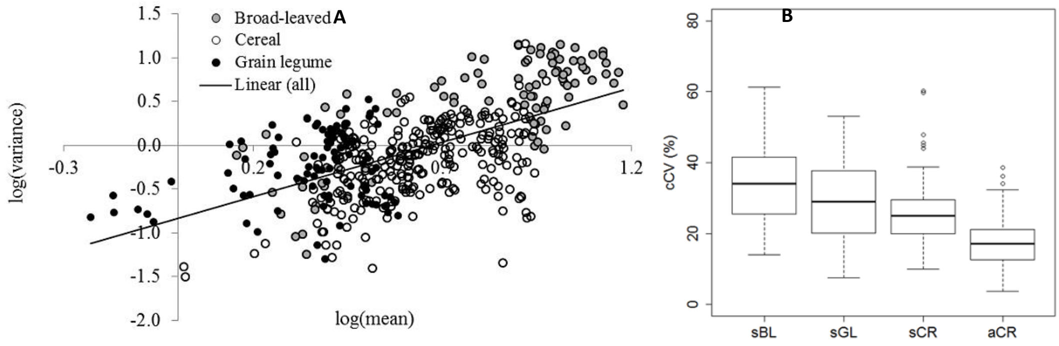

Figure 1. **A) Relationship between the logarithm of the variance against the logarithm of the mean using. Each data point represents the mean and variance of an 8-year period from long-term experiments for grain legumes (n = 100), other broad-leaved crops (n = 96) and cereals (n = 275). The relationship is shown with a linear regression line over all groups of crops. B) Yield stability of spring-sown broad-leaved crops (sBL) (n = 75), spring-sown grain legumes (sGL) (n = 100), spring-sown cereals (sCR) (n = 117) and autumn-sown cereals (aCR) (n = 158), estimated with the corrected coefficient of variation (cCV).**

Conclusions

Yields of grain legumes are not inherently less stable than those of other crops, as has been interpreted from previous research. The novel scale-corrected cCV removes the dependency of variance on the mean yield. Our findings contribute to improving the perception of grain legumes, showing that they are effective as an option to provide protein for food and feed, and support ecosystem services in agricultural landscapes.

Acknowledgements

We thank the Swedish University of Agricultural Sciences, Rothamsted Research, the Humboldt-University of Berlin and the Julius Kuehn Institute for providing the data from their long-term experiments. The work was financed by the FACCE-ERA-NET+ project Climate-CAFE (Grant PTJ-031A544).

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TOPSIS-GRA Coupled Model for Multifunction Orientation of Rural Landscape in Metropolitan Suburb Shanghai, China

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Introduction

Rural landscape function exhibits significant spatio-temporal heterogeneity (Willemen *et al.*, 2010; Bolliger *et al.*, 2011; Rodriguez *et al.*, 2015). With the urban sprawl, the modernization and industrialization of agriculture in China, diversification and differentiation of rural landscape functions are constantly enhanced, and the multifunctionality grows stronger (Wu, 2007). However, the ignorance of spatio-temporal variability, hierarchy and malfunction of the rural landscape functions leads to the inaccuracy in the evaluation of multifunctionality. Scientific orientation of rural landscape multifunction has attracted considerable academic interest (Fischer and Lindenmayer, 2007; Termorshuizen and Opdam, 2009). Our study proposed a new framework integrated with the coupled model TOPSIS-GRA (technique for order preference by similarity to ideal solution and grey correlation analysis) for an accurate evaluation and orientation of the multifunctionality of rural landscape in Metropolitan Suburb Shanghai, China.

Materials and Methods

The study was carried out in Qingpu District in the west side of Shanghai (QPDS), located on the south edge of the estuary of the Yangtze River in the middle portion of the East China coast (Figure 1).

1. A research framework was developed in our study in accordance with the Millennium Ecosystem Assessment (MEA, 2005) consists of "Production-Living-Ecology" three functional dimensions in consideration of the territorial context.
2. An orientation index system of rural landscape multifunction including 36 indicators was constructed based on the relevance and data availability (Qingpu Statistical Yearbook, Land Resources Bulletin, and Water Conservancy Data in QPDS 2004–2014).
3. Using data from 2004 to 2014, the multidimensional evaluation model and the coupled model TOPSIS-GRA were employed following the steps "rural landscape multifunctionality orientation – leading function and secondary function orientation – malfunction orientation" to conduct the scientific orientation of the rural landscape functions in QPDS, China.

Results and Discussion

1. The results of the multifunction orientation of the rural landscape are below.
2. The integrated orientation method "rural landscape multifunctionality orientation – leading function and secondary function orientation – malfunction orientation" can accurately orientate the multiple functions of rural landscape in this area.

3. The multiple functions of rural landscape in this area are complex. Multifunctionality of rural landscape is different from the east to the west; regions of high value are highlighted and present the state of aggregation; leading and secondary functions as well as malfunctions of the spatial heterogeneity of the rural landscape are remarkable; and the dependence degree between functions are high.

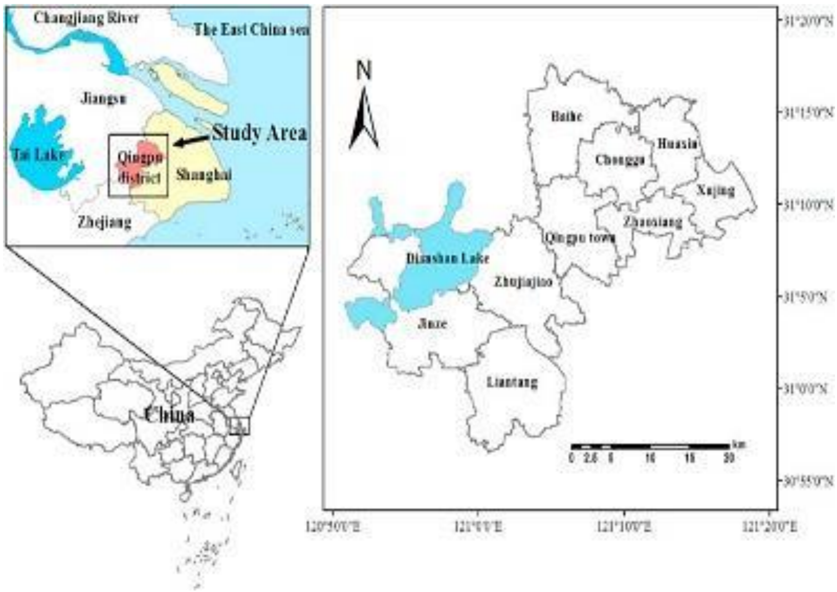

Figure 1. Location of the case study area.

Table 1. The Multifunction orientation of rural landscape.

Function orientation	Multifunctionality	Leading function	Secondary function	Leading malfunction	Secondary malfunction
Jinze	Weak	HCF	EMF	—	—
Liantang	Moderate	ERF	APF	SSF	EDF
Zhujiajiao	Strong	—	—	SCF	NASF
Xianghuaqiao	Moderate	NASF	EDF	EMF	ERF
Yingpu	Moderate	SCF	NASF	HCF	EMF
Xiayang	Moderate	SSF	CIF	ERF	APF
Baihe	Moderate	APF	ERF	EDF	SCF
Zhaoxiang	Strong	—	—	NASF	CIF
Chonggu	Moderate	CIF	SSF	APF	HCF
Huaxin	Moderate	EMF	HCF	CIF	SSF
Xujing	Weak	EDF	SCF	—	—

NOTE: ADF: Agricultural Production Function, **NASF**: Non-Agricultural Supply Function, **EDF**: Economic Development Function, **SCF**: Space Carrying Function, **SSF**: Social Support Function, **CIF**: Cultural Inherit Function, **ERF**: Ecological Regulation Function, **HCF**: Habitat Conservation Function, **EMF**: Environmental Maintain Function.

Conclusions

1. The spatial functions of rural landscape which have the maximum values cannot be confirmed as the dominant functions simply.
2. It is obvious that the multifunctional combination of rural landscape and the interdependency among rural landscape functions are high.
3. Quantitative description of the malfunctions of rural landscape could reflect the multifunctionality of rural landscape more comprehensively.

Acknowledgements

This study is funded by the National Natural Science Foundation of China (No. 41471455).

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Assessing the Hydrologic and Economic Impacts of Agricultural Irrigation at the Landscape Level under the Influence of Climate Change

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Introduction

Climate change will have an impact on the demand and supply of water used for agricultural irrigation. In order to keep irrigation at a sustainable level, farmers and policy makers need information on how the future situation will affect production opportunities. At the landscape as well as watershed level, this information needs to be aggregated in order to be able to capture the overall effects of a continued level of irrigation as well as increasing irrigation demands.

Especially in north-eastern Germany, an increase in agricultural irrigation is a likely adaptation measure to cope with climate change in drought-prone regions of northern and eastern Germany. Therefore, water use in agricultural crop production needs to be balanced against the groundwater recharge, minimum environmental flow in streams or peat protection in wetlands (e.g. Thomas *et al.*, 2011). The objective of our study is on how an existing hydrological water balance model can be expanded to analyse both the hydrologic as well as the agro-economic implications of climate change and the resulting changes in water use (Steidl *et al.*, 2015).

Materials and Methods

In our study, the impact of climate change and increased irrigation area on future hydrologic and agro-economic conditions was analysed for a representative basin in north-eastern Germany using an expanded version of the WBalMO (water balance model) for water management (WBalMo, 2005). The model expansion represents various temporally and spatially differentiated irrigation water use processes, including agricultural irrigation, as part of a river basin's water management. Our scenario-driven approach uses irrigation demand as an independent variable based on individual farmer behaviour. The agricultural irrigation demand was calculated based on time specific irrigation demands calculated with crop specific coefficients which are then reflected in additional crop yields.

Data were available on the irrigation permits in the region, on the hydrologic situation of the basin described in WBalMo, the current situation of agricultural production represented by IACS data and three different climate projections for future climatic situations: (1) EH5r3_RE-ENS from the Max Planck Institute for Meteorology, (2) ARP-ALD51 from Météo-France, Centre National de Recherches Météorologiques; and (3) HCQ0-HRQ0 from the Hadley Centre for Climate Prediction and Research.

Results and Discussion

Our results show that climate change leads to increasing irrigation water demands in the future, which not always can be met by available water sources. The resulting water deficits were shown for different crops depending on their irrigation priority and the water available.

Depending on the month when irrigation is needed for a specific crop, water deficits show considerable variation. With an increasing irrigation area, water deficits will rise especially for crops with a lower priority. This may limit the overall profitability of agricultural irrigation, since the yield potential of the crops within a crop rotation cannot be reached. With regard to drivers of water demand, the impacts of climate change on low-flow conditions in the river are much higher than those of an potentially increased irrigation area.

Conclusions

The module developed can describe the processes of agricultural irrigation water use in a temporally and spatially differentiated way more effectively than conventional water management models based on WBalMo. In addition to water management, the module can also take into account economically driven irrigation decisions. Its application in the study area showed that climate changes will slightly affect the availability of irrigation water in the 2018–2052 period. However, in drier years, competition from other water uses, such as the drinking water supply, minimum ecological flows in streams or the conservation of wetlands, can create constraints on water availability. Nevertheless, the impact of climate change on the low flow situation in streams was much higher, meaning that a further expansion of irrigation calls for the careful monitoring of water availability to mitigate additional impacts on low flows. Furthermore, since the basic model is already in use by the water authorities, it can also be used to test the impact of issuing new permits or that of new water management policies.

Acknowledgements

This work was carried out with financial support from the Federal Office for Agriculture and Food (BLE) (project 2813HS007).

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Crop vs. tree: Can agronomic managements reduce trade-offs in tree-crop interactions?

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Introduction

The centuries-old practice of managing scattered trees on crop fields has been suggested as one of the pathways for sustainable intensification of smallholder agriculture in SSA (Pretty *et al.*, 2011). Regardless of established ecological and provisioning contribution of trees (Bayala *et al.*, 2002), their direct contribution to increased crop yield is often contested (Bucagu *et al.*, 2014) and context specific (Brandt *et al.*, 2012). Although crop yield penalties are expected as a result of tree-crop competition for resources, farmers still maintain trees on their farms, perhaps for other reasons and possibly minimize tree-crop competition effects by managing both crops and trees. Many studies assessing the negative effects of tree-crop interaction have focused on management practices that manipulate the tree component such as root and canopy pruning (Bertomeu *et al.*, 2011). Studies exploring the potential impact of manipulating the crop component are scarce. We hypothesized that manipulating agronomic practices such as field preparation, fertilization rate, variety selection, and cultivation could minimize trade-offs in tree-crop interactions at landscape level.

Materials and Methods

We recorded agronomic practices within the fields of 135 randomly selected farms starting from seedbed preparation. At harvest, we measured maize yields from paired open field and under canopy plots. In addition, on-farm tree density, economic values of different tree products and farmers' perceptions of the importance of on-farm trees were appraised. A multivariate analysis showed that farmers maintained on-farm trees because of their direct timber, fencing, fuelwood, and charcoal production values.

Results and Discussion

Trees generally had a significant negative effect on maize yield (Figure 1). Mean grain yields of 1683, 1994 and 1752 kg ha^{-1} under the canopies of Cordia, Croton and Acacia, respectively, were significantly lower compared with their respective open field yields of 4063, 3415 and 2418 kg ha^{-1}. Besides, higher incomes from trees were accompanied by lower incomes from maize, highlighting trade-offs (Figure 2). However, agronomic practices such as early planting, variety selection, improved weed management, fine seedbed preparation and higher rates of nitrogen fertilizer reduced tree-associated yield penalties significantly. We found an inverse relationship between land size and on-farm tree density, implying the increased importance of trees for land-constrained households. With the expected decline in per capita land size, scattered trees will likely remain an integral part of these systems.

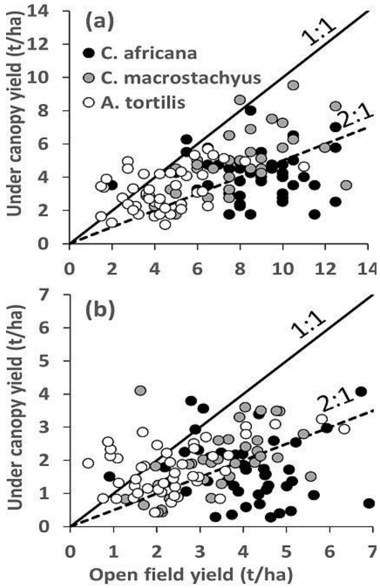

Figure 1. **Comparison of total aboveground biomass (a) and grain yield (b) between open field and under canopy for Cordia africana, Croton macrostachyus, and Acacia tortilis.**

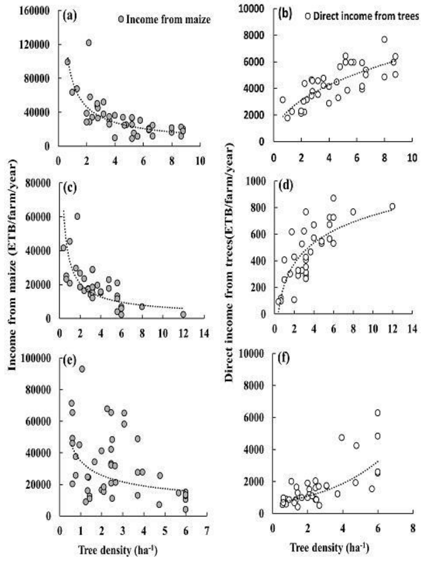

Figure 2. **Relationship between total annual farm income from maize and on-farm tree density (a, c, e) and Net Present Values of annual direct income from tree products (b, d, f) for Cordia africana (a-b), Croton macrostachyus (c-d) and Acacia tortilois (e-f)**

Conclusions

Thus, utilizing 'good agronomic practices' could be vital to minimize tree-crop trade-offs in tree-based sustainable intensification pathways. As these trees were proved to enhance the overall productivity of a system, landscape approaches that minimize the trade-offs are required.

Acknowledgements

This work was funded by the Australian Centre for International Agricultural Research (ACIAR).

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Peri-urban landscapes as the arena of human – wildlife interactions: environmental governance recommendations

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The Anthropocene era is going along with many and intensive human interventions into nature and landscapes so that wildlife faced tremendous changes in habitats, their quality, processes and connectivity. However, many species, among them the most "iconic" ones such as wolf, lynx, bear, beaver, deer or wild boar, have developed highly adaptive behavior and start even obtaining even some benefits from anthropogenic landscapes. Consequently, there is a rising need to better understand human–wildlife interactions in dynamically changing landscapes.

Peri-urban landscapes (PUL), are a particular example of landscape types emerging from increasingly anthropogenically shaped environments. They are characterized by a dense mosaic of different potential habitats, among them gardens or urban green space with extremely diverse vegetation pattern, brownfields that are only sparsely frequented by human beings and thus are attractive residence areas for wildlife during daylight and dump sites at which fodder can be easily collected. Green infrastructure connects the urban fringe with rural areas so that migration pathways between cities and their surroundings facilitate the movement of wildlife into cities.

In this paper, we focus on **human – wildlife interactions (HWI)** in peri-urban landscapes, with a particular focus on iconic species. We hypothesize that PULs gain in increasing relevance and importance as arenas of intensified HWI. These may have a biased character: the experience to observe some iconic species as deer close to or within urban areas can be considered as a cultural service, providing inspiration and education. On the other hand, spatial closeness between humans and wildlife can lead to dangerous and unpleasant situations, which are often perceived or experienced as disservice. In conclusion, adapted concepts of spatial guidance of wildlife and humans are required to maintain the service side of HWI and reduce or mitigate the potential problems.

Governance approaches that include actions and agreements between different planning actors can be seen as a complementary tool in spatial planning, avoiding too schematic spatial organization concepts such as Euclidian functional zones. Adaptive governance is here understood as a multilevel process linking the social (actors, actor groups and their networks) with the ecological sub-systems.

By offering a comprehensive up-to-date opportunities for a broad and effective public engagement and use of novel-innovative research concepts such as citizen science, multi-channel enhanced communication, HWI governance could provide solutions basing on a higher degree of awareness, dialogue and eventual real participation of actors then classic spatial planning approaches in the context of PULs.

We **hypothesize** that due to intensive urbanization of many non-urban areas human–wildlife interactions (HWIs) increase in peri-urban areas/zones. Thus peri-urban landscapes (PULs) become the "arenas" of HWI. Managing the impact of human interventions on wildlife habitats within PULs requires tailored governance approaches and existing governance approaches are not always sufficient.

In this research we **aim to** critically discusses experiences concerning to human– iconic spices interactions as a particular type of human – wildlife interactions observed in the peri-urban landscapes and to describe subsequent lessons learnt concerning to environmental governance. With this we hope to enrich theoretical insights on governance of highly dispersed cross-sectoral policy issues.

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Reduction of soil-related ecosystem services by erosion – scenarios based on monitoring data

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Introduction

The capacity of agroecosystems to provide Ecosystem Services (ES), especially provisioning and regulating ES, is directly related to soil properties such as water storage capacity (WSC) (Dominati *et al.*, 2010). Therefore soil protection is mandatory for sustaining the capacity of agroecosystems to supply ES. Soil erosion by water is a major threat to soils in central Europe (Panagos *et al.*, 2015). The related ES 'soil erosion regulation' (SER) describes the control of potential soil loss. Conceptually, SER provision can be defined as a reduction of structural impact through land cover (Guerra *et al.*, 2014), which in agroecosystems is defined by crop rotation and tillage.

We developed SER maps for monitored croplands in northern Germany, combining measured soil loss rates with data on potential soil loss derived by USLE (Wischmeier and Smith, 1978). Additionally, we projected monitored soil loss rates into the future to assess the reduction of ES related to soils.

Materials and Methods

High-resolution data on mean soil loss rates [t ha^{-1} a^{-1}] stem from a soil erosion monitoring programme, established to close knowledge gaps in regard to occurrence and intensity of soil erosion by water. 450 ha cropland in Lower Saxony has been monitored since 2000. Soil loss is measured in field surveys and farmers are interviewed about applied land management systems (Mosimann *et al.*, 2012). Potential soil loss rates in t ha^{-1} a^{-1} were derived by USLE, using the national standard method (DIN 19708, 2017). SER maps for monitored croplands, showing a reduction of soil loss, were created by calculating differences between potential and monitored soil loss. As an example and proxy for degradation of ES related to soils and to assess the importance of soil erosion regulation, WSC of soils for two degradation-scenarios were calculated: (A) WSC after 50 years of potential erosion (total structural impact) and (B) WSC after 50 years of monitored soil erosion (reduced impact). Degradation of soils is represented by shortening of soil profiles and the related reduction of WSC.

Results and Discussion

As can be seen in Table 1, mean potential soil loss (18.44 t ha^{-1} a^{-1}) is much higher than recorded soil losses (0.91 t ha^{-1} a^{-1}). Accordingly, the results for SER show general high service provision. Negative SER values, indicating high loss rates, are spatially linked to topographically defined flow paths with large contributing catchment areas.

Table 1. **Statistical values for potential soil loss, monitored soil loss and ES 'soil erosion regulation [t ha^{-1} a^{-1}] on the investigated cropland, based on raster data (12.5 m), (n = 29146).**

Type	Min	Mean	Max	STD
potential soil loss	0.00	18.44	91.40	10.89
monitored soil loss	0.00	0.91	66.78	2.40
ES 'soil erosion regulation'	-47.25	17.53	91.35	11.15

Figure 1 shows the impact of soil loss on WSC for the assumed degradation-scenarios. The mean initial WCS for the investigation area is 185 mm. 50 years of structural impact reduce mean WCS to 157 mm. Due to service provision in scenario B, reduction in WCS is very small (mean WCS: 184 mm).

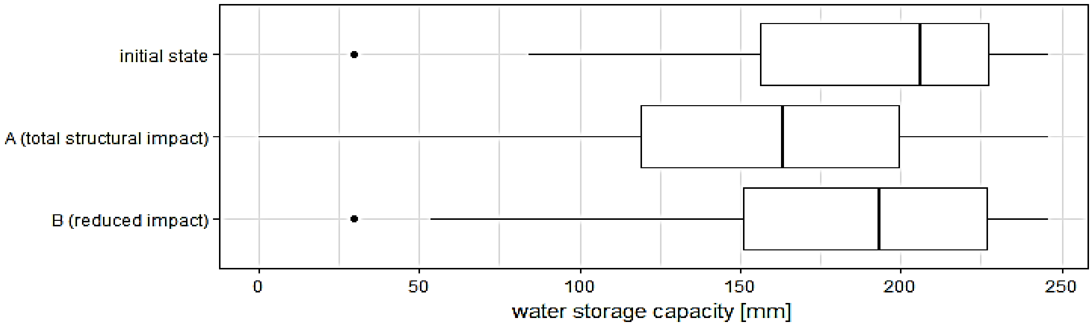

Figure 1. **Water storage capacity (available soil water in the root zone) [mm] for 'Initial Status' status of soils and two degradation scenarios (A: 50 years total structural impact, B: 50 years reduced impact).**

Conclusions

The comparison of total structural and reduced impact of soil loss on water storage capacity in scenarios demonstrates the importance of soil erosion regulation. Additionally, the monitoring data give evidence that famers, using adapted management strategies, can minimize soil loss to sustain ES related to soils.

Acknowledgements

This study uses field data collected in the Lower Saxonian soil erosion monitoring programme. The monitoring is funded by the Lower Saxonian State Authority for Mining, Energy and Geology (LBEG).

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CoMOLA: A tool to explore multifunctionality of landscapes

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Introduction

The sustainable use of land resources and the design of multifunctional landscapes require not only understanding the manifold interactions among multiple land use demands and ecosystem functions and services but also finding solutions to mitigate their trade-offs. Properly addressing multifunctionality of landscapes often translates into complex land use allocation problems, which can be solved by combining multi-objective optimization algorithms and simulation models (Memmah *et al.*, 2015). The resulting Pareto-optimal solutions illustrate the best possible trade-offs among conflicting objectives and thus offer a set of solutions from which decision makers can discuss and select appropriate solutions according to their preferences. However, Pareto-optimal alternatives have little or no value for decision making when they ignore real-world constraints. Since Pareto-based optimization methods, by their nature, are unconstrained procedures, the difficulty is to find proper ways of incorporating those constraints. We introduce a tool for Constrained Multi-objective Optimization of Land use Allocation (CoMOLA), which was developed to explore a landscape's potential for ecosystem service supply and biodiversity conservation considering constraints on the transition and areal coverage of single land use classes.

Materials and Methods

CoMOLA utilizes the Non-dominated Sorting Genetic Algorithm-II (Deb *et al.*, 2002) in combination with different alternative constraint-handling methods to optimize land use raster maps for up to four objectives. Its flexible architecture allows for a simultaneous integration of various modelling approaches, such as biophysical watershed models and statistical species distribution models. We tested the functionality and performance of CoMOLA for different complexity levels regarding the number of objectives and decision variables as well as the strength of underlying constraints using a virtual landscape and simple conceptual models predicting agricultural production, water yield and two biodiversity measures.

Results and Discussion

Our results indicate that CoMOLA is able to identify near-optimal and feasible, i.e. constraint-satisfying, solutions for up to four objectives (cf. example in Figure 1). However, increasing the complexity from 41 spatial units to 100 and 400, each with up to seven land use options depending on the pre-defined constraints, led to a performance loss of 16 and 42% (dominated hypervolume), respectively.

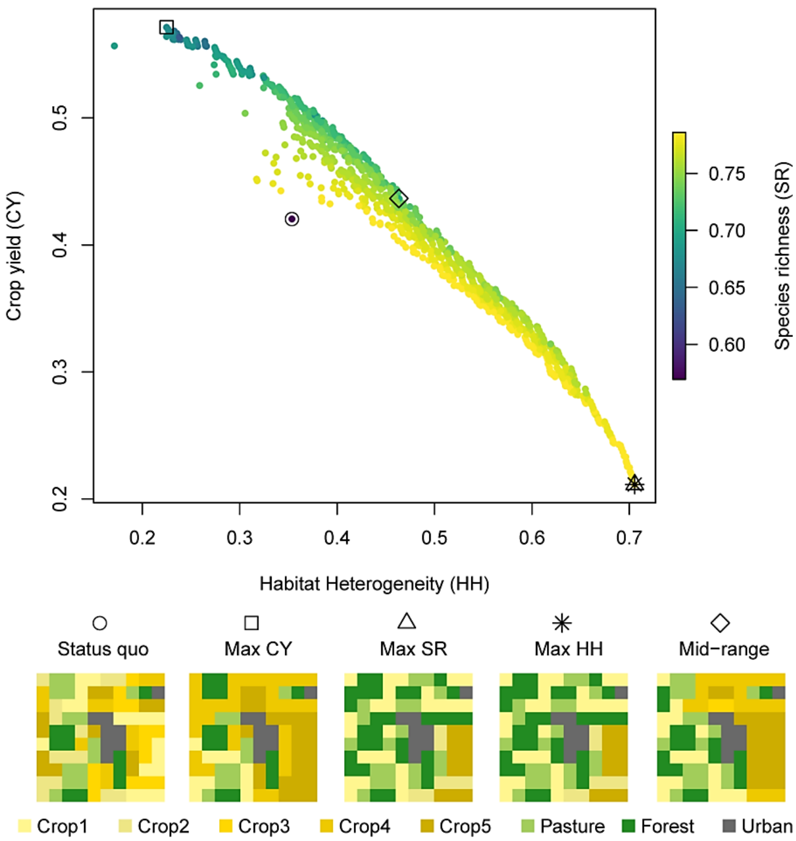

Figure 1. **Exemplary Pareto-optimal solution set for a 3-objective optimization problem with constraints for both land use transition and areal coverage (e.g. status quo forest must remain while other land uses can be converted into forest; however a maximum forest coverage of 30% on total area must not be exceeded).**

Conclusions

Although the algorithm requires a simplified formulation of the optimization problem in terms of spatial complexity, CoMOLA can be considered as a promising tool to explore a landscape's multifunctionality while explicitly considering real-world constraints.

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Infrastructure for open soil and agricultural research data as basis for sustainable landscape management

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The BonaRes Project

The German research initiative BonaRes ("Soil as a sustainable resource for the bioeconomy", financed by the Federal Ministry of Education and Research, BMBF) was launched in 2015 with a duration of 9 years and perpetuation envisaged. BonaRes includes 10 collaborative soil research projects and, additionally, the BonaRes Centre. The BonaRes Centre provides support for communication, a seamless data exchange and creates modelling concepts and assessment tools for a sustainable soil and landscape management respectively.

IT-infrastructure and open data concept

Within the BonaRes Centre the IT-infrastructure for upload, management, storage, and provision of research data from soil and agricultural as well as data from long-term field experiments is maintained. According to the Priority Initiative "Digitale Information" (Alliance of Science Organizations in Germany) these data will not be subject to any restrictions on re-use. After a limited embargo-time, all research data will be provided open for the international research community. Prospectively, the data infrastructure will be open for all soil-related research data e.g. from other research projects.

To enable smooth data management and to fulfill open and accessible data requirements from the beginning, all research data must be described by standardized metadata. Benefits of open and well described data are its high visibility, easy accessibility, long-term availability and re-usability, and interoperability with international data. The developed metadata schema is based on existing and accepted international schemes and combines all elements from DataCite and INSPIRE.

Our contribution

Accessible, structured and well described and organized soil and agricultural research data as managed within the BonaRes data infrastructure are predestined to be part of future sustainable landscape management.

We will present the main components of the research data infrastructure and address technical, legal and publishing aspects as well as possibilities to find and explore stored research data. The technical components include a web based user interface which enables a standardized metadata and data upload. The legal component contains embargo and copyright issues. The publishing component refers to the service of Digital Object Identifier assignment (DOI creation via DataCite).

Effect of the landscape complexity on biocontrol of the millet head miner, *Heliocheilus albipunctella* (de Joannis) (Lepidoptera: Noctuidae) in Senegal

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Key words: BSI, Heliocheilus albipunctella, Habitat complexity, Landscape variables, Pleiades.

Introduction

Pearl millet (Pennisetum glaucum (L.) R. Br.) is one of the main cereal crops in Senegal representing about 60% of the total cereal production, with approximately 600.000 tonnes per year. Adapted to arid and semi-arid climates, millet production is mostly located in the peanut basin. The millet head miner (MHM), Heliocheilus albipunctella de Joannis (Lepidoptera: Noctuidae) is the major millet pest in West Africa, causing important yield losses up to 85% (Youm, Owusu, 1998). Despite years of research, control strategies developed through agricultural practices as deep ploughing or late planting have shown little success (Youm, Gilstrap, 1993). Recent studies on insect ecology have pointed out the importance of landscape-pest interactions as a crucial determinant of biocontrol success (Hunter, 2002). In Senegal, main natural enemies have been identified (Gahukar, *et al.*, 1986; Nwanze, Harris, 1992), but their natural habitats are still not well known. To better understand the environmental determinants of biocontrol of the MHM populations, we proposed a landscape approach focusing on the role of natural vegetation. We first used a very high spatial resolution of remote sensing data to map and to quantify the key landscape elements around a set of millet fields. A statistical analysis was then performed to identify environmental factors enhancing natural regulation of the MHM

The objective of this study is to investigate the effect of landscape complexity on biological control of the Millet Head Miner (MHM), *Heliocheilus albipunctella* (de Joannis) (Lepidoptera: Noctuidae) which is identified as the major insect pest in West Africa. This work was carried out in 2013 and 2014 around Dangalma village (14° 43′ 42′′ N, 16° 33′ 98′′ E), located in Djourbel region, Senegal.

Method

The quantification of biocontrol of *H.albipunctella* was measured using Biological control services index (BSI) developed by Woltz *et al.,* (2012), which was calculated on 45 millet fields separated at a distance of 2 km from each other. Covering a square region of 20*20 km, the habitat complexity was also measured yearly around each sampling sites using four landscape metrics assessment as pertinent for pest regulation. Calculated from two land cover maps generated from Pleiades satellite imagery, each landscape variables were evaluated at nine spatial scales ranging from 0.250 km to 2.250 km radii (at 0.250 km intervals) from the field center.

To study the effect of landscape attributes on BSI values a generalized linear model was performed. Finally, the best statistical model according to the Akaike Information Criterion (AICc) was used to identify the environmental key variables enhancing biological control of the millet head miner.

Results and Discussions

We found that BSI values increased with landscape complexity, measured as Shannon's Diversity Index (SHDI). Landscapes dominated by millet fields provides less biocontrol services to *H. albipunctella* than landscape dominated by natural vegetation. The study showed also that landscape diversity and composition at a scale of 1750 m surrounding the sampling sites explained the greatest proportion of the variation in biological control of this pest.

Conclusion and perspectives

This study indicates that natural vegetation and more specifically trees which are dominant in our study area have to be maintain to enhance biocontrol of *H.albipunctella*. Furthermore, it suggests that management to enhance landscape diversity has the potential to stabilize or increase biocontrol services. To improve this landscape management, we suggest to take into account the tree species and thus to better understand their key role as host habitat for natural enemies of this pest.

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Modeling and discussing trade-offs between food production, ecosystem services and biodiversity in agricultural landscapes in Europe

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Introduction

Many rural landscapes in Europe deal with competing demands for land, at a cost of trade-offs between multiple objectives, such as food production, ecosystem services and biodiversity. Understanding and balancing these trade-offs has a high priority on the policy agenda to promote sustainable landscapes. Stakeholder interaction is increasingly seen as an important element in developing suitable policies, as well as in policy-relevant tool development.

Various tools and models are available to assist policy makers and planners to assess trade-offs related to environmental management, ranging from exploratory and assessment tools to decision support systems (DSS). A specific set of DSS combines biophysical or process models with optimization algorithms, to find optimal, spatially explicit, management outcomes. Seppelt *et al.,* (2013), among others, highlight the potential of combining optimization approaches with scenario analysis to study trade-offs at a landscape scale, to identify optimum solutions for land use and/or policy mixes given stakeholder-generated constraints and preferences. However, there is little empirical evidence of the suitability of these methods for trade-off assessment and planning, especially regarding the suitability of the generated information for policy development (e.g. Albert *et al.*, 2014).

Therefore, this presentation focusses on the question: How suitable is combined optimization and scenario analysis to address the 'wicked problem' of sustainable landscape management? Furthermore, we aim to discuss the opportunities and challenges to address trade-offs in regional planning, including a reflection on the type of information and (visualization-) methods that are seen as valuable by stakeholders.

Materials and Methods

We use the outcomes of a participatory scenario development and optimization modelling process in five different European agricultural case studies (in Austria, Germany, Spain, Switzerland and the Netherlands). In these case studies, a series of stakeholder workshops (during and after the modelling process) was undertaken. For this presentation, we focus on the outcomes of the final workshops, in which stakeholders reflect on the modelling outcomes, different visualization methods, as well as on the role of trade-offs within regional landscape planning.

Results and Discussion

We present an empirical 'lessons learned' on addressing trade-offs in agricultural landscapes, with a particular focus on the use of optimization models (incl. different types of visualization methods, see Figure 1 as example), as well as the suitability of these methods for regional planning and policy.

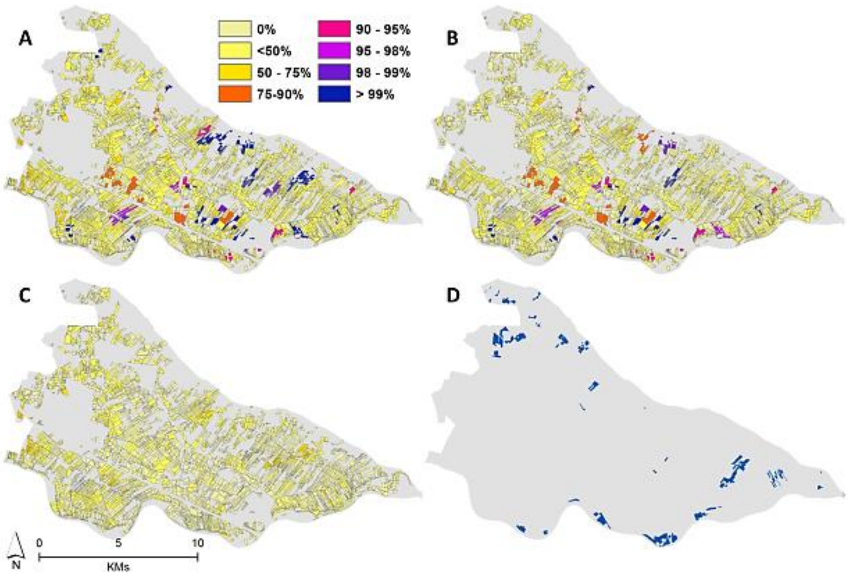

Figure 1. **An example of a visualization of the results of an optimization modelling outcome, for a case study in the Netherlands (Kromme Rijn). The results display a priority map for different on-farm and off-farm measures (A-C depict different combinations of measures). The higher the priority the more often a field is assigned to an alternative. Panel D shows areas targeted in the current nature conservation plan.**

Conclusions

Improved methods to understand and balance trade-offs between different landscape functions are important for sustainable land management at a landscape-scale. By focusing on the needs of stakeholders, such as planners and policy makers, we aim to understand to opportunities and barriers for a successful policy uptake of decision-support tools for trade-off assessment.

Acknowledgements

This research was part of the BiodivERsA/FACCE-JPI project "Towards multifunctional agricultural landscapes in Europe (TALE)", funded by the Netherlands Organization for Scientific Research (NWO).

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III. Landscape Synthesis
Integrated Systems Analysis –
Towards a Landscape Theory

Scientific Committee

Erling Andersen (Københavns Universitet, Denmark)

Cécile Albert (IMBE, France)

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Landscapes are characterized by tight coupling and feedback loops between numerous abiotic features, biota and man, forming highly complex systems from which unexpected behaviour can emerge. System behaviour rarely becomes evident if single processes in landscapes are studied in isolation. A systems approach is therefore required to effectively study landscape processes from a landscape system perspective.

Such systems perspective requires both practical methods and a theoretical basis for landscape research. This session addresses the following issues related to the development of landscape systems research and theory: Is there evidence for emerging behaviour or fundamental constraints that determine landscape dynamics? How can landscape dynamics be systematically studied? Which pathways for developing a general theory of landscape processes are suggested?

Session Keynotes

Erle Ellis (University of Maryland, Baltimore County, USA)

Matthias Bürgi (Swiss Federal Research Institute, WSL, Switzerland)

Session Chairs

Peter Verburg (Vrije Universiteit Amsterdam, The Netherlands)

Gunnar Lischeid (ZALF, University of Potsdam, Germany)

Oral Presentations

Keynote: Why do landscapes change?

Matthias Bürgi

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Landscapes are not stable in time – they change due to internal and external driving forces. Insights into these causes of changes, but also information about impeding and stabilizing factors are of high interests to scientists and landscape planners alike. The search of general pattern in forces driving change and fostering persistence in landscapes might also contribute to the development of a general theory of landscape processes. Apart from landscape/land use changes and the related driving forces, the core agents on the land also have to be conceptualized and assessed in studies of land change. As it is often these actors that take certain decisions and leave traces in the land, understanding their decision making process is crucial.

In this talk, I will outline and illustrate the development of my thinking on driving forces research, and confront the findings with my experience as a farmer.

Land tenure in European agricultural landscapes

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Introduction

The paper explores land tenure in European agricultural landscapes. More than half of the agricultural area in the European Union is not managed by the owners. Ownership is seen as the best way of securing a responsible relation with the land and its sustainable management (European Parliament, 2017)) and also as a factor hampering participation in agri-environmental schemes (Wilson and Hart, 2000). At a more general level land tenure is a component in the survival strategy of family farms (Bowler, 1992). This presentation analyses land tenure at the landscape level across the European Union using statistical data. Agricultural landscapes are seen as the outcome of combined natural and human factors over time and are defined as specific patterns of farming systems and landscape elements in specific biophysical and administrative endowments.

Materials and Methods

The analysis assumes that the agricultural landscapes can be defined as specific patterns of farming systems and landscape elements in specific biophysical and administrative endowments (Andersen, 2017). Specifically, the analysis focuses on the pattern of farming systems as described in Andersen, 2017 based on data from the FADN (European Commission, 2017). This means that the analysis takes into account the dimensions scale, intensity and specialization of the agricultural production at the landscape level. As an indicator of land tenure, information on the share of the agricultural area in rented land from the FADN is used. In the analysis it is tested how the different dimensions of the farming systems and the pattern at landscape level affects the share of the agricultural land rented using the GLM feature in SPSS. The analysis is applied to agricultural landscapes across the European Union.

Results and Discussion

At the farming system level the results show that the share of the agricultural land rented varies substantially for the European Union. Large scale systems rent a significantly higher share of their land (66%) compared to medium scale systems (36%) and small scale systems (21%). In relation to intensity of farming, the medium intensity systems stand out with 56% rented land compared to 43% on both low and high intensity farms. Selected results on specialization show that beef and mixed cattle/temporary grass, mixed farms and arable/cereal systems have a very high proportion of rented land (>60%), whereas permanent crop, poultry, land dependent sheep & goat and land dependent pig systems all rent less than a third of their land. However, at the landscape level results are more inconclusive. Some differences occur between landscapes characterized by different patterns of farming systems according to size, intensity and specialization. However, more than 90% of the variation between agricultural landscapes regarding the rented land share of the agricultural area can be explained as national and/or regional variation. This indicated that the land tenure characteristics of the agricultural landscapes are linked to different national and regional histories, social conventions and legal institutions as suggested by Bowler, 1992.

Land tenure is generally considered to be an important factor affecting farming and thus agricultural landscapes. However, land tenure does not appear to explain the general structure of agriculture at the landscape level, i.e. the farming system pattern. More detailed landscape characteristics, i.e. single plot and landscape element management, might be linked to land tenure, but other research methods are needed to explore this.

Conclusions

The analysis presented has tested how land tenure is linked to the farming system pattern at landscape level across the European Union. Contrary to the expectation, the farming system pattern could not explain the differences in the variation in the extent of rented land between different landscapes. The variations in rented land are much closer linked to higher spatial levels, regions or even countries. This indicates that land tenure is not a decisive factor in shaping the overall structure of agricultural landscapes.

Acknowledgements

The paper is based on data from the SEAMLESS Association integrated database and includes aggregated data from EU-FADN - DG AGRI L-3 and JRC/MARS Data Base - EC – JRC.

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Proximate drivers of crop land use change in two intensive agricultural regions

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Introduction

Understanding decision-making processes that drive changes in the land system require empirical research, particularly information about land managers values or preferences (Rounsevell *et al.*, 2012). Farmers' decisions are complex because they are comprised of internal drivers (inherent to the farmer) and external drivers (relating to the biophysical and socio-economic context of the farm), see Schaller *et al.*, (2012); Irwin and Geoghegan (2001). To better represent farmer decisions in land use change scenarios, four farmer groups in developed agricultural regions were asked to rank factors influencing their cropping land use choices. The ranked decision-making factors were used to develop a spatially distributed land use scenario for their watershed.

Materials and Methods

A postal questionnaire was sent to farmers, in two watersheds (376 km^2 and 629 km^2, respectively); one in the Altmühl (Bavaria, Germany) and the other one in Pike River (Québec, Canada). The questionnaire focused on why certain crop changes had taken place historically on the farm, and what factors would bring about a future possible change of crops on the farm. It was administered to four independent groups of farmers representing farmers from two distinct regions (Altmühl and Pike River) and two generations (Young and Experienced). The factors for deciding which crops to grow each year were selected and ranked by each farmer.

From the results, the ranked factors in each question were evaluated. A farmer "influencing factor" (IF) was calculated composed of the rankings indicated by the farmers within each group and established the relative importance of every driving factor in each question, similar to Sattler and Nagel (2010). In this study, the term influencing factor is used to define an identifiable individual decision-making factor.

Land use changes to 2040 were developed by using exploratory scenario storylines (Rounsevell and Metzger, 2010) based on the casual relationships of change determined from knowledge gained of the respective study sites. A spatial land use layer in each watershed was developed focusing on the farmers' decisions scenario.

Results and Discussion

The questionnaire was distributed to 923 farmers; responses from 150 farmers were received and analyzed. Despite the differences in the farmer age, geographic location, and farming experience between the groups, farmers ranked the influencing factors very similarly; indicating regional and generational consistencies amongst the farmers surveyed. The indirectly-related financial factors had almost identical rankings.

The replies indicated that while financial income for the farmer plays an important role in making a decision, it does not clearly stand out as being the only factor for land use decisions; there are multi-factorial drivers of comparable influence involved in choosing which crops to plant. Figure 1 shows the responses to one question from the older farmer group in the Altmühl watershed.

The directly-related financial factors (revenue, markets, subsidies, etc.), are important drivers for change, however farmers also consider indirectly-related financial factors, such as climate, available technology, new information, their experience, and their farming tradition, to be approximately half of the weighting in making a decision.

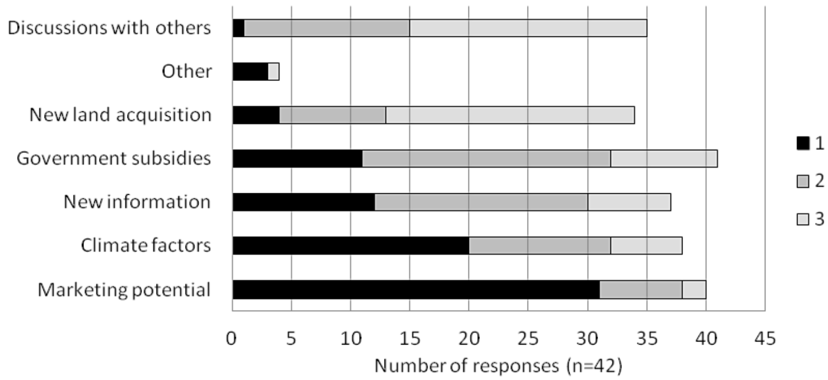

Figure 1. **Responses from "AltmühlExperienced" group to the question: What has prompted you, in the past 10 years, to grow crops that you previously had not grown on the farm before? (choose all relevant factors by ranking the following with 1 = very important, 2 = medium, and 3=low).**

Conclusions

Farmers use a suite of decision-making factors to alter their crops, of which the financial factors make up approximately 50%. Some non-financial factors (i.e. access to farm equipment, farmer experience and climate) ranked higher, or just as high, as the financial factors. By ranking the farmers' influencing factors for crop changes in the watershed, quantification is provided that supplements the human decision-making component for land use models, and provides explanations for current agricultural land use patterns not explained by financial factors alone.

Acknowledgements

Support was provided by Canada's Natural Science and Engineering Research Council, Ouranos Consortium, Government of Québec, and McGill's Global Environmental and Climate Change Centre.

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A framework to analyse the resilience of EU farming systems

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Introduction

Farming systems form a major component of most landscapes in Europe. Landscape dynamics are therefore largely influenced by dynamics in farming systems. These dynamics can be analysed using resilience theory, by analysing the robustness, adaptability and transformability of farming systems and landscapes as response to changes and shocks in their natural, social, economic and institutional environment. In this paper we develop a framework to analyse the resilience of EU farming systems.

The resilience concept

At the heart of resilience thinking is the concept of adaptive cycles (Holling *et al.*, 2002). We emphasize three main adaptive cycle processes that are essential for farming systems: governance processes (including risk management and policy), farm demographics processes and agricultural production processes (Figure 1). These processes are driven by multiple challenges, and together influence the delivery of private and public goods, including the landscape.

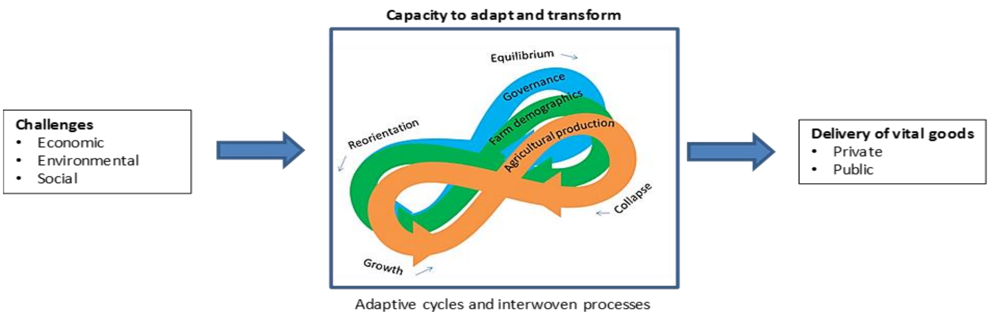

Figure 1. **The resilience concept for farming systems.**

From concept to empirical analyses

A farming system is a system hierarchy level above the farm (Giller, 2013) at which properties emerge as a result of the interactions and interrelations among farms, stakeholders in the value chains, actors in rural and urban areas, consumers, policy makers, and the environment. Our assessment framework includes three levels of indicators (Figure 2). Firstly, sustainable development (SD) indicators related to the delivery of public and private goods ('the purpose'). Secondly, indicators of resilient behaviour, which are linked to the SD indicators, e.g. the recovery rate of farm income after a negative shock. Thirdly, resilience attributes that relate to resilient behaviour and are generally easier to measure (e.g. equity capital buffering farm income). Strategies to improve sustainability and resilience often directly influence the resilience attributes. The operationalization of this framework will be presented based on case studies.

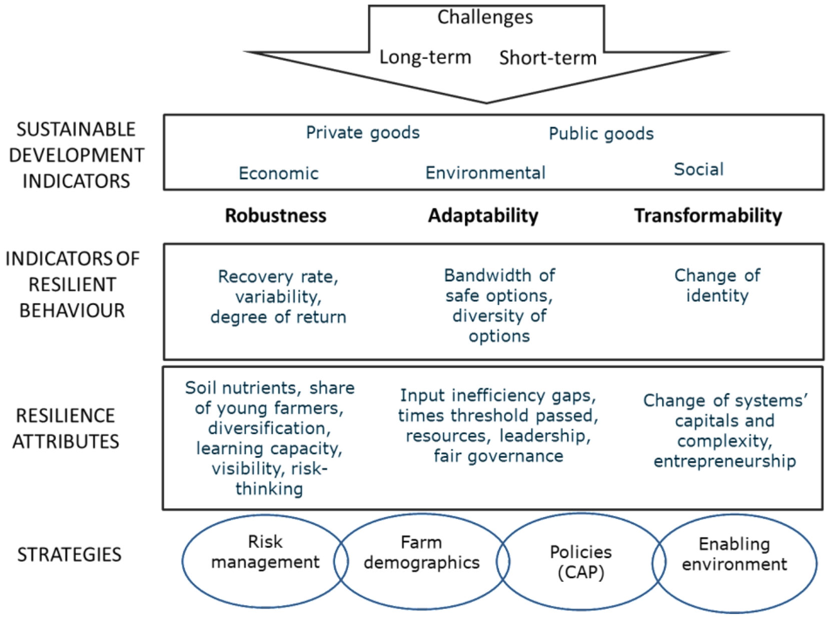

Figure 2. **Framework to analyse sustainability and resilience of farming systems, incl. example indicators.**

Acknowledgements

This framework is developed and applied within the SURE-Farm (Towards SUstainable and REsilient EU FARMing systems) project, funded by Horizon 2020 (http://surefarmproject.eu/). We thank the whole consortium for their contributions to this framework.

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Accounting for incremental crop management adaptations to climate change in agricultural integrated assessments

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Introduction

Understanding how climate change will impact agriculture and land use must simultaneously consider changes in climate, technology, prices and trade. Recent studies have demonstrated the sensitivity of macro-economic (Nelson *et al.*, 2014) and poverty (Hertel *et al.*, 2010) outcomes to estimates of how crop yields response to climate change. While an increasing number of studies have evaluated how climate change may impact European crop productivity, most studies have assumed static crop management for scenario and baseline periods. However, farmers are expected to change their sowing dates and varieties, making incremental adaptations (Rickards and Howden, 2012), as average temperatures increase. The objective of this study was to quantify how sensitive impacts on a range of agricultural indicators are to assumptions about crop sowing dates and variety choice under climate change.

Materials and Methods

Three disciplinary models were used in an integrated modelling exercise to assess agricultural changes in Europe for three SRES scenarios to 2050. Six crops were simulated with the SIMPLACE crop modelling framework in response to climate, water limitation and CO_2 concentration to determine relative yield changes for (1) no adaptation (NoAdp), (2) optimal adaptation (Opt) and (3) non-optimal „actual" adaptation (Act) cases. Opt adaptations were determined as the managment that resulted in the highest crop yield for a particular scenario, whereas Act adaptation adjusted Opt changes by subtracting the amount which yields could be increased in the baseline period with optimized baseline managment. Changes in land use, supply, demand, and prices were simulated with the economic agricultural sector model CAPRI. Historical yield trends were extrapolated for each scenario to give relative yield changes due to technology progress (Ewert *et al.*, 2005), while SIMPLACE supplied the yield changes due to climate and adaptation changes. INTEGRATOR determined agricultural emissions based on changes in crop yields and land use.

Results and Discussion

With no adaptations, crop yield changes for grain maize and potato were negative for scenarios A1B and B2, while the relative changes in winter wheat, barley, canola and sugar beet were positive for all scenarios. Use of either adaptation cases lead to positive yield changes for all crops, with the resulting adaptation highly variable across Europe and crops. Technology changes were always positive and resulted in larger changes in crop yields than any climate change or adaptation combination. Results indicate that the method of specifying adaptations had a very large influence on projected yields of approx 15% points, with the relative uncertainty decreasing for the land-use, economic and emissions indicators (Table 1, Zimmermann *et al.*, 2017). Challenges in specifying crop management in integrated assessments are discussed.

Table 1. **Percentage point difference (averages across crops/products) between actual (Act) and optimized (Opt) management cases of selected impact variables for different scenarios (from Zimmermann *et al.*, 2017).**

Impact variable	Scenario		
	A1B	B1	B2
	Act-Opt	Act-Opt	Act-Opt
Crop yield (CC, CO2)	-15	-14	-15
Crop yield (CC, CO2, tech)	-15	-14	-15
Crop yield (CC, CO2, tech, econ opt)	-4	-7	-7
Land use	0	2	2
Production	-3	-4	-4
NH3 emission	0	-3	-2
N2O emission	-1	-1	-2
N leaching +runoff	0	-1	-1

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The impact of global food trade on food security and land use in the context of climate change – an empirical agent-based model

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Introduction

We are interested in the impact of global food trade on food security and land use in the context of climate change. Global food trade plays an essential role in ensuring food security and nutrient sufficiency of nations, promoting regional stability and equality. Lacking purchasing power and political leverage, it is developing countries that are most vulnerable and in danger of food shortage (Marble and Fritschel, 2014). The global market and trade outcomes dictate agricultural land type and production in many countries, which can be a significant cause of environmental degradation and CO_2 emissions.

Materials and Methods

We have developed an empirical agent-based simulation model to study the impact of global food trade on food security including nutrient deficiency under the context of extreme weather and changing international relationships and geopolitics. Using FAO data from the UN, we model bilateral trade of various food categories (cereal and pulses, oil crop, meat, fish, vegetable, stimulants etc.) between more than 170 individual countries. Each country is simulated as an agent. We study the impact of economic development, trade, land use and agricultural production, international relationships and geopolitics on food security and nutrient sufficiency in each country, and their potential implications for regional stability (Bailey and Wellesley; Natalini *et al.*, 2017) and migration. The model is based on the notion that climate, land-use, environment and natural resources, human societies, nations and economic systems are all interconnected and exert influence on each other (Sartori and Schiavo, 2015; Schmidhuber and Tubiello, 2007). It also allows us to take into account the overall impact on all the affected systems and nations when assessing policy interventions.

Results and Discussion

A screenshot of the resulting model in its current stage of development is shown in Figure 1. The bilateral trade of multiple agri-groups between the 171 countries in the model is complex and evolving process (Ercsey-Ravasz *et al.*, 2012; Puma *et al.*, 2015). Trade between any two countries depends on many factors. First, it depends on the production and domestic needs of the two countries. Second, countries that have closer general trade relationship will give trade priority to each other.

The general trade relationship is inferred from the United Nation trade data, which reflects multiple factors influencing the general trade volumes between two countries, such as the countries' economic power, their historic relationship, their political stance and geographic distance. Third, economic power and GDP per capita of the countries will directly determine its purchasing power and position in trade. Finally, previous trade record will influence future choice of trade partners. Once two countries have established a trade relationship, it becomes easier for them to trade from then on.

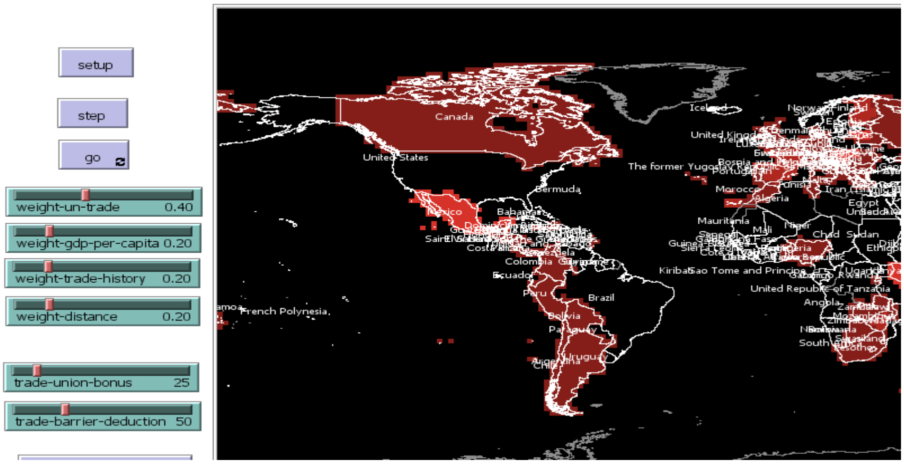

Figure 1. **The model interface, highlighting intermediary countries (the brighter the shade, the more goods for which countries act as a intermediary between source and end-use countries)**

Acknowledgements

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NOAHMP-GECROS: Soil-plant-atmosphere-interactions of winter wheat and silage maize in model regions of Germany against the background of climate change

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Introduction

Reliable weather and climate simulations depend to a large extent on how well interactions in the soil-plant-atmosphere system can be represented on a regional scale. The model coupling of the land surface model N OAHMP (Niu *et al.*, 2011) and the plant growth model GECROS (Yin and van Laar, 2005) developed as part of the DFG research group “Regional Climate Change” (FOR 1695) at the University of Hohenheim allows to investigate past, present and future effects of climate change on the soil water balance, plant growth and land surface exchanges. Compared to state-of-the-art land surface models in NOAHMP-GECROS the vegetation dynamics are driven by the prevailing weather conditions. By this means, reliable statements of practical relevance on the resilience of agricultural ecosystems to climate change can be derived.

Materials and Methods

The land surface model NOAHMP represents land surface heterogeneity with a semi-tile subgrid scheme. On the one hand shortwave radiation transfer is calculated over the whole grid cell, on the other hand longwave radiation, latent heat, sensible heat as well as ground heat flux are simulated separately over two tiles: vegetated respectively bare ground area (Niu *et al.*, 2011). The resistor network theory is used to calculate surface energy fluxes.

GECROS is a generic, photosynthesis-based crop growth model, developed to simulate genotype-by-environment interactions (Yin and van Laar, 2005).

The NOAHMP-GECROS coupling (Figure 1), was calibrated for the early covering winter wheat and the late covering silage maize. In the two model regions Kraichgau and Swabian Alb, which are very different with regard to climate and soils, eddy covariance and soil water measurement networks have been operated since 2009. Eddy covariance data of the surface energy fluxes net radiation, sensible, latent, and soil heat flux were collected. Besides that, water flow, the soil water balance, plant growth and yield of the individual plant compartments were used to calibrate and validate NOAHMP-GECROS. In a second validation phase, TERENO and ICOS data were used to check the capability and robustness of NOAHMP-GECROS simulating a wide range of environmental conditions representative for Germany. Finally NOAHMP-GECROS was forced with an ensemble of climate projections to evaluate the possibilities and limitations of the coupled model for climate change impact assessments.

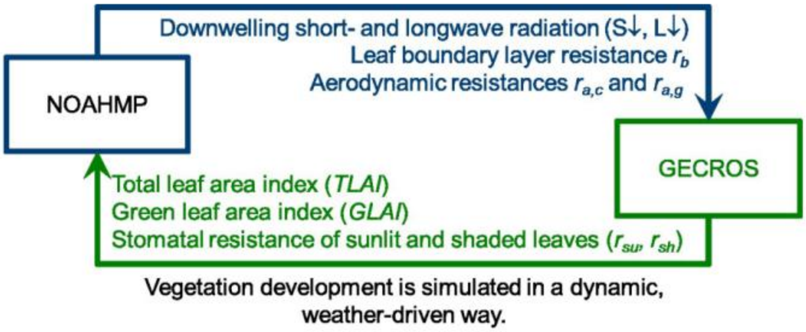

Figure 1. Coupling scheme of NOAHMP-GECROS (Ingwersen *et al.*, 2017).

Results and Discussion

Satisfactory model parametrizations were found for the early covering winter wheat and the late covering silage maize that showed robust results over a wide range of environmental conditions. The performance of the winter wheat simulations was slightly higher compared to maize. For example, the model efficiencies of plant development stages and the generative biomass in the validation runs for winter wheat were 0.98 and 0.52, respectively, for silage maize, model efficiencies were 0.93 and 0.77, respectively (Ingwersen *et al.*, 2017).

NOAHMP-GECROS showed advantages during the senescence phase compared to state-of-the-art land surface models where vegetation dynamics are usually prescribed in lookup tables resulting in the same development each year neglecting the prevailing weather conditions. In contrast, NOAHMP-GECROS with its dynamic, weather driven simulation of plant growth significantly reduced errors concerning sensible and latent heat flux. The evolution of the planetary boundary layer, the spatial distribution of rainfall as well as changes in regional air and surface temperature could be optimized.

Conclusions

The coupled model NOAHMP-GECROS is highly suitable for climate change impact assessments since it is evident, that climatic changes will effect crop development.

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Cyber-physical landscapes – a framework for agriculture 4.0

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Introduction

Emerging technologies foster an increased connectivity of humans, but also of their gadgets and machines. Real-time information collected by new sensors and communication networks has also found its way into agriculture. Facing 'peak farmland' and the need to feed 10 billion people by 2050, a constant pressure is on agriculture. Sustainable intensification seems the only way out. The digital revolution of agriculture opens opportunities to provide better knowledge to meet the future societal demands and global challenges. With the emerging technologies, improved biophysical models, and shared interlinked data, a sustainable intensification of agriculture seems feasible.

We merge theoretical frameworks from industry and ecology to the concept of Cyber-Physical Landscapes, presenting a roadmap for implementing a digital platform for agricultural landscape modelling to support information flow and decision support.

The 5C+ setup for a Cyber-Physical Landscape

Socio-technical ecosystems comprise the cooperation of humans and their wellbeing with the demand of nature protection by efficient use of technical applications and tools. Cyber-Physical Landscapes are meant to represent such systems and to facilitate the joint optimisation of all three social, technical and ecosystems towards an optimum supply of ecosystem services. Besides socio-technical ecosystems (the '+'), Cyber-Physical Landscapes comprise five levels of functions and attributes (5C, according to Lee *et al.,* 2015):

Connection

Real-time edge computing and 5G mobile networks are at the dawn to boost interconnectivity of the new machines, tools and sensors being currently introduced widely to agriculture. Sensor technology, architecture and precision have to be developed towards the different types of data that provide insight to ecosystem services in landscapes.

Conversion

The enormous quantity of environmental data that will be available in the near future needs to be converted to information. Collected and processed data are assimilated into models to analyse processes and to derive information for decision making. E.g., a simulation model for crop growth could predict expected grain qualities as a function of today's management decisions. Models embedded in Cyber-Physical Landscapes have to be diverse to reflect the different landscape features.

Cyber

The conceptual gap between single-ecotope models poses a serious challenge to integrated landscape modelling. Overcoming the scaling problem in the representation of processes in landscapes will lead to the construction of a digital copy of existing landscapes, a "playground" in which landscape functioning can be investigated and ecosystem services can be optimised. Deep learning and other data analysis techniques provide feedback to the following steps.

Cognition

Understanding landscape functioning and concluding rightly from this knowledge should be technically supported, e.g. by visualisation techniques. In the near future, augmented reality will have a bigger influence on our cognitive processes to understand complex systems. Such digital landscape visualisations will bridge the gap between decision makers and information.

Configuration

In the configuration phase, processed information and knowledge is sent back to the data-collecting devices and actuators for self-adjustment, -configuration and -optimisation. This implies improvements of work flows and fleet management, but also machine emissions and energy consumption, sensor settings and network configurations.

Conclusions

(Real-time) simulation modelling will play a significant role in the future of agriculture. At the landscape scale, the consideration of ecosystem services in the optimisation of land use promises further improvements of livelihood. Along this avenue, Cyber-Physical Landscapes and their visualisation will prove very useful to put sustainable intensification into effect.

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Agent-based modelling of a synthetic pastoral landscape

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Introduction

This model allows the spatial dynamics stemming from the interactions between mobile agents (herbivores) and their environment (rangeland) to be simulated. It features a herd grazing on a pasture. With a sustainability aim a dynamic balance must be found between grass intake by the animals and herbage growth. However, two behaviours may threaten this equilibrium: overgrazing, leading to desertification; under-grazing, leading to excessive vegetation and landscape "closure" by invasive shrubs (issue dealt with in Anselme *et al.*, 2010). Both processes may lead the herd, considered as free-grazers, to extinction by starving. This model's aim is not to mimic real specific rangelands but to offer a generic simple synthetic ecosystem to check ecological hypotheses.

Materials and Methods

The model has been implemented with the agent-based simulation NetLogo platform (Wilensky, 1999). It comprises two types of agents: spatial cells, called "patches" in NetLogo, representing the landscape as a grid, and mobile agents, called "turtles", standing for herbivores. Vegetation on patches are characterized by their color ranging from very light to very dark shades of green: darker the shade, higher the grass biomass and lower its quality. Herbivore attributes are their birth date, age, sex, previous location, destination, pathway, travelled distance, ingested feed, live-weight, calving dates. At each simulation time-step each individual iterates the following actions: stay on the current patch or move to another, graze, gain and lose weight, age and, possibly, reproduce or die. Although deliberately naive, the model was parameterized with real rangeland data borrowed from various authors (Bayer and Waters-Bayer, 1999; INRA, 1988; Vayssières *et al.*, 2009). Based on a reference landscape comprising 1,225 patches (1 ha each) and 1,225 cattle heads (1 head/ha), simulations have been made to check variants of the ecosystem's structure and animal behaviours (see below). The main criteria of simulation assessment are animal and vegetal productions, herd demography, landscape fragmentation over temporal horizons spanning up to 55 years. Whereas the focus was put on comparing animal walks, the emphasis is now on challenging ecological theories (optimal foraging, ideal free distribution, marginal value theorem).

Results and Discussion

Heterogeneity of landscape at initialization: starting with patches uniformly green or with different greens in a narrow range makes little difference. However, with higher heterogeneity the system's performances quickly decrease in terms of population size, pasture and shrub extensions. Whatever their initial state, all landscapes converge eventually towards a similar heterogeneity degree.

Heterogeneity of spatial distribution of animals at initialization: starting with all cattle on the same patch leads to a quick resource depletion radiating in concentric circles around the origin with huge mortality. The remnants colonize a few peripheral patches where they stabilize at very low level, abandoning the rest of space to shrub invasion.

Should I stay or should I go? The best strategy for turtles proved to be: if grass on the current patch is above a certain biomass*quality value, then keep on grazing, otherwise move to another patch.

Walk types: a directed walk like moving to patches with maximum herbage tends to create too high local animal density, inducing overgrazing, high mortality and bush extension. However, keeping the same rule within a limited perception range of animals may lead on the long run to sustainable rangelands with low-biomass but high-productivity pastures supporting a huge animal stock above 8 times the initial one; this emerging phenomenon, known as "grazing lawns" (Bonnet *et al.*, 2010), is illustrated on Figure 1.

Move length: short moves lead to better animal and herbage production than long ones.

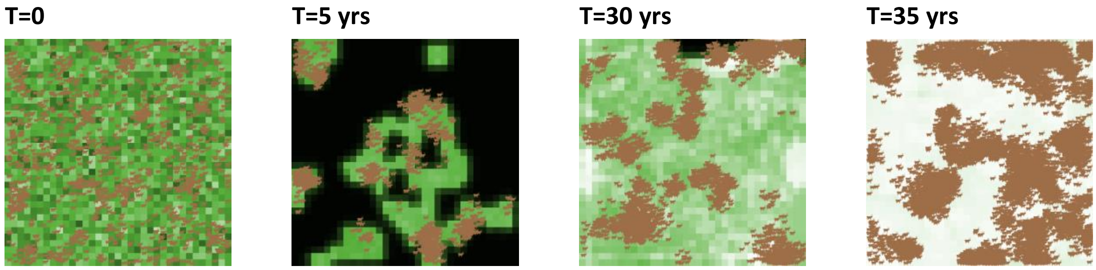

***Figure 1*. Example of a simulated 1,225ha landscape over 30 years. T=0, randomly generated rangeland with 1.12 heads/ha free-grazing cattle; T= 5 yrs, closing landscape, 0.76 heads/ha; T=30 yrs re-opening landscape, 3.36 heads/ha; T=35 yrs, stable "grazing lawn", 8.48 heads/ha.**

Conclusions

The most sustainable foraging strategies were found to be those fostering space occupation, local foraging, short walk steps and anticipating resource exhaustion. Animal movement proved to be crucial in shaping the system. The model also was used for testing theoretical hypotheses like "Ideal Free Distribution". Simulations made on a long run allow the emergence of interesting succession of extreme phenomena also found in real cattle farming systems or natural ecosystems (e.g. grazing lawns).

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A gradient perspective on landscape classification

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Introduction

Regardless of approach, any system for landscape classification inevitably implies a strong simplification of the almost infinite variability of landscapes, into spatial units suitable for communication in management and research (Bunce *et al.*, 1996). The multidimensional structure of the physical landscape makes all approaches involving classification difficult, because they involve drawing boundaries in a basically continuous variation in the composition of landscape elements. An understanding of natural variation based upon knowledge about environmental gradients and species' responses to these gradients – a gradient perspective on species-environment relationships (Halvorsen, 2012) – is supported by evidence from ecosystems all over the world and has prevailed in plant and community ecology for more than 50 years (Gleason, 1939; Whittaker, 1967). This approach is, however, less commonly applied to understand and describe variation at the landscape level of organisation (Cushman *et al.*, 2010). While turning a multidimensional space into types by combining gradient intervals has a long history in vegetation ecology (e.g., Tuomikoski, 1942; Økland & Eilertsen, 1993), similar approaches to landscapes are uncommon. Our research project explores 'gradient perspectives on landscape classification'. The aim of this approach is to explain as much of the variation in landscape properties in the simplest possible way, by identifying major gradients of variation. A practical application of this concept is exemplified with the new extensive and area-covering landscape classification for Norway within the framework of 'Nature in Norway' (NiN); a comprehensive system that addresses variation within the hierarchy of biodiversity levels (Noss, 1990), from microhabitats through ecosystem types to landscape types.

Materials and Methods

Based on a largely successful pilot study in Nordland county (Erikstad *et al.*, 2015), a refined method for gradient-based landscape classification was applied to the entire terrestrial land mass of Norway. Basic methodological characteristics of the new Norwegian landscape classification are: 1) a rule-based division of the landscape into discrete spatial units; 2) recording of a broadest possible selection of physical landscape attributes within each spatial unit; and 3) multivariate statistical analyses of the data set in order to identify 'landscape gradients', i.e., 'gradual variation in the presence and/or abundance of landscape elements'. The resulting typology was obtained by dividing the identified, few, major complex landscape gradients that explained most variation in the composition of landscape elements into standard intervals, and then defining landscape types by combining intervals along several gradients. The first phase of this classification process used data collected in 100 test areas, covering a total of 56 400 km^2, in which a total of 4 166 sampling units (landscape polygons, 4–30 km^2) were delineated according to principles from the Nordland pilot. Each sampling unit was described by more than 80 landscape variables.

Results and Discussion

Based on the patterns revealed by multivariate statistical analyses, the landscape units were grouped in five major types: coastal plains, inland plains, fjords, valleys and hills/mountains. Within each major type, a unique set of independent complex landscape gradients were identified. Examples of such gradients are: 1) terrain form; 2) variation from coast to inland; 3) hydrographic variation; 4) soil-type variation; 5) vegetation cover: 6), agricultural land-use intensity; and 7) other human land-use intensity. Based on the typology derived from the initial analyses, an area-covering, complete, detailed (1:50 000) landscape type map of Norway is under development, which is scheduled to be published in 2018. An attribute system with variables that cover landscape variation not captured by the type system opens for describing a wide range of properties of importance for scientific, monitoring and management purposes.

Conclusions

Preliminary results indicate that the gradient perspective on landscape classification is appropriate for area-covering landscape type mapping. We argue that the gradient perspective on landscape classification may contribute to a more coherent understanding of the gradual biophysical and land-use related variation within landscapes, which is also consistent with fundamental ecological theory.

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Landscapes as thermodynamic, optimizing systems: Formulation and applications

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Landscapes are composed of a range of complex processes, combining the physical processes that heat and cool the surface with hydrologic processes that moisten and dry the soil, biotic processes that build and maintain the vegetative cover, and human processes that alter these dynamics through agriculture to provide food and resources to human activity. Here, I formulate a comprehensive theory of how landscapes function as a coupled, thermodynamic system that converts energy of different kinds (Figure 1) and that, overall, evolves towards converting energy at the maximum possible rate that is set by thermodynamics. This theory is first being described (which is similar to the formulation at the planetary scale in Kleidon, 2016 and Frank *et al.,* 2017), applications are provided where this theory has already demonstrated its success, and a perspective is given on how this theory could help to better understand how complex landscapes function and how they may evolve in the presence of human land uses.

I describe landscapes here as a thermodynamic system that is composed of a sequence of energy conversions, where the direction and limits on the magnitude of these conversions is set by the laws of thermodynamics. Such a sequence of energy conversions taking place in a landscape is illustrated in Figure 1. Absorption of solar radiation heats the surface, and thermodynamics sets a fundamental limit to the magnitude of the resulting turbulent heat fluxes and the convective motion that takes place within the atmospheric boundary layer. Since greater fluxes result in a lower temperature (constituting a feedback on the radiative forcing), this results in a maximum in the physical power that can be derived to sustain convective motion. The optimum turbulent heat fluxes associated with this maximum power limit agree well with observations (Kleidon *et al.*, 2014). Turbulent fluxes are directly linked to evapotranspiration, which in turn is intimately connected to the gas exchange of the vegetative cover. Since the water loss of the vegetative canopy is directly linked with the carbon uptake, this thermodynamic constraint on evapotranspiration acts to constrain gas exchange and thus plant productivity. This constraint, however, can be modified through the effect of the vegetative cover on the surface albedo and thus on how much solar radiation is being absorbed, and on the access to soil water through the rooting depth of the vegetative cover, thus being able to maintain gas exchange over longer dry episodes. Biotic activity thus feeds back to the constraint set by turbulent exchange (arrow labeled “feedbacks” in Figure 1), likely resulting in a maximum ability to perform photosynthesis by altering the constraints on gas exchange. The last link in the sequence in Figure 1 deals with the use of a fraction of the biotic activity by humans in terms of crop yields in an agricultural setting. A fraction of the produced biomass is removed and appropriated by humans, which alters biotic activity as shown by the dashed arrow in Figure 1. The resulting feedbacks should then result in states in which the crop yield of the landscape could be maximized (Kleidon, 2006).

This formulation of landscapes as thermodynamic, optimizing systems describes a basic, physical theory that can be tested with observations. It should help us to better understand and predict the functioning of landscapes and how these respond to global change.

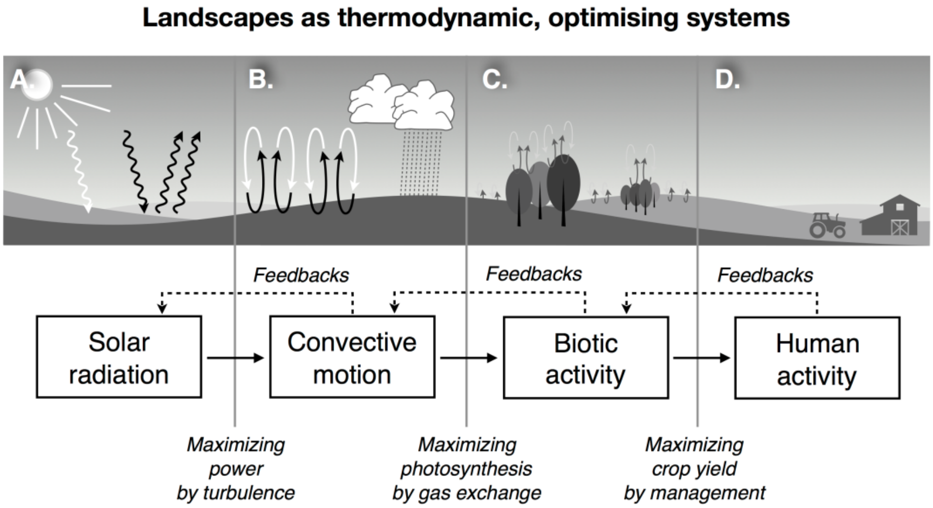

Figure 1. **Illustration of a landscape as a thermodynamic, optimizing system that converts energy of different forms, from solar radiation to crop yield used by human activity. The four boxes represent (A.) radiative processes as the driver for energy exchange, (B.) convective motion and hydrologic cycling that are driven primarily by radiative heating of the surface, (C.) biotic activity that creates chemical energy from light and requires gas exchange of water and carbon dioxide, and (D.) human activity that appropriates some of the carbohydrates generated by biotic activity.**

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Understanding the effect of land cover change in southeastern Amazonia with a thermodynamically-constrained surface energy balance approach

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Introduction

Understanding the climatic effects of land cover change requires the study of the changes in the biogeophysical and biogeochemical surface fluxes and their effects on the atmosphere (e.g. Pielke *et al.*, 2011). Land surface-atmosphere interactions can be investigated in different ways ranging from land surface models that involve empirical and semi-empirical parametrizations of turbulent fluxes (e.g. Oke, 2002; Pitman, 2003) and the use of field observations to describe the system dynamics at the time-scale of interest (e.g. Betts *et al.*, 1996), to regional and global coupled surface-atmosphere models (e.g. Perugini *et al.*, 2017). Here, we aim to understand the changes in the land surface energy balance driven by tropical deforestation from first-order physical principles applied to the land surface-atmosphere system and to evaluate the extent to which such physical principles can explain observed changes for contrasting land covers.

Materials and Methods

We use an analytic formulation of the surface-atmosphere system in which turbulent heat fluxes are constrained by the thermodynamic maximum power limit (e.g. Kleidon and Renner, 2013) and apply it to field observations over a rainforest and a soybean site in southeastern Amazonia. Our formulation explicitly accounts for the diurnal heat storage changes within the lower atmosphere that play a critical role as a buffer over land (Kleidon, 2016; Kleidon and Renner, 2017) and only requires absorbed solar radiation at the surface (and the ground heat flux) to predict the partitioning into net longwave radiation and turbulent fluxes. Sensible and latent heat fluxes are derived using micrometeorological partitioning in the absence of soil water limitation. We use half-hourly eddy covariance measurements of surface sensible and latent heat fluxes together with local measurements of radiation and the ground heat flux recorded at the Tanguro Ranch (13.08S, 52.39W) situated at the southeastern Amazonian agricultural frontier. We analyze monthly aggregated data of the period from April 2016 to March 2017 for the two different land surface covers monitored by the eddy flux stations.

Results and Discussion

We find a very good agreement between predicted and observed turbulent fluxes over both sites during the day, despite the differences in wet and dry conditions over the year (Figure 1). The contrasting land cover types thus primarily affect how much solar radiation is being absorbed by the surface and how turbulent fluxes are partitioned into sensible and latent heat, yet the fraction of turbulent fluxes in the energy balance, as predicted from the thermodynamic limit, is about the same despite the difference in the surface vegetative cover.

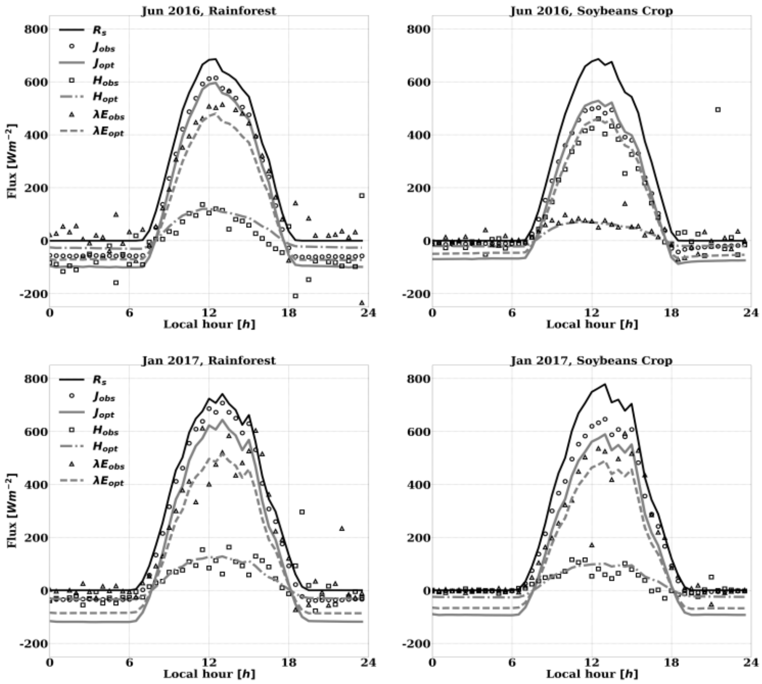

Figure 1. **Monthly mean diurnal cycle in June 2016 (dry season, top) and January 2017 (wet season, bottom) for the rainforest (left side) and the soybean crop (right side). The black solid line represents the observed surface absorbed radiation (Rs); the observed total turbulent fluxes (Jobs), latent (LEobs) and sensible heat flux (Hobs) are respectively the black circles, triangles and squares; the respective estimates from the thermodynamic limit are the solid (Jopt), dashed (LEopt) and dot-dashed (Hopt) gray lines.**

We further find reasonable estimates for the sensible and latent heat fluxes over the rainforest for both wet and dry seasons, while water limitation shapes the latent heat flux during the dry season for the soybean field, when the land surface can be considered mainly as bare soil. This insight emphasizes the role of vegetative cover and rooting depth in ensuring the access to soil water storage for the evaporation that we recognize here as one of the major system changes driven by deforestation. The agreement can be further improved when diurnal and seasonal variations in downwelling longwave radiation are accounted for by adjusting a parameter related to the strength of the atmospheric greenhouse effect.

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Cross-disciplinary links in environmental systems science: Current state and claimed needs

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Introduction

Terrestrial environmental systems are characterized by numerous feedback links between their different compartments. However, scientific research is organized into disciplines that focus on processes within the respective compartments rather than on interdisciplinary links. Major feedback mechanisms between different compartments might therefore have been systematically overlooked so far. Without identifying these gaps, initiatives on future comprehensive environmental monitoring schemes and experimental platforms might fail. This study aims at a comprehensive overview of feedbacks between different compartments currently represented in environmental sciences and explores to what degree missing links have already been acknowledged in the literature which might point to emerging new integrated fields in environmental sciences.

Materials and Methods

As an exhaustive survey of the literature of all relevant disciplines is not feasible we focused on process models. Models can be regarded as repositories of scientific knowledge that compile findings of numerous single studies. In total, 118 simulation models from 23 model types were analysed. Missing processes linking different environmental compartments were identified based on a meta-review. A systematic analysis of 346 published reviews, model intercomparison reports and papers, and model descriptions was performed. Eight disciplines of environmental sciences were considered and 396 linking processes were identified and ascribed to the physical, chemical or biological domain. Hierarchical clustering and network modeling were used to synthesize and analyze collected data.

Results and Discussion

There were clear and significant differences between model types and scientific disciplines with respect to implemented interdisciplinary links.

The most wide-spread interdisciplinary links were between physical processes in meteorology, hydrology and soil science that drive or set the boundary conditions for other processes (e.g. ecological processes). In contrast, most chemical and, especially, biological processes were restricted to links within the same compartment. Integration of multiple environmental compartments and interdisciplinary knowledge was scarce in most model types. Ecological model types had a simplified representation of the physical and chemical environment of the biological system, whereas models focused on physical and chemical transformations, and/or flow of matter had a simplified representation of life forms and biological processes. There was a strong bias of suggested future research foci and model extensions towards reinforcing existing interdisciplinary knowledge rather than to open up new interdisciplinary pathways.

Conclusions

No clear pattern across disciplines exists with respect to suggested future research efforts. There is no evidence that environmental research would clearly converge towards more integrated approaches or towards an overarching environmental systems theory. This might severely limit our ability to understand, predict, and manage current future challenges to the environment in a world that is increasingly changing and interconnected.

Acknowledgements

Part of the work has been funded by the German Research Foundation (DFG), funding no. LI 802/5-1, which is highly appreciated. Additional funding by the Helmholtz Centre for Environmental Research (UFZ) is acknowledged. This study would not have been possible without initiation, valuable contributions and comments from members of the expert group on Environmental Systems Theory within the working group of the Alliance of Science Organisations in Germany about Infrastructures in Terrestrial Research, led by Ingrid Kögel-Knabner and Georg Teutsch.

Conceptualising fields of action for sustainable intensification – a systematic literature review and application to regional case studies

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Introduction

After two decades of research on sustainable intensification (SI), namely the aspiration to expand food production on less environmental costs (Gadanakis *et al.*, 2015), blurred boundaries of theoretical notions and overlap of concepts characterise a controversial debate (Wezel *et al.*, 2015). Based on a systematic literature review and focusing on SI implementation, the objectives of this study are (1) to comprehensively explore the SI literature and provide a structured analysis of its scope, (2) to propose a practice-oriented conceptual framework using the portfolio of SI practices, and (3) to demonstrate the applicability of this framework for specific problem settings in selected European case study regions (Weltin *et al.*, 2017).

Materials and Methods

We carried out a systematic review of the literature in the field of sustainable intensification for an interdisciplinary, comprehensive overview of the topic and quantify trends. Using the Scopus database, we applied the search term “sustainable intensification” in title, keywords or abstract for papers, which have been published until December 31st, 2016 (N=330). For each paper the metadata was recorded as well as information on geographical coverage and proposed SI practices. Subsequently, we intertwined the review with the development of a conceptual framework of SI practices. Its applicability to specific regional problem settings was tested in four European case studies using participatory stakeholder processes involving in total 68 participants from the fields of agriculture, administration, environment and research. Case study regions were selected in order to capture a variety of geographical contexts, land use and landscape characteristics.

Results and Discussion

The temporal and geographical development of the SI literature consists of three phases connected to parallel debates, such as livelihood support for smallholder agriculture as well as the eco-system service and climate change discourses, leading to recent publication increase, especially in Europe. The heterogeneity of the SI debate becomes explicit in systematic differences in the coverage of scientific disciplines, citations and keywords. We demonstrate that understanding of the SI approach emerges when focusing on its implementation by proposing a conceptual framework for SI practices.

In this framework, SI practices are structured with regard to space from farm to landscape scale and activity scope referring to land-use and organisational optimisation. Assigning identified practices in the literature, four fields of action emerge labelled "Agronomic development", "Resource use efficiency", "Land use allocation", and "Regional integration". It becomes obvious that studies tend to investigate SI practices in isolation. Only one third of the literature deals with two or more fields. The distribution of practices across fields shows that the literature engages more with practices on the farm level, especially with agronomic developments. Addressing SI at a superordinate level of regional land-use planning or steering societal interactions is underrepresented. Stakeholders in four European case studies selected regional SI practices based on the framework. Practices depend on regional problem contexts and local knowledge and cover all fields of action which demonstrates its applicability. For the future, stakeholders in all regions see a need for coordinated action on the landscape level, especially regarding regional integration.

Conclusions

The proposed conceptual framework structures a heterogeneous discourse and can serve as baseline to capture the scope of SI. Opportunities to couple practices on farm and landscape level should be identified to catch up with practitioners' needs. This requires interdisciplinary research efforts. For successful and coordinated implementation, the decision-making rationales of farmers and stakeholders involved in regional governance and land-use planning have to be explored.

Acknowledgements

This research was financially supported by the European Commission under grant agreement 652615 and conducted in the context of the ERA-Net FACCE SURPLUS project VITAL, with the national funders NWO (Netherlands), BMBF (Germany), INIA (Spain), ANR (France).

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Success in transdisciplinary landscape research

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Introduction

Transdisciplinary research (TDR) is discussed as a promising approach in land-use science and spatial research to address complex multifaceted 'real-world problems' and to design strategies and solutions for sustainable development. TDR has become a widespread research approach in sustainability science and is increasingly promoted by research programmes and agencies (e.g., Future Earth, Horizon 2020). But up to now it is an open question whether the often-promised benefits of transdisciplinarity will realized and measurements of TDR impacts may become possible.

In consequence one major part of the literature on TDR is dedicated to the search for adequate evaluation approaches. However, empirical studies often consider expert perspectives; knowledge of the experience, attitudes and motivations of a broader science-practice community applying transdisciplinarity remains rare. In addition, as known from previous contributions (see Fuest and Lange, 2015; Zscheischler and Rogga, forthcoming) there is an evident gap between the 'idealised' concept of transdisciplinarity and 'real world' adopted practice.

The presentation will introduce results of a study that aimed to gather insights into the practice of TDR as well as the perceptions and assessments of success from scientists and practitioners. We argue that a study of the perceived project success can provide valuable insights into the quality of cooperation between scientists and practitioners. Moreover, it takes into account that a plurality of TDR notions persists.

Materials and Methods

The study is based on a mixed-method approach. We combined qualitative expert interviews with a quantitative survey obtaining 178 completed questionnaires of scientists and practitioners from 21 TDR projects. All investigated projects are part of the same funding program dealing with land management issues.

Results and Discussion

Results show a high commitment to the targets of TDR projects and a basic shared 'success profile'. Nevertheless, there is currently a strong 'practice tendency', while TDR-specific benefits for the scientific knowledge gain remain ignored. Remarkably, perceptions of overall project success are highly associated with process quality and output performance, but personal targets, such as career opportunities, seem to have little influence.

Conclusions

Results reflect a consolidating concept of TDR in the application field of land-use science that emphasises practical relevance. Still, adequate sets of criteria to describe quality and success of TDR are needed, also to prove its merits for science.

Acknowledgements

This work is supported by the German Federal Ministry of Education and Research (BMBF) under Grant FKZ 033L004.

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Recent progress in eliciting diverse values and meanings of landscapes

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Abstract

Landscapes exhibit diversified and interconnected types of values ranging, for instance, from intangible features such as spiritual values and outdoor recreation through water and climate regulation to the provision of food (Termorshuizen and Opdam, 2009). Landscape research into such services is typically focused on how different types of landscapes provide different services, and how different parts of society value them, depending on the cultural background, scarcity, and accessibility of the services provided. Precise understanding of the complexity of assigning values to landscapes is important for decision making on the protection or development of cultural landscapes, in particular for evaluating trade-offs around alternative trajectories of landscape change.

Some landscape values are well investigated, such as landscape aesthetics (Daniel *et al.*, 2001), recreational values and touristic values (Bell *et al.*, 2007), or sense of place (Manzo and Devine-Wright, 2013). One important insight from studies of landscape values is that, although landscape values are closely connected to landscape patterns, intensity of use, and structure, they cannot be assessed in terms of purely material site attributes (Stephenson, 2008). Rather, they possibly evolve from human interaction with sites in the course of a cultural process of acquiring a sense for them, resulting in the creation of meaning and knowledge.

Promotion of sustainable landscape management with the intention of providing multiple landscape values is promoted by rural development policies in many Organization for Economic Co-operation and Development (OECD) member countries. Several qualitative and quantitative methods have been developed to reveal such values and conflicts at land-/seascape level, for example freelisting, monetary valuation, or culturonomics (content analysis of large digital text bodies). Public Participation Geographic Information Systems (PPGIS) have been particularly widely used as they allow putting landscape values on a map.

Here, I present an assessment of landscape values perceived and mapped by residents across 13 multifunctional (deep rural to peri-urban) landscapes in Europe. This study identifies the most intensively perceived landscape values, their spatial patterns, and the respondent and landscape characteristics that determine landscape value perception. The study finds settlement areas are landscape value hotspots but many landscape values are also related to forests, waters and mosaic landscapes. Some landscape values are spatially clustered, while many others are dispersed. Perception of landscape values is linked to people's relationship with and accessibility to a landscape. This study highlights the importance of local-level perspectives for the development of contextualized and socially acceptable policies for the management of landscape values.

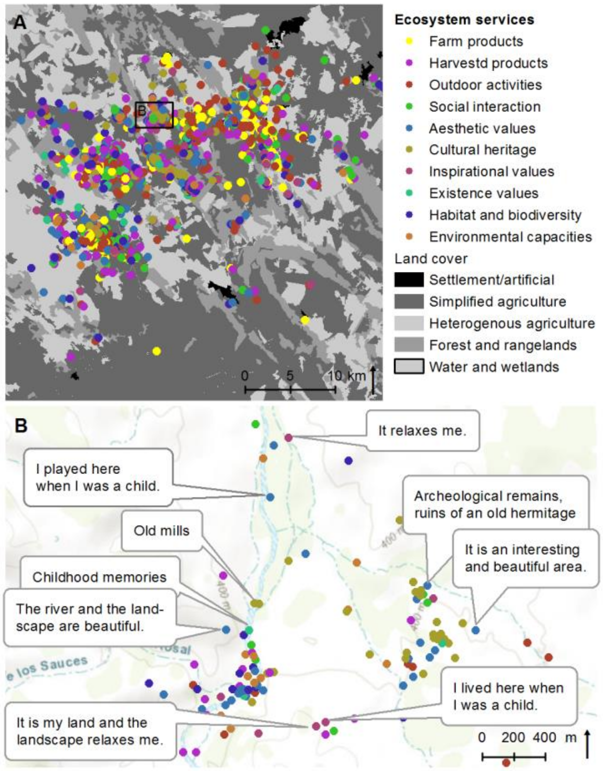

Figure 1. **Spatial distribution of landscape values in Serena Campiña, Spain (SP-SC). 181 residents mapped in total 2,438 places related to their everyday landscapes shown in panel A. Panel B presents the spatial distribution of these mapped sites on local scale and descriptive attributes given to mapped locations.**

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Understanding the evolution of land systems from complex system perspective: resilience, tipping point and regime shifts

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Abstract:

Land systems are coupled social environmental systems (SESs) and characterized by intrinsic complexity entailing non-linear dynamics, self-organization, multi-scale feedbacks and emergence. Understanding the dynamic evolution of land systems is a pivotal task of land change science and has profound policy implications for sustainable management of land resources and ecosystem services. Yet, most land system researches are focused on quantitative changes and remain essentially static and linear. The non-linear changes, such as leap frogging kind of land system changes, remains notoriously challenging to analyze and simulate. Recently, regime shifts emerged as a conceptual tool to understand the qualitative and systematic changes of land systems. Regime shift is defined as a persistent, radical, abrupt, and often surprising change to an alternative system state with distinct structure and functions. The concept of regime shifts has roots in physics and politics and has been increasingly applied in ecological researches; but it has received relatively little attention in land system science. While regime shift seems like a promising theoretical concept for land system change, misunderstandings and skeptics remain among many researchers. In this talk, we will present the concept and related terminologies, the implications for modelers and policy makers, research challenges, and case study examples. We hope this talk will stimulate further discussions and maybe develop working groups to promote the researches on regime shifts in land system science.

Keynote: Landscapes of the Anthropocene: Evolving towards a Shared Biosphere

Erle C. Ellis

University of Maryland, Baltimore County, USA

As human societies continue scaling up and expanding their influences across Earth's landscapes, the challenges of conserving wild species and wild places across the Anthropocene appear to be growing ever greater. As human populations race past 10 billion and living standards improve, is it even possible to stave off a sixth mass extinction and a near complete loss of nonhuman habitat? While no one should underestimate the unprecedented challenges involved in conserving biodiversity in an increasingly human biosphere, there is evidence that a radical increase in the scale and effectiveness of conservation might not only be desirable, but also increasingly feasible in this century. Underpinning such a transformational strategy are long-term evolutionary shifts in socio-technological capacities and cultural values facilitated by the emergence of societies governed by the common aspirations of all people to live better lives. Though conservation and development certainly can compete for land, at the same time, poverty reduction and development also enhance societal demands for conservation and the social-technological capacities that enable land to be used more efficiently and less harmfully. By embracing, promoting, and developing the aspirational natures that people want – locally, regionally and globally – conservation has the potential to evolve into the truly universal human project needed to sustain Earth's ecological heritage into the deep future.

Erle Ellis is Professor of Geography and Environmental Systems at the University of Maryland, Baltimore County (UMBC) where he directs the Laboratory for Anthropogenic Landscape Ecology (http://ecotope.org). His research investigates the ecology of human landscapes at local to global scales to inform sustainable stewardship of the biosphere in the Anthropocene. His recent work examines the causes and consequences of long-term changes in Earth's ecology produced by human societies (anthroecology; anthromes). Other projects include online tools for global synthesis of local knowledge (GLOBE) and inexpensive tools for mapping landscapes in 3D (Ecosynth). He is a member of the Anthropocene Working Group of the International Commission on Stratigraphy, the Scientific Steering Committee of the Global Land Project and a Senior Fellow of the Breakthrough Institute. He teaches environmental science and landscape ecology at UMBC, and has taught ecology at Harvard's Graduate School of Design.

Impact assessment of soil management and soil functions for a bioeconomy

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Introduction

Bioeconomy strategies that aim at intensifying agricultural production have been implemented in many countries around the world (Fund *et al.*, 2015). This has implications for soil functions which are essential for efficient use of resources and maintenance of ecosystem services (Keesstra *et al.*, 2016). However, resource use efficiency assessments rarely address the role of soil functions and the link between ecosystem services and soil functions and management is still not well established. This study is the first to conceptually link socio-economic processes of external drivers and soil management changes with soil functions, and impacts on societal targets.

Materials and Methods

We developed an analytical framework for impact assessment of soil management and soil functions that integrates the DPSIR framework with the five steps of impact assessment (Gabrielson and Bosch, 2003; Helming *et al.*, 2013). We assessed state of the art literature on the links between soil management and soil functions on the one side, and resource use efficiency and ecosystem services on the other side.

Results and Discussion

The framework contains five steps: (1) analysis of future trends and driving forces for soil management; (2) definition of soil management activities exerting pressures on soil systems; (3) analysis of management effects on soil processes and soil functions; (4) assessment of impacts on resource use efficiency and ecosystem services; (5) elaboration of governance instruments based on assessment results – to provoke responses on impacts. The framework accounts for modes of interaction between soil management and societal targets: soil-borne via changes in soil processes and functions (solid arrow, Figure 1) and management induced irrespective of changes in the soil system (thin arrows, Figure 1). Furthermore, the framework establishes the analytical basis for the identification of indicators. For example, soil functions are so far mostly implicitly addressed by indicators of resource use efficiency, e.g., via the role of soils for crop growth, and many assessments of complex soil functions' contributions to ecosystem services use single indicators. Resource use efficiency and ecosystem services are complementary concepts essential for sustainable bioeconomies. Both require consideration if increases in production are to be achieved without aggravating environmental pressures. Finally, opportunities and limits of the framework are discussed.

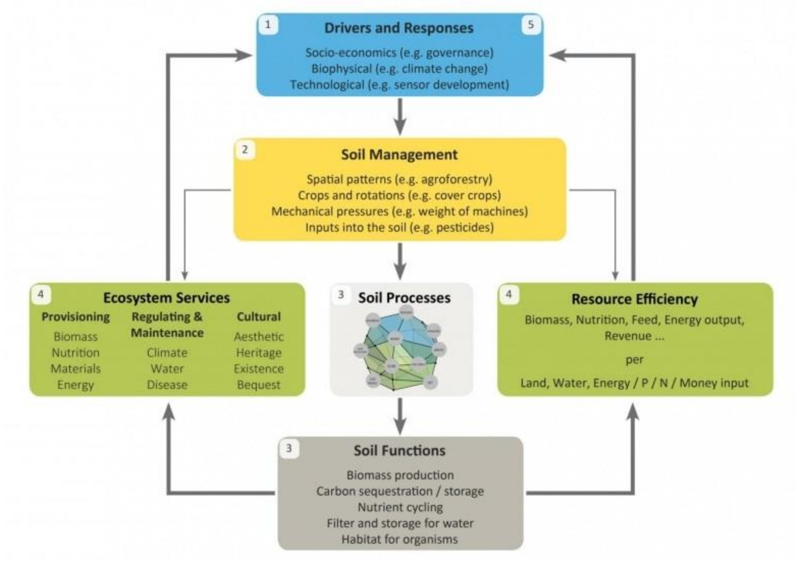

Figure 1. **Assessment framework linking drivers and soil management to soil processes, functions and societal value targets.**

Conclusions

Soil functions affect provision of ecosystem services and influence resource use efficiency of agricultural production. They are modified by management and may change due to drivers such as climate change, technological progress or demand for biomass. To achieve sustainable development, it is necessary to assess impacts of changes on societal targets. Our framework adapts established methods of sustainability impact assessment to allow evaluation of effects of soil function changes. It gives guidance on definition of system boundaries, indicator selection and integration of results while addressing analytical challenges such as rebound-, cascade- or leakage effects.

Acknowledgements

This research is funded by the German Federal Ministry of Education and Research (BMBF) in the framework of the funding measure "Soil as a Sustainable Resource for the Bioeconomy – BonaRes", project "BonaRes (Module B): BonaRes Centre for Soil Research, subproject A, B" (grant 031A608A, B).

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Innovative farming systems in landscapes under change – a plea for a long-term system approach

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Introduction

A growing human population, climate-change mitigation and adaptation, together with changing societal demands for food, energy and renewable materials, pose interrelated challenges for future farming systems. Sustainable intensification, diversification and fine-scale land sparing are some of the concepts discussed and investigated as transition pathways towards more sustainable farming systems. Assessing the feasibility and effectiveness of such transitions requires profound theoretical and practical understanding of the farming systems (both reference and innovative system) and of the landscape characteristics of the regions in which the farming systems are embedded. Gaining such understanding is often hampered by the difficulties of landscape-scale experimental manipulation of farming systems. We here present a landscape-scale farming systems approach we are testing in two projects, F.R.A.N.Z.[*] and RELEVANT[**], discuss the difficulties we are facing in applying this approach and derive ideas for a long-term systems approach.

Materials and Methods

Both projects cover sets of farms situated in different regions across Germany and are aimed at enhancing biodiversity and associated ecosystems services (i.e. pollination and biocontrol) by implementing project-specific changes in land use (i.e. fine-scale land sparing via agri-environmental measures on farmland and diversification of crop rotations with faba bean and pea respectively). To test the effects of those land-use changes at the landscape scale, the establishment of treatment and control landscape pairs is a prerequisite. To do so, we selected areas of 1 x 1 km, covering those patches of each farm that are subject to land-use change and analyzed the landscape composition of these areas, together with the composition of their wider surroundings (3 x 3 km). We used data on land-cover composition (ATKIS), soil types and digital aerial images to conduct a semi-automated selection of potential matches of areas with comparable landscape and soil characteristics. We chose a distance of at least 3 km between treatment and control landscape pairs to secure independence of sampling areas with regard to mobility of indicator taxa. Following a BACI-design (Before-After-Control-Impact), sampling of indicator taxa was conducted in the 1 km^2-windows of the paired landscapes. Land use and landscape metrics from both 1 and 9 km^2-windows will be used as explanatory variables for testing treatment and landscape impacts on biodiversity.

Results and Discussion

We successfully identified suitable matched pairs of landscapes for each participating farm, based on best available data. Subsequent detailed mapping of land use (crop types, semi-natural habitats, and patches with agri-environmental measures) during the vegetation period, revealed stronger discrepancies in land use between the matched pairs than we had expected from the semi-automated site selection applied.

Further hurdles became apparent: In both projects only one farm in a respective area participates and only for this farm detailed land-use data is available. Agricultural fields of farms are, however, spatially dispersed. Our landscape approach therefore covers the fields of many different farms for which detailed information is not easily accessible. The selection of paired landscapes would have been facilitated by an availability of field-specific land-use information, including information about agri-environment schemes and ecological focus areas. Such data could easily be provided by the Integrated Administration and Control System (IACS), which is mandatory for all EU Member States, but the use of those data is restricted by data protection regulations in Germany and not accessible in some German states. Alternatively, missing land-use information could potentially be acquired by interviewing all farmers managing fields in a landscape and/or by interpretation of time series of remote sensing data. Both approaches would require more time, money and personnel. Farm-scale approaches have been proposed as a suitable approach to demonstrate and test the impacts relevant for the economic entity of a single farm but may be of limited use for studying drivers or impacts which are operating at a landscape or regional scale. Moreover, studying effects of system transitions such as converting homogenous into diversified farming systems via longer crop rotations require time because many of the intended outcomes take time to develop. The funding of scientific monitoring within farming system transition projects therefore requires a long-term perspective which should not be restricted by administrative hurdles such as fixed maximum funding periods of three years.

Conclusions

Assessing the feasibility and effectiveness of transformation pathways for farming systems requires a landscape system approach. The transformation measures should be implemented jointly by the farms operating in the particular landscape, turning this landscape into a real-world laboratory. This approach is time and space intensive and requires strong participatory and co-innovation actions. Therefore, this approach challenges not only science but also the traditionally short duration of funding programs.

[*] http://www.thuenen.de/de/institutsuebergreifende-projekte/franz/

[**] http://www.thuenen.de/de/bd/projekte/relevant/

Seeing the landscape for the farm: combining conceptual and empirical approaches to understand agricultural systems

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Introduction

Agricultural landscapes are set to play an important role in achieving Sustainable Development Goals globally, regionally, and locally because of their importance for providing food, fibre, fuel, livelihoods, and cultural services. Crops and livestock also cause major damage to biodiversity, water quality, and greenhouse gas emissions (Foley *et al.*, 2011). Thus, evaluating the performance of agricultural landscapes in regards to environmental and socio-economic goals across a range of scales is a priory for research and management. Understanding and evaluating the sustainability of any system requires a conceptual model of how that system is structured and functions (Reyers *et al.*, 2017). Here we present a conceptual model of agricultural systems as interacting components, namely environmental and social drivers, management choices, and outcomes, based on a review of existing conceptual models of agricultural systems (e.g., TEEB, 2015) and European agricultural land use research. We then examine which components of agricultural systems are the focus of empirical land use research, policies, and sustainability assessment tools, using Europe as a case study.

Materials and Methods

First, we conducted literature reviews of 1) how agricultural systems have been conceptualised and 2) which components of European agricultural systems have been included in both research (a structured literature review of 69 peer-reviewed papers) and policy and practice (EU sustainability and agricultural policy, agricultural sustainability assessment tools). Following these reviews, and based largely on the TEEB for Agriculture and Food report (TEEB, 2015), we developed the conceptual model of agricultural systems as interacting environmental and socio-economic drivers, management choices, and outcomes (Figure 1). We then categorised the variables identified from research, policy, and assessment tools as either drivers, management choices, or outcomes to determine the relative focal areas from these different perspectives. Finally, using R, we conducted a cluster analysis of research papers based on which variables were examined in each study. Differences between groups were assessed using PERMANOVA and the 'envfit' routine. We also identified 'indicator' variables, typifying which system components are the focus of research within each of the research paper groups.

Results and Discussion

We found a long history of systems thinking in agriculture, although holistic conceptual models of agricultural systems were not always made explicit or were difficult to apply across landscape- or larger-scales. Explicit and holistic conceptualisation of system components and hypothesised interactions that can be applied across multiple scales is essential for empirically examining agricultural landscapes as systems.

Further, we found that agricultural land use research at the European scale predominantly focused on drivers, whereas assessment tools often focus on management choices and policy is concerned mainly with outcomes. We also found some areas important in assessment tools and policy were not well-studied in academic literature (e.g., health, gender equality). Five distinct groups of research papers emerged from the cluster analysis. Two groups could be distinguished by their focus on how landscape configuration variables (e.g., remoteness, topography) drive land cover and land abandonment, respectively. A third group was specified by a focus on how demographic factors (e.g., farmer age, education) drive land cover. A focus on how land use affects outcomes such as timber production, species composition, and biomass flow marked the fourth group. The fifth group was characterised by research investigating how a variety of different drivers and management choices affect land use intensity. These different groups indicate that research is often focused on a particular part of agricultural systems (e.g., in the environmental or social domain, or on drivers, management choices, or outcomes). Research on individual parts of agricultural systems is fundamentally important, but should be explicitly positioned within the context of the many interacting parts.

Conclusions

We argue that a systems approach using the presented conceptual model will help to better understand, evaluate, and guide the sustainability of agricultural landscapes. We argue that contextualising the focus of research, policy, and assessment within a holistic conceptual model of agricultural systems will help to bring the pieces of the puzzle together to better align these three important parts of understanding and managing agricultural landscapes.

Acknowledgements

This research was supported by Swedish Research Council Grant #2014-5899/E0589901.

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The power of scientists as constructors of landscape dynamics – a contribution to integrated systems analysis

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Introduction

Landscapes are 'social constructs' – the description and definition of what determines a landscape highly depends on the disciplinary view, the interests and the socio-cultural context of the respective actor(s) engaged (Greider and Garkovich, 1994; Knierim, 1994). Research approaches to study 'landscape' and 'landscape dynamics' thus imply the integration of inter- and transdisciplinary perspectives in order to reflect the complexity of the topic and to appropriately frame the problem at hand.

Hence, actors' perspectives and perceived agencies with regard to landscape dynamics are key constituents for the research design in landscape studies. With our paper we address the conceptual gap concerning 'the role and identification of actors in landscape change' (Plieninger *et al.*, 2016: 213). In particular, we focus our quest on landscape researchers as one of the main actor groups beside policy-makers and practitioners (Hernandes-Morcillo *et al.*, 2017). How can we understand scientists as 'influential factors' in designing and determining landscape concepts, how can their power as creator of landscape constructs be taken into account?

Concepts, materials and methods

For the conceptualization, we operationalize actors according to the degree of their involvement in the shaping and making of landscapes (Grimble and Wellard, 1997; Hersperger *et al.*, 2010). We focus on researchers as conceptually performative, powerful actors and differentiate 'power' with respect to Partzsch (2015) in *power over, power to* and *power with*. *Power over* signifies a situation where someone can make another person do something either directly or indirectly, *power to* expresses a person's agency to get things done and *power with* is the capacity to initiate collective change and transformation through learning in and leadership of groups and organisations. We concretise our concept with the case of sustainable intensification in agriculture, implying the transformation of agricultural landscapes (Wolters *et al.*, 2014). In general, the study of sustainable intensification of agriculture has to consider "the spatial and temporal variability of [.. farming] systems (…) by addressing local conditions, the landscape context and climate change" (Wolters *et al.*, 2014: 226). We make use of a scenario-based ex-ante impact assessment study of agricultural intensification at landscape scale (Gutzler *et al.*, 2015) as empirical case. Here, the authors combine soil and crop growth simulation, hydrological and bio-economic modelling with contextual data for biodiversity and landscape scenery analyses at field, farm and regional levels.

Results and Discussion

The analysis of the study's research design shows that choices were done based on conceptual assumptions: E.g. (i) the DPSIR framework (Gabrielsen and Bosch, 2003) provided a rather loose general conceptual frame of linear logic, aggregating various drivers of agricultural practice, and unspecific to actors, (ii) hydrological modelling got a key influential role representing one dominant source of intensification, (iii) change of agricultural practices was translated by farm-level economic rationality and (iii) landscape impacts were expressed through shares of high value areas and those with recreational or touristic purposes.

These choices show, how disciplinary explanations dominate the establishment of the overall research logic which results in a distributed *power to* influence of the single scientists. Additionally, the DPSIR framework concept seems to be only of weak support to problem targeting, and not integrative enough for a *power with* approach of proper interdisciplinary collaboration among researchers. The discussion of the general framing and a number of assumptions of the study with policy makers prompted some critical feedback on the conceptional premises and thus revealed weaknesses in the research's targeting.

Conclusions

We conclude that the research design for landscape dynamics has to be conceived as a process of mutual understanding, profound conceptual debate and concertation among researchers and – depending on the problem at hand – in exchange with policy makers and practitioners in order to get the theoretical bases 'right' and to assure targeted, relevant research (Batie, 2008). As a procedural component, conducive for such successful inter- and transdisciplinary knowledge creation, we refer to system reflexivity (Ison, 2010).

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III. Poster Session
Integrated Systems Analysis – Towards a Landscape Theory

Authors alphabetical

The study of spatial heterogeneity of landscapes of Baikalian Siberia

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Introduction

The investigation into the spatial-coenotic changes of the mountain taiga and sub-taiga forests and steppe geosystems of the Baikal Region allowed us to establish the dependence of the spatial landscape heterogeneity on the variability of the hydrothermal conditions and litomorphic nature of habitats. The application of a structural dynamic approach to the analysis of the spatial landscape heterogeneity in our study made it possible to show the order of changes of the facies due to the variability in ecological conditions in the form of models, namely, factoring-dynamic models.

Materials and Methods

According to landscape ecology theory, landscape structure is determined by the composition, the configuration, and the proportion of different patches across the landscape, while function refers to how elements in the landscape interact based on their life cycle events (Turner, Gardner, 1991). We studied this landscape structure as a set of the geosystems existing in different dynamical states as a result of their directed transformation under spatial and temporal changes in natural conditions and under anthropogenic impact] (Sochava, 1978; Isachenko, 2004).

Results and Discussion

The Preol'khon landscapes, which are located in the centre the Western Baikal Region, and Tunkinskie Goltsy Range and Khamar-Daban Range landscapes located in the Southern Baikal Region are the focus of this study (Figure 1).

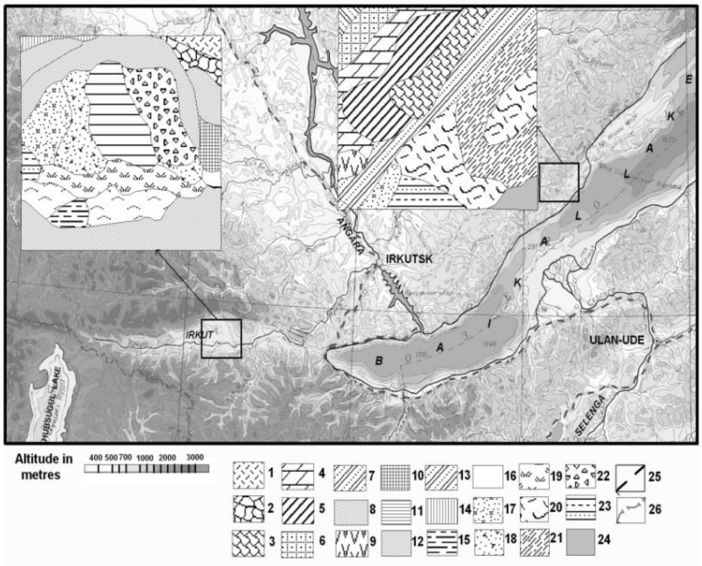

Figure 1. **The study areas location within the Southern (A) and Western (B) Baikal Region and fragments of landscape map, which was created by Mikheev, Ryashin (1977).**

The character of the natural conditions in the southern and western part of the Baikal Region, including mountain relief, climate variations, and diversity in vegetation and soil cover, are the cause of this landscape heterogeneity.

Our investigations into the spatial-coenotic changes of mountain taiga, sub-taiga and steppe vegetation within the study areas made it possible to identify the spatial variability features for typical regional and local geosystems. We identified dominant and edificatory species of tree, shrub and herbaceous-subshrub layers of vegetation of the typical facies, and peculiarities of it spatial heterogeneity in the key plots.

Landscape structure analysis was made of the middle-scale landscape profiles using the comparative-geographical method, since the landscape topographic profile and spatial combination of the facies within it reflect the main structural and dynamic features of the territorial landscape structure with regard to regional nature characteristics.

Northern-Asian Golets and Taiga Geosystems:

Golets and sub-golets Baikal-Dzhugdzur and Easten-Sayan: I. Golets tundra: 1 – lichen flattened surface, 2 – slopes talus with lichen cover and sparse cedar dwarft cover; II. Sub-golets shrubs and open larch woodland: 3 – leveled surface and slopes open larch woodland with cedar. Mountain-taiga Baikal-Dzhugdzur: III – Mountain-taiga larch forest of limited development: 4 – slopes larch forest with pine, 5 – slopes larch forest with cedar and mixed undergrowth, 6 – valley yernik; IV. Mountain-taiga larch forest of optimal development: 7 – slopes larch forest shrubby undergrowth with the dominated Rhodendron dauricum, 8 – slopes larch forest with pine and forbs, 9 – valley of meadows with gramineous (sometime steepificated) cover, 10 – piedmont birch-larch upland with shrubby undergrowth and herbaceous cover, 11 – valley swampy meadows, 12 – bottoms of depressions larch forest with pine and forbs. Mountain-taiga Southern-Sibirian: V. Mountain-taiga dark-coniferous forest of limited development: 13 – gently sloping forest from cedar and fir with fruticulose – small herbaceous and true moss cover, 14 – slopes sedar forest with spruce, larch and small herbaceous – true moss cover; VI. Mountain-taiga pine forest: 15 – slopes pine forest with shrubby undergrowth and herbaceous cover, 16 – slopes herbaceous steepificated with Rhodendron dauricum. VII. Submountain-taiga pine forest: 17 – plain pine forest with Rhodendron dauricum bushes, 18 – bottoms of depressions pine forest with Rhodendron dauricum bushes, 19 – valley poplar-pine forest and osier-bed plain meadow.

Central-Asian steppe geosystems:

Mountain Easten-Zabzikalskie: 20 – bottoms of depressions gramineous steppe (feather and wheat grass), 21 – terrace low-bunchgrass steppe, 22 – bottoms of depressions fescue, and cobresia and shortgrass medow-steppe with frozen, 23 – valley carex-gramineous swampy of solonetzic meadows. 24 – Aquatory of the Baikal Lake. 25 – Federal highway. 26 – National boundaries.

Reference samples

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Impacts of climate change adaptation options in agriculture on soil functions: Evidence from Europe

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Introduction

Soil systems are fundamental to sustainable development due to their multifunctional role in providing services including biomass for food, feed, energy and fibre; habitats for organisms and gene pools (biodiversity); mitigation of greenhouse gas (GHG) emissions; contributions to carbon sequestration (C); and provisions to cultural, recreational and human health assets. Climate change can affect soil functions in two ways: directly and indirectly. While direct effects have been subject of research in many studies, knowledge of the indirect effects of agricultural adaptation options on soil functions is difficult to anticipate because it depends on an uncertain future climate and corresponding adaptation.

The objective of this paper was to carry out a meta-study on the potential impacts of climate change adaptation options in agriculture on soil functions using regional case studies in Europe and to interpret these in the context of the Sustainable Development Goals (SDGs).

Materials and Methods

The research was designed as a meta-study of 20 case studies across Europe (Figure 1). Each case study undertook an integrated assessment by integrating a variety of quantitative tools (e.g. modelling) with stakeholder engagement processes.

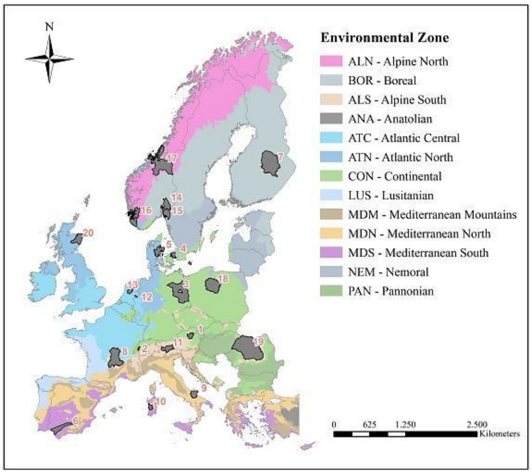

Figure 1. **Location of the 20 case study areas and their environmental zones in Europe.**

The experts were asked to assess the impacts based on previous study results and expert knowledge. A semi-structured questionnaire was circulated among researchers of the MACSUR network. The questionnaire was completed for 20 regional cases representing NUTS-2/3 levels. The 20 case studies represent 13 European countries and cover 11 of the 13 major environmental zones of Europe (Metzger *et al.*, 2005).

Results and Discussion

The results show that all the case studies considered soil degradation, although they all had other primary research objectives (e.g., yields, profitability, and GHG emissions). This confirms the high awareness of soil degradation issues in agricultural climate change research. In general, the adaptation options under climate change conditions seem to have positive impacts on soils. Five main groups of agricultural adaptation options could be distinguished: introduction of new crop species and crop rotation changes; alteration of the intensity of tillage practices; implementation of irrigation and drainage systems; optimization of fertilization; and conversion of arable land into grassland or vice versa. Results are summarized in a manuscript currently under revision (Hamidov *et al.*, under revision).

Conclusions

Although the results depend on the scenarios and adaptation options considered, the meta-study provides some clear general insights. The results show that adaptation options are expected to reduce the threats of soil erosion and declining soil organic carbon in most cases. Soil compaction remains a major threat. The possible impact of adaption options on soil biodiversity is least explored. Therefore, future research should focus on these shortcomings. Furthermore, the adaptation options reveal generally positive effects on the soil functions of food and biomass production, C sequestration in soil, and improvement in storing, filtering, transforming and recycling capacities. Impacts on soil microorganisms and soil fauna are poorly understood. The results suggest that anticipated climate change adaptation options in agriculture have the potential to offset some of the deteriorating impacts of climate change on soil functions if farmers implement them to the best knowledge available. In addition, the linkage between soil functions and the SDGs indicates a positive contribution to achieving SDG 2 (food security and sustainable agriculture) and 13 (climate action), while a clear signal regarding impacts on SDG 15 (terrestrial ecosystems) could not be identified.

Acknowledgements

The research was done in cooperation with researchers providing evidence from 20 case studies across Europe. Please see the joint authorship publication in the reference list. This research was supported by the Modelling European Agriculture with Climate Change for Food Security (MACSUR).

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Effect of soil and climate data aggregation on regional crop yield simulations in Tuscany (Italy)

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Introduction

When applying field-scale crop models to regional scales, the required input data (such as climate and soil data) is often only available in an aggregated form. The aggregation of data from higher to lower resolution reduces the data variability as well as the extreme values in the input data set (Ewert *et al.*, 2011). The aggregation effects of climate data and of soil data on regional crop yield simulations have been assessed by Hoffmann *et al.*, (2015, 2016) for a humid temperate region in West Germany. In this study, we explored the aggregation effects of soil and climate data on simulated crop yields for a Mediterranean region (Tuscany, central Italy) to quantify the aggregation effects of soil and climate at different aggregation levels from 1 km to 100 km resolutions.

Materials and Methods

Five dynamic crop models (EPIC, STICS, DayCent, Century and LINTUL) were applied to simulate crop yields (above ground biomass for silage maize and grain yield for winter wheat) under water limited condition. The outputs (crop yield) of the different crop models were averaged to represent the model ensemble. The aggregation effects on the crop yield simulation by different crop models depends on the sensitivity of the model to aggregated input data. The aggregation effects in the model ensemble is to represent a mean aggregation effect of all crop models. The following matrices (eq. 1 to 3) were used to quantify the aggregation effects of soil and climate data on simulated crop yields.

$$AbsPD_i = \left(\frac{|Y_{ci}-Y_{fi}|}{Y_{fi}}\right) * 10 \quad (1)\,,\; Avg_{yf} = N^{-1} * \left(\sum_{i=1}^{N} Y_{fi}\right) \quad (2),\; rAAD = \frac{N^{-1} * \left(\sum_{i=1}^{N} |Y_{ci}-Y_{fi}|\right)}{Avg_{yf}} \quad (3)$$

Where, $AbsPD_i$ is the absolute percentage difference, Y_{ci} is the yield simulated at coarser resolution which is disaggregated to finer resolution of ith pixel and Y_{fi} is the yield simulated at finest resolution of ith pixel, Avg_{yf} is the average yield at finest resolution, N is number to pixel at finest resolution (1 km), $rAAD$ is the relative average of absolute yield difference.

Results and Discussion

The aggregation effects of soil and climate input data on crop yield increased with decreasing resolution from 1 km to 100 km (Figure 1A, 1B). The aggregation effects on regional crop yield simulations for winter wheat and silage maize in Tuscany were up to 20% and 30% respectively in absolute yield difference compared to the finest resolution of soil and climate data at 1 km. The majority of aggregation effects as quantified by percentage yield difference for winter wheat is between 0–15% (Figure 1A in winter wheat). The aggregation effects quantified as rAADi are depending on the crop and the model (Figure 1B).

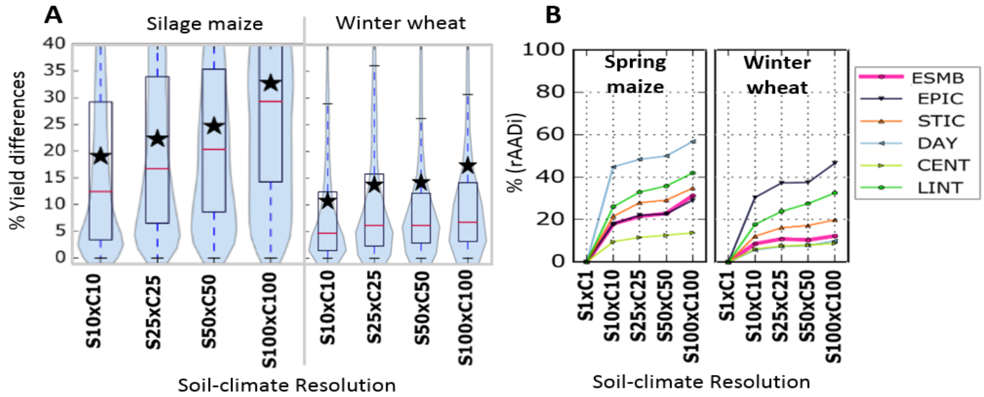

Figure 1. **A) Variability of aggregation effect of input data on crop yield simulation and B) Regional mean of aggreation effects by different crop models and the model ensemble (ESMB) for Tuscany, Italy. S00xC00 represents the combination of soil and climate data from 1 to 100 km resolution.**

Conclusions

In general the aggregation effects of soil and climate on regional crop yield simulation in Tuscany (Italy) were higher for silage maize than for winter wheat. In addition, the aggregation effect differs between crop models. Therefore, regional yield simulations for Tuscany may require the use of input data at high resolution in order to obtain adequate accuracy.

Acknowledgements

This work was financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Office for Agriculture and Food (BLE), (2851ERA01J).

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Tree species composition of a landscape in North-Eastern Germany in 1780, 1890 and 2010

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Introduction

Past land use is a well-known determinant of patterns and processes in current ecosystems (Munteanu *et al.*, 2015) and may have long-lasting effects for decades (Wallin *et al.*, 1994), centuries (Boucher *et al.*, 2013) or even millennia (Berglund, 1991). In particular, the global carbon balance has been linked to worldwide historical land use (Houghton, 2003). Land-use legacies are likely to be revealed in forests, as they are composed of long-lived plant species and thus represent a more-or-less persistent land cover type. For example, studies have shown greater carbon (C) sequestration in ancient vs. recent forest ecosystems (habitat continuity of >200 or <150 years, respectively) (Leuschner *et al.*, 2013, 2014). Here, we demonstrate tree species compositional changes in 1780, 1890 and 2010 at a fine scale (1:50,000) in a north-eastern German landscape. Our aim is to inspire ecologists to reconstruct historical landscapes by focussing on the use of different historical sources, with the valuable outcome of furthering ecological research in landscape ecology.

Materials and Methods

We used old map series from the late 18th and 19th centuries showing the main land-cover types (arable fields, grasslands and forests) in detail. The first series (presenting forest areas of the entire Uckermark in detail) was the hand-drawn Schmettau map (1767–1787; scale 1:50,000), and the second series was the Prussian Land Survey from Brandenburg (undistorted; 1879–1902; scale 1:25,000). Additionally, we checked approximately 200 maps and nearly the same number of archival documents, books, unpublished works and publications in the “grey” literature for getting information on tree species localities.

Results and Discussion

The area of forest with available data on the main tree species covered approximately 80% of the total forest area (111,171 ha) in 1780, approximately 90% of the total forest area (93,999 ha) in 1890, and 100% of the forest area in 2010. Beech (Fagus sylvatica L.) and oak (Quercus robur L. and Q. petraea (Mattuschka) Lieblein) both declined in terms of coverage from 40% to 16%, while the coverage of pine (Pinus sylvestris L.) increased from 36% to more than 70%.

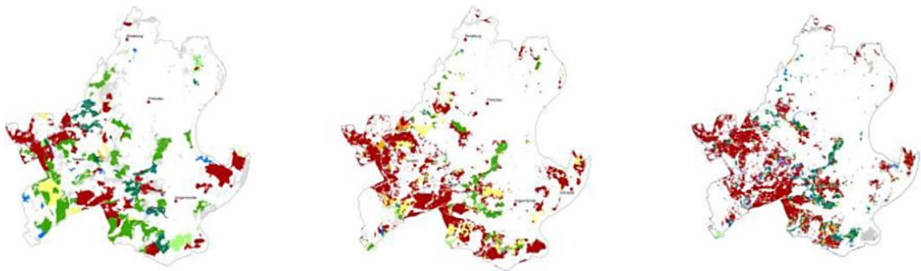

Figure 1. **Map of the tree species composition in 1780, 1890 and 2010 (from left to right).**

Table 1. **Main tree species at time points 1780 – 1890 – 2010**

	1780 [%]	**1890 [%]**	**2010 [%]**
Beech and Oak	40.8	12.9	16.3
Pine	35.9	75.9	53.2
Others	23.3	11.2	30.5

Conclusions

The maps reveal species compositional changes that had been previously generalised as a loss of deciduous cover at the expense of coniferous species. Showing that C sequestration depends on tree species and former land use will give researchers the advice to take these aspects in their research into account.

Acknowledgements

We heartily thank our enthusiastic students for supporting us with their contributions via maps and local reports on tree species composition, and say many thanks to Tobias Naaf and Mike Perring for providing valuable advice for improving the manuscript.

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Statistical methods of Chernozems characteristics and diagnosis in North-Western Circum-Pontic region

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Introduction

Nowadays, it is clearly established, that individual soils, even within low taxon levels, are representing a rather heterogeneous set of variants with certain properties (parameters), which are varying within fairly wide limits. However, in the North-Western Circum-Pontic steppe, the boundaries between the neighboring polypedons are actually often borderlines between the soils, which are different at sufficiently high taxonomic levels – even subtype and type (Moroz, 2011). Therefore, in the North-Western Circum-Pontic region, the spatial layout of separate individual pedons is as interesting as the spatial changes of soil properties both within individual polypedons and between different soil taxonomic units.

Materials and Methods

The parameters of the most diagnostic (in our opinion) soil properties were statistically processed with the definition of the arithmetic mean (M), the standart deviation (m), the mean squared error (δ), and the coefficient of variation (V) (Dmitriev, 2009). The differences in the individual soil properties' degree of variation, in our opinion, may serve as one of their significance criteria for soil classification. The coefficient of variation, as a quantitative indicator of a certain soil property's variability, in this case, serves as a measure for assessing this property's taxonomic significance (the higher is the coefficient of variation, the lower is the taxonomic significance of the property).

Results and Discussion

According to morphological characteristics, as well as indicators of the humus state, we have established a clear difference between the soils of the slopes' upper parts and the soils of the plains as well as the soils of the slopes' lower parts (Table 1). In particular, by statistically processing the indicators of soils' properties, we have established that deflation and xeromorphysm in the upper parts of the slopes have led to a decrease in the organic matter content and thickness of the A and AB horizons, and also led to an increase in the depth of the strong effervescence from 10% HCI. By estimating the taxonomic significance of the individual soil properties (using the coefficient of variation), it was determined that the depth of the strong effervescence from 10% HCI, due to high variability, is a diagnostic feature at a lower taxonomic level than other morphological parameters. It is characteristic that the highest spatial stability among the indicators of the humus state has the humic acid to fulvic acid ratio (5.46–8.57%). A slightly higher variability is observed in the spatial distribution of organic matter content (7.80–15.25%). Therefore, it can be stated that on the research territory, in the first place, the humic acid to fulvic acid ratio should be used for soil type diagnostics.

As we see, erosion and xeromorphysm lead to the leveling of a random variation and increase monotonicity in the slopes upper parts soils' properties (in comparison with the soils of the plains and the lower parts of the slopes).

Therefore, it can be stated that destructive elemental soil processes lead to a decrease of the of the soil cover structure contrast on individual elements of the relief.

Table 1. **Statistical indicators of soils properties**

Soil parameters	*	n	M±m	δ	V,%
Lower limit of A horizon, cm	1	16	34.69±1.21	4.83	13.92
	2	17	30.88±0.70	2.89	9.36
	3	14	34.57±1.54	5.77	16.69
Lower limit of AB horizon, cm	1	16	51.94±1.38	5.53	10.65
	2	17	43.12±1.40	5.78	13.40
	3	14	48.21±1.60	6.00	12.45
Lower limit of BC horizon, cm	1	16	70.88±2.58	10.32	14.56
	2	17	61.12±2.47	10.19	16.67
	3	14	63.93±2.05	7.86	12.29
Depth of the strong effervescence from 10% HCI, cm	1	16	55.69±1.79	7.16	12.85
	2	17	42.29±3.61	14.89	34.71
	3	14	56.50±4.42	16.52	29.23
Organic matter content, %	1	13	2.95±0.06	0.23	7.80
	2	12	2.54±0.08	0.26	10.24
	3	11	2.82±0.13	0.43	15.25
Humic acid/Fulvic acid ratio	1	13	1.75±0.04	0.15	8,57
	2	12	1.83±0.03	0.10	5.46
	3	11	1.70±0.04	0.12	7.06

Notes: * Position on the slope: 1 – plains; 2 – upper parts of the slopes; 3 – lower parts of the slopes. n – the number of soil profiles.

Conclusions

Study of the soils properties' spatial variations by statistical methods allows to distinguish mathematically the objectively existing in the nature groups of soils, and the coefficient of variation can serve as a measure of the classification-taxonomic importance of their properties. The least variable among the parameters of the soils of the North-Western Circum-Pontic steppe are the humus state indicators (organic matter content and humic acid/fulvic acid ratio) and, therefore, they should be used for the purposes of soils diagnostics and classification.

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Integrating the local context into policy adoption and decision making, landscape management and benefit generation: a conceptual development and revisiting of case study examples

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Introduction

Rural development and agri-environmental policies influence the agricultural landscape management, and thus the capacity of landscapes to deliver ecosystem services (ESS) and related socio-economic benefits. Numerous models and frameworks (van Zanten *et al.,* 2014) have been developed to improve the understanding of these interrelationships.

The local context and spatial dimension are particularly relevant for policy adoption and landscape valorization (Piorr and Viaggi, 2015; Lefebvre *et al.,* 2015). Therefore, we are proposing a conceptual model for depicting these mechanisms. It offers a socio-ecological system perspective by integrating the critical role of the local context within the process of policy adoption, landscape management and ESS as well as social benefit provision in a comprehensive way.

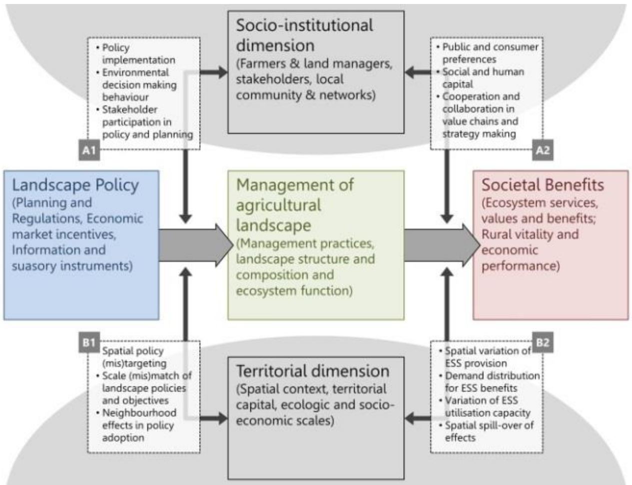

Figure 1. **Conceptual model integrating the socio-institutional and territorial dimension. A1: Influence of the farming community and institutional framework on landscape policy adoption; A2: Role of stakeholders and general public in the creation of benefits from landscapes; B1: Spatial and scale targeting in defining policy effectiveness; B2: Territorial conditions and assets affecting the capacity for benefit generation.**

The conceptual model (Figure 1) considers the socio-institutional and the territorial dimensions of the local context. The former includes the local actors and stakeholders, their preferences, interests and interrelationships and their subsequent decision-making behavior. The latter refers to the territorial socio-economic and environmental conditions, resources and governance systems, which determine underlying ecological functions, demand and supply for these services as well the capacity for their socio-economic valorization.

Materials and Methods

Literature review and regional case study evidence is used to establish a comprehensive understanding and exemplification of the four links: A1: Willingness of farmers to participate in a measure for climate friendly peatland management through water logging (Häfner *et al.*, in prep.); A2: Willingness of farmers to pursue diversification strategies in order to utilize given social and natural capital (Weltin *et al.*, 2017); B1: Spatial distribution of RDP measures at local level in dependency of territorial conditions (Zasada and Piorr, 2015); B2: Local level variations of landscape capacity to provide ecosystem services due to territorial conditions (Ungaro *et al.*, 2014).

Results and Discussion

The conceptual model allows to identifying local and regional scale mechanisms causing policy failure e.g. through mis-targeting and behavioral bias. The individual studies clearly show, that policy adoption, ESS and societal value provision from agricultural landscapes is very case sensitive, depending on the socio-institutional and territorial situation, which manifests at a very local level. These individual and small-scale variations require acknowledgement in research and policy fields. Inter- and transdisciplinary approaches help to include the different dimensions and their complex interlinkages for a comprehensive understanding of landscape development.

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Exploring the factors influencing the polarization of cattle farms in Scotland

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Introduction

Scottish cattle farms produce a premium product with an internationally recognized brand. In spite of this, the number of cattle in Scotland has been in decline since the 1970s (Scottish Government, 2016). Three of the potential explanations for this pertain to profitability, succession, and reliance on income from the farm business in the farming household. Profitability has been in decline because of increasing costs, decreasing soil quality, climate change mitigation, and competition from abroad. As a consequence, Scottish cattle farms are increasingly reliant on subsidy (Barnes *et al.*, 2011), and with the decoupling of subsidies from cattle production in 2005, cattle numbers were in decline. Succession is a significant issue in Scottish farms: children of farmers are more likely to prefer jobs in the city to working on the farm (Burton and Fischer, 2015). Farms without a successor tend to gradually reduce herd size as the farmer approaches retirement, when they then sell the remaining herd. Some farms are bought by 'lifestyle farmers' who are not solely concerned with profit because the household has other sources of income. Others may be bought by industrialized farm enterprises. Medium-sized farms have a greater requirement for the whole household to be involved in farming, with less time available to access alternative sources of income. They also benefit less from economies of scale than larger farms. Analysis of June Agricultural Census (JAC – a compulsory annual survey of Scottish farms) data (Figure 1) shows a decline in medium-sized farms, with increasing small and large farms.

Materials and Methods

We have built an agent-based model to explore the dynamics of farm size polarization in Scotland (Ge and Polhill, 2017). The model integrates various data sources and features the simulation of over 13,000 Scottish cattle farms.

Results and Discussion

The results in Figure 2 show that a qualitative reproduction of the phenomenon observed in Figure 1 is only achieved in the model when options for profitability change, off-farm income and succession are all enabled.

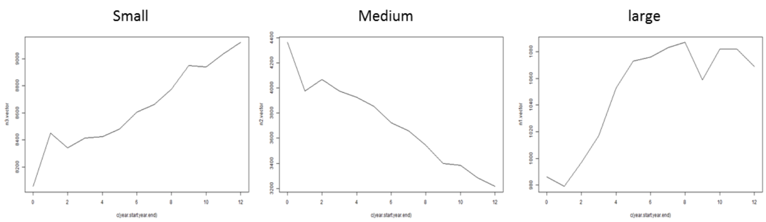

Figure 1. **Trends in small, medium-sized and large cattle farms in Scotland from 2000–2012.**

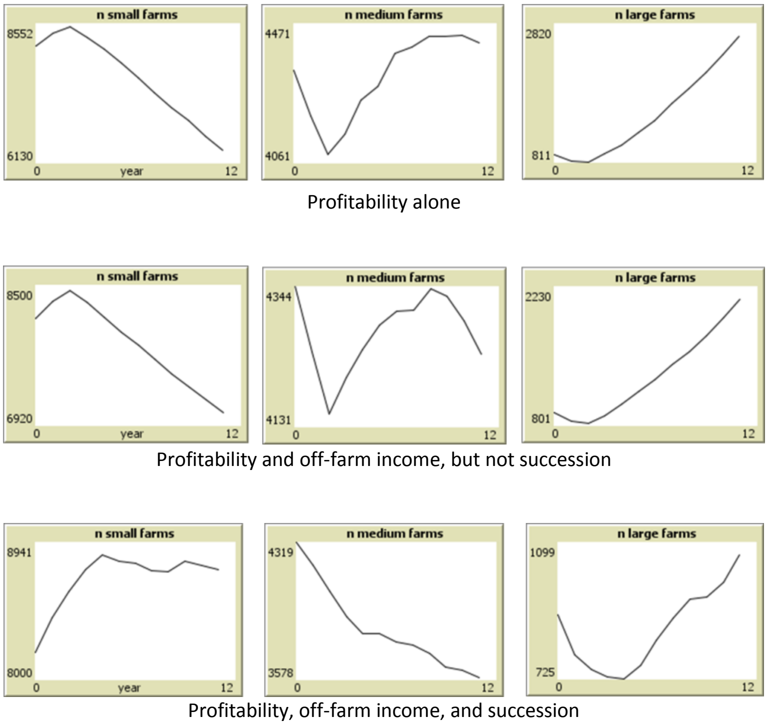

***Figure 2*. Results. From left to right: small, medium-sized and large simulated farms.**

Acknowledgements

This work was funded by the Scottish Government Environment, Agriculture and Food Strategic Research Portfolio, work package 2.4: Rural Industries.

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Functional and structural diversity aspects of a crop sequence typification approach

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Introduction

Crop rotation practice is an essential parameter to assess agricultural management practice and for the typification of land use systems (Leenhardt *et al.*, 2010; Glemnitz *et al.*, 2011; Steinmann and Dobers, 2013). We present a crop sequence typology which combines characteristics of historical approaches (Andreae, 1952; Brinkmann, 1950) with recent solutions (Leteinturier, 2006) including structural as well as functional diversity aspects.

Materials and Methods

The annual crop data of the Land Parcel Information System (LPIS) which are administrated by the European Union member States are a valuable source for crop rotation analysis. For our analysis we used annual crop data of about one quarter of all arable parcels in Lower Saxony for the year 2005–2011. The 7-year sequences were assorted to groups in two processing steps according to their structural and functional diversity. The first step assigns the sequences' main type according to its sum of transitions and its sum of crops while these main type groups were sub-divided in a second step according to the proportion of leaf crops and the proportion of spring crops.

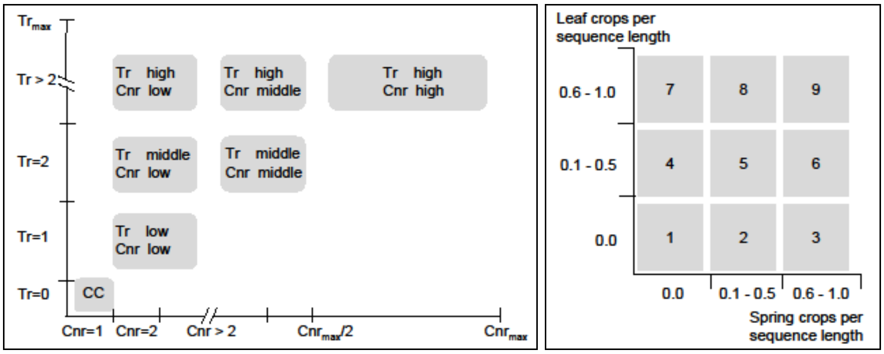

Figure 1. **Schema of the main typification step (left figure) concerning concerns the sum of transitions [Tr] and the sum of different crops [Cnr] (continuous cropping [CC] is the lowest possible range) and the sub-typification step (right figure).**

Results and Discussion

Nearly all forms of structural diversity, represented by the main types of the typification, where cropped in significant extent. At 60% of the arable area of Lower Saxony was cropped by ten different crop sequence types with a high proportion of simplified crop sequence but also a significant amount of diverse crop sequences.

Alarming is the fact that about one third of the arable area was cropped with only one or two crops in seven years with locally higher values in regions with life stock farming.

For some of the sequence types their high structural diversity is put into perspective when the functional diversity is considered. About 20% of the arable area were cropped without any spring crop and 41% without any leaf crop.

Maize is a characteristic crop of the least diverse sequences but plays an important role in the most diverse sequences as well.

Conclusions

The combination of structural and the functional diversity aspects are indispensable for a crop sequence typification. The presented approach provides a detailed picture of the crop rotation practice in a region.

Acknowledgements

We are grateful to the Ministry for Human Nutrition, Agriculture, Consumer Protection and Rural Development of Niedersachsen (Lower Saxony), which provided administrative data. Data analysis was supported by the Federal Ministry of Food and Agriculture (grant number FKZ 12NR109 FNR).

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Foresight for Agricultural Soil Management

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Introduction

Soils play a vital role for landscape functions and services. But agricultural soils are suffering from degradation processes. Agricultural soil management is the key pressure that shapes soil processes, soil functions and soil services. Taking appropriate actions to foster sustainable soil management requires the identification of drivers and trends of future soil management and the challenges and opportunities these offer for shaping a sustainable future. For this reason we conducted a foresight study for agricultural soil management in Germany, as an example for industrialized agricultural systems with low yield gaps.

Materials and Methods

The conceptual starting point of the analysis was the DPSIR (Driver-Pressure-State-Impact-Response) framework. We analyzed which factors drive soil management and how these drivers are coined in Germany. From this we derived assumptions for potential developments of soil management in Germany.

In 2016 we reviewed a total of 267 sources (Techen and Helming, in review). The priority was given to peer-reviewed publications.

In spring of 2017 we conducted 19 semi-structured interviews with experts from soil and agricultural sciences, agriculture and authorities (see acknowledgements) to validate and complement our review results. The structured questions are evaluated quantitatively and the open questions are evaluated with qualitative content analysis. Questions included the likelihood and possible timeline of the emergence of new management practices as identified in the literature review.

Results and Discussion

We identified two modes of future soil management changes: (1) Quantitative changes concerning only changes of the applied quantities of given input factors. (2) Qualitative changes that refer to five categories: spatial patterns, crops and rotations, mechanical pressures, inputs into the soil and general soil conservation behavior.

We found that strong signals for emerging management practices are tied to the development of information and communication technology with more precision, e.g. of fertilizer and pesticide application, optimized routes and automatic tire pressure adjustment expected in the near future (Figure 1). Significantly more irrigation is expected in the context of climate change on average within 10–15 years. Two areas of change that have disruptive potential and that are expected to occur significantly with a medium probability on average are small autonomous machines, and biotic inoculation of soils and seeds with plant mutualists and pest antagonists.

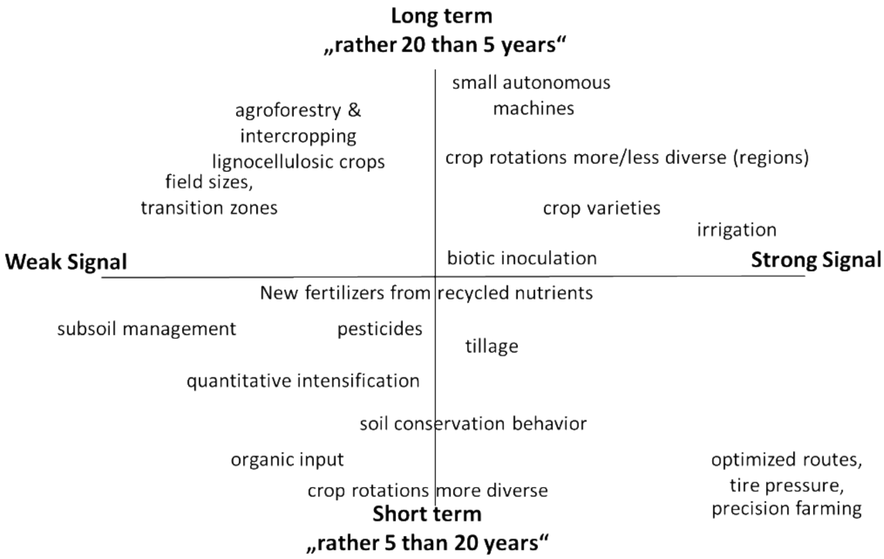

Figure 1. **Likelihood and time frames of change in agricultural soil management in Germany.**

Conclusions

While the specific impacts of such emerging practices on soil functions and landscape services are subject of research, initial studies suggest that some of the new technologies have the potential to improve the integration of agricultural production with environmental performance. In the landscape context, the development of new, partly autonomous machinery is particularly interesting, since it may allow field sizes to become smaller and cropping systems to become spatially more heterogeneous while at the same time being cost-efficient. Stakeholders, such as researchers, politicians and farmers have to become active to seize opportunities and avoid threats of the potential future developments.

Acknowledgements

This research has been funded by the German Federal Ministry of Education and Research (BMBF) through the program BonaRes – soil as a sustainable resource for the bioeconomy (Forderkennzeichen 031A608B). We thank the experts who participated in the interviews: Thomas Assheuer, Keith Bristow, Lijbert Brussaard, Frank Ewert, Juliane Filser, Udo Folgart, Jörn Fröhlich, André Grosa, Frank Glante, Oliver Hakemann, Katarina Hedlund, Thomas Herlitzius, Lothar Hövelmann, Dorit Kuhnt, Martin Kunisch, Luca Montanarella, Reimund Rötter, Thomas Scholten, Ulrich Schurr, Kate Scow, Hartmut Stalb and Thilo Streck.

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Linking processes in the soil-plant-atmosphere continuum to the water cycle at landscape scale in a stochastic modeling framework

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Introduction

One of the enigmas of environmental sciences is the fate and behavior of agrochemicals (nitrogen, pesticides) on landscape scale. Experimental results obtained in the lab or on the column or plot scale, e.g., transformation rates, are often in stark contrast to rates documented in natural systems, the heterogeneity of which is typically only vaguely known. Against this background, a new stochastic modelling framework will be developed to synthesize *in situ* results from different compartments of the water cycle on the landscape scale. The backbone is a 3D model for water flow, which enables process-based reactive-transport modeling using an efficient scheme of solving non-linear reactive transport along pathlines. Ensemble techniques will be used to quantify associated epistemic and aleatory model uncertainties and rigorous approaches will be applied to assess model legitimacy and optimized data acquisition.

Materials and Methods

One-dimensional soil-crop model ensembles will be weakly coupled to a stochastic model of the subsurface. With this the effects of uncertainty and spatial variability of land-surface units on coupled water and nutrient fluxes and vegetation dynamics in the soil-plant system is addressed by providing statistical distributions of water and solute fluxes at rooting depth. Flow in the deeper vadose zone, in groundwater, and in streams is solved by a spatially explicit partial differential equation-based model, whereas reactive transport is based on travel times, exposure times, and the new concept of “cumulative relative reactivities” along particle trajectories (Cirpka *et al.*, 2011).

Since soil-plant-atmosphere processes are a key control for element cycles and forcings in the water cycle beyond the rooting zone where feedbacks are known to be strong, spatially and temporally explicit process model representation is adopted. As model domain setup is inherently uncertain, 2D Monte Carlo double looping approach integrates (Beyer *et al.*, 2009) i) spatially variable but explicit soil columns in which information on soil type and agricultural management at the landscape scale is contained (Figure 1, left), and b) stochastic soil-plant model parameters and input variables (Figure 1, right)

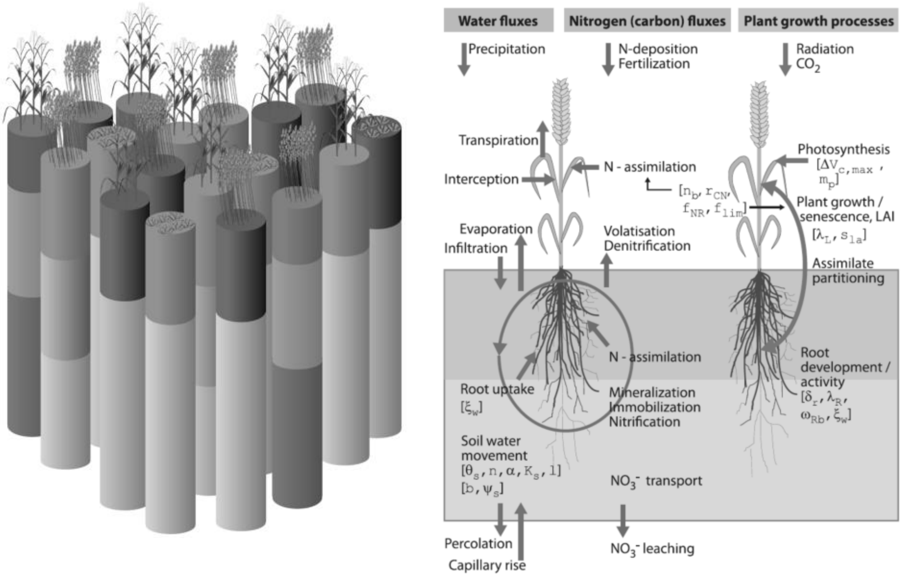

Figure 1. **(left) Ensemble of cropped soil columns (right) schematic representation of the main processes of the water cycle, the nitrogen and carbon cycle, and plant growth processes in the coupled soil-plant system (Wöhling *et al.*, 2013) in the modular model library Expert-N (Priesack, 2006).**

Expected Results

The outcome of the stochastification of near surface processes and input variables are transient spatially explicit soil column wise pollutant concentrations with information on a) median residence times of pollutants in the soil profile, b) breakthrough curves, and b) quantified uncertainties. They can be compared to measured chemical concentrations throughout the landscape's water cycle compartments, such sub-catchments, rivers, groundwater bodies, floodplains, as groundwater monitoring wells.

Acknowledgements

The authors greatly thank the German Research Foundation (DFG) for funding the Collaborative Research Center 1253 CAMPOS Catchments as Reactors: Metabolism of Pollutants on the Landscape Scale.

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Acknowledgments

Many thanks to all the ZALF people who were involved in the preparation and making of this Book of Abstracts:

Viola Kranich

Heike Schobert

Julia Lidauer

Anke Hollburg

Tom Baumeister

Hendrik Schneider