Integrated impact analysis of agricultural adaptation and mitigation measures on landscape appearance and biodiversity

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***Abstract* - Climate change is expected to be among the major drivers of future agricultural land use change. We analyse landscape and biodiversity impacts from mitigation and adaptation measures for two Austrian case study landscapes. An integrated modelling framework is applied in context of policy, market, and climate change scenarios. The spatially explicit results are input to field and landscape level indicators based on empirical observations and visualization techniques. Results include the landscape level assessment of status-quo landscape appearance and biodiversity, which both serve as reference values for the scenario analysis. For example, we observe a clear dependency of species richness on land use intensity and land cover, which likely are driven by land use changes from mitigation and adaptation. Previous experiences and results from this project already reveal the value of landscape level case studies to supplement large scale climate change land use studies.**

INTRODUCTION

Climate change is expected to be among the major drivers of agricultural land use change in the future. Farmers usually adapt their management to mitigate losses or exploit gains. Furthermore, they react on climate change mitigation policies such as subsidies on renewable energy production or carbon sequestration. Results of climate change impact analysis show moderate increases of average producer rents up to 2040 due to more favorable production conditions and autonomous adaptation in Austrian agriculture (Schönhart et al., 2013). However, the impacts are expected to be i) heterogeneous with winners and losers among regions and farm types, ii) uncertain due to unpredictable changes in precipitation patterns and extreme events, and iii) unclear with respect to the consequences for environment, biodiversity and landscape appearance. Land use change is among the main drivers for visual landscape appearance, environmental quality, and biodiversity, which are affected, experienced, and measured mainly at field to landscape levels.

Several scientists reveal landscape and biodiversity to be poorly represented in current land use and farm models despite the necessity to analyse agricultural functions such as cultural landscape protection and biodiversity provision (e.g. Janssen and van Ittersum 2007). This is even truer for the specific case of climate change impact analyses at the landscape level. For example, Schönhart et al. (2011) analysed landscape and biodiversity impacts of agri-environmental payments in the Austrian "Mostviertel" region at high spatial resolution. However, they neither took climate change impacts nor farm adaptation and mitigation measures into account. Briner et al. (2012) analysed climate change impacts on provisioning of ecosystem services in the Swiss "Visp" region, but did not account for biodiversity effects from land use change.

We address issues i-iii as well as the revealed methodological gaps by developing an integrated modelling framework (IMF). It allows analysing landscape, biodiversity, and abiotic environmental impacts from agricultural mitigation and adaptation measures at field, farm and landscape level. The IMF is applied to two contrasting grassland and cropland dominated landscapes in Austria.

METHODS AND DATA

The IMF combines the crop rotation model CropRota, the bio-physical process model EPIC and the economic farm model FAMOS[space] (Fig. 1).

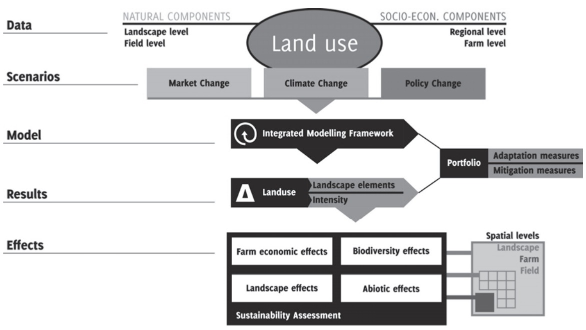

Figure 1. The integrated modelling framework (IMF).

EPIC is applied to a portfolio of crop management options and climate change scenarios. Simulated crop yields and environmental effects are input to FAMOS[space], which maximizes total farm gross margin subject to resource endowments and several balance equations. FAMOS[space] utilizes field-

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specific management data from the IACS-database and landscape element data from orthophoto analysis. Adaptation and mitigation policy scenarios are analysed and spatially explicit model results are linked to a landscape metrics and visualization approach as well as to biodiversity indicators based on ecological field observations. For measuring landscape appearance a new indicator was developed. It analyses the backdrop of a landscape from a specific point (Schauppenlehner and Amon 2012).

Results

The results present the landscape level assessment of status-quo concerning landscape appearance and ecology, which both serve as reference values for the scenario analysis. Apart from common landscape metrics we evaluate landscape structures with vertical extent like forests, field and orchard trees based on spatially explicit economic model output. Figure 2 gives an impression on the high resolution land use data base. Furthermore it presents landscape metrics results of three exemplary landscape sample viewpoints.

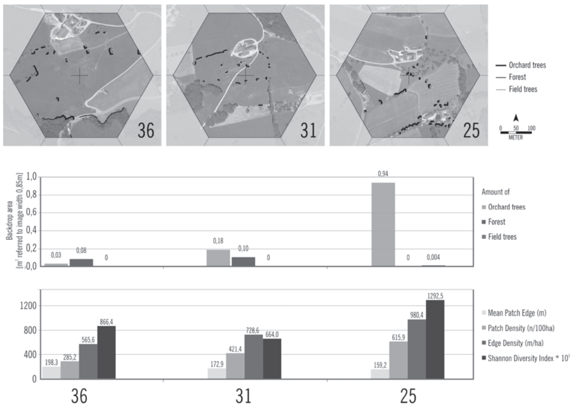

Figure 2. Sample viewpoints and landscape metrics.

The evaluation of ecological quality comprised a series of pre-stratified vegetation surveys along with an indicator driven assessment of the hemerobiotic state of the target sites (n=120). Altogether more than 250 vascular plant species could be identified. Local hotspots of plant biodiversity appeared in extensively used land use classes of hedgerows, fruit tree meadows and pastures, mainly located in the grassland dominated landscape. Linear regression analysis revealed a clear dependency of in situ species richness from land use intensity (corr $r^2 = 0.63$). Additional comparison of various functional land use groups such as *corridors*, *stepping stones* and *matrix classes*, showed significant differences between the case study landscapes. In a next step scenario-based model output will be evaluated to reveal impacts from adaptation and mitigation processes on these indicators of environmental quality.

Discussion

Quantitative analyses of complex systems like the "climate change – landscape change – environmental change" nexus require integrated modelling tools. They should be spatially explicit and location specific with respect to farm and land use structures. Biodiversity indicators such as species-area relationships ideally rely on regional observations.

Previous research experiences and results of this study confirm the importance of high resolution landscape assessments to supplement large scale land use studies on climate change. Spatial relationships among fields determine landscape functions and environmental outcomes, which can be hardly accounted for in studies that frequently build on raster-based data. The vector-based landscape data in the IMF enables analysis of changes in landscape structure and field scale intensity that are major determents of landscape appearance and biodiversity and may likely be impacted by climate change. However, there emerge considerable challenges such as the implementation of common land use activities across all model components. Furthermore, the IMF must include realistic alternative land use activities for farm level adaptation. Challenging are alternatives, which have not been observed in the region so far, such as new species or technologies (e.g. irrigation). Their adoption is uncertain and not represented by species-area relationships. A stakeholder approach is planned and may help to overcome some these remaining challenges.

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References

Briner, S., Elkin, C., Huber, R. and Grêt-Regamey, A. (2012). Assessing the impacts of economic and climate changes on land-use in mountain regions: A spatial dynamic modeling approach. *Agriculture, Ecosystems & Environment* 149, 50–63.

Janssen, S. and van Ittersum, M.K. (2007). Assessing farm innovations and responses to policies: A review of bio-economic farm models. *Agricultural Systems* 94, 622-636.

Schauppenlehner, T. und Amon, H. (2012). Landschaftskulissen – ein GIS-basierter Ansatz zur Analyse der räumlichen Landschaftsstruktur und Bewertung landschaftsästhetischer Aspekte. In: Strobl, J., Blaschke, T., Griesebner, G. (Hrsg.). *Angewandte Geoinformatik 2012*, pp. 652-661. Heidelberg: Wichmann.

Schönhart, M., Koland, O., Schmid, E., Bednar-Friedl, B. and Mitter, H. (2013). Bottom-up and top-down modelling of climate change impacts on Austrian agriculture. *Jahrbuch der ÖGA (under review)*.

Schönhart, M., Schauppenlehner, T. and Schmid, E. (2011). Integrated bio-economic farm modeling for biodiversity assessment at landscape level. In: Flichman, G. (ed.). *Bio-Economic Models applied to Agricultural Systems*, pp. 185–213. Dordrecht et al.: Springer.