Sustainable agricultural land use in mountain regions under climate change: Insights from modelling studies in the ‹Mountland› project

Huber Robert[1]

[1]Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürcherstrasse 111, 8903 Birmensdorf, Switzerland

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Abstract

Mountain regions provide essential ecosystem goods and services (EGS). Global change however endangers the capacity of mountain ecosystems to provide key services. The ‹Mountland› project is focusing on three case study regions in the Swiss Alps and aims at proposing land-use practices and alternative policy solutions to ensure the provision of EGS under climate and land-use changes. In ‹Mountland› an integrative approach is applied, combining methods from agricultural economics and the political and natural sciences to analyse ecosystem functioning from a holistic human-environment system perspective. In this poster paper, I give a short introduction to the project and summarize those results which are based on the socio-economic land-use model ALUAM which provided a platform for the integration of different inter- and transdisciplinary data and knowledge on a common scale.

Keywords

Climate change, land-use change, landscape models, economic modelling, policy analysis, social-ecological systems, interdisciplinary, transdisciplinary

1. Introduction

The ‹Mountland› project started in 2008 with the goal to establish a research network analysing the provision of mountain ecosystem goods and services (EGS) under global change in an integrative framework. The project investigates the sensitivity of EGS to both climatic and land-use changes and studies alternative policies and governance structures for mitigating the impact of such changes and enhancing sustainable management practices in mountain regions. Between 2008 and 2013, the project published more than 70 ISI journal publications (http://www.cces.ethz.ch). Thereby, the socio-economic land-use model ALUAM (Alpine Land Use Allocation Model) emerged as a focal point in the overall assessment of global change impacts in our case study regions. In this poster paper, I introduce the project and summarize the findings from six articles that included simulation results from ALUAM.

2. The ‹Mountland› project

The project applied an integrative approach combining methods from (agricultural) economics and the political and natural sciences to analyse ecosystem functioning and management in mountain regions (Huber, et al., 2013b). The various, widely different disciplines collaborated from the very outset in order to achieve a holistic human-environmental perspective. Our research explicitly considered feedback effects from changing socio-economic and political conditions on land-use and adaptation to climate. The collaboration between the different research disciplines was based on four pillars:

1) A common set of research questions guaranteed a consistent focus in the three different case study regions (a pasture-woodland ecosystem in the Swiss Jura, a drought-sensitive inner Alpine ecosystem in the Valais and a temperature-sensitive high Alpine ecosystem in Davos). The guiding research questions were:

a) What is the effect of a changing climate on sensitive ecosystem processes and their spatial interactions, which in turn affect the ability of mountain ecosystems to provide crucial EGS such as protection against natural hazards, food and fiber production and biodiversity?

b) What are the effects of climate, socio-economic and policy-driven changes in land-use on EGS provided by mountain landscapes?

c) Which existing sectoral and cross-sectoral policies and policy instruments have what effect on the provision of EGS in mountain regions? Which policy solutions could best mitigate negative climate effects and major socio-economic changes in mountain regions and enhance sustainable land-use?

2) Throughout ‹Mountland›, all analyses were based on a common set of scenarios (Walz, et al., 2013). In these scenarios, the consequences of global change at climatic, market and policy levels were downscaled consistently with the global IPCC SRES scenarios to tally with our case study regions and then summarized in storylines. This strongly improved the feasibility of a synthesis of the different research findings across regions.

3) The explicit coupling of ecological and socio-economic models in the case study regions allowed for the quantification of feedback effects. These feedback effects were analysed using plot-based observational and experimental evidence explored in a modelling framework and upscaled to the landscape level. They also allowed for an integration of alternative policy solutions and institutional reforms to mitigate the negative impacts of climate change and thus the feedback between ecological impacts of climate change, land-use changes and policy could be closed.

4) The methods chosen – i.e. formative scenario analysis (Brand, et al., 2013) to downscale scenarios, or network analysis to describe the existing policy network (Ingold and Balsiger, 2013) – made a good and intensive collaboration with residents and local decision-makers essential. An institutionalized dialogue with the stakeholders allowed our research to be anchored in the ‘real’ world.

This approach resulted in truly inter- and transdisciplinary work. The added value of this approach was that (i) data and models were based on biophysical realism; (ii) local trade-offs could be considered; and iii) a comprehensive but critical involvement of stakeholders within the studies was achieved (Huber, et al., 2014). In general, the project provides: (i) new basic scientific findings regarding the impacts of climate and land-use changes on ecosystem processes in three sensitive mountain regions of Switzerland, (ii) an assessment of the feedback effects arising from changing socio-economic and political conditions, land-use and adaptation to climate change, using modelling techniques and transdisciplinary stakeholder interactions, and (iii) suggestions for alternative policy solutions to ensure sustainable land-use in mountain regions. Linking to our coupled human and natural systems approach, we found the following key characteristics of such systems to be central to our case study areas in mountain regions: non-linarites and thresholds; heterogeneity; trade-offs, as well as feedbacks (Huber, et al., 2013c). These characteristics were also important in the context of our simulation studies briefly summarized in the next chapter.

3. Modelling results from ALUAM

Table 1 gives an overview to six articles using ALUAM simulation results. The underlying mechanism of the model was described in Briner et al. (2012). ALUAM simulates the competition between forest and a range of agricultural land-uses to estimate land-use conversions in a spatially explicit manner at high resolution. Using a modular framework, ALUAM was linked with forest-landscape models (LandClim and WoodPaM), and a crop yield model,

that simulate the response of forests and crops to changes in climate. An iterative data exchange between the models allows a detailed assessment of the dynamic changes in the provision of agricultural and forest based services. ALUAM exists in two versions for simulating different time horizons. For medium term simulations (e.g. 2035), a dynamic agent-based farm approach is applied (ALUAM-AB). For long-term simulations (e.g. 2080) a comparative static approach maximising the sectoral income is applied.

Table 1: Overview ALUAM publications

Title of publication	Mountain case study region	Global change scenarios	Applied models
Assessing the impacts of economic and climate changes on land-use in mountain regions: A spatial dynamic modeling approach	Visp (Drought-sensitive inner Alpine ecosystem in the Valais)	A1, B1	ALUAM, LandClim
Evaluating the relative impact of climate and economic changes on forest and agricultural ecosystem services in mountain regions	Visp	A1, B1	ALUAM, LandClim
Trade-Offs between Ecosystem Services in a Mountain Region	Visp	A1	ALUAM, LandClim
Modeling Social-Ecological Feedback Effects in the Implementation of Payments for Environmental Services in Pasture-Woodlands	Jura (Pasture-woodland ecosystem in the Canton of Vaud)	B2	ALUAM-AB, WoodPaM
Combining Policy Network and Model-Based Scenario Analyses: An Assessment of Future Ecosystem Goods and Services in Swiss Mountain Regions	Jura and Visp	A1, A2, B1	ALUAM-AB, LandClim, WoodPaM
Inter- and transdisciplinary perspective on the integration of ecological processes into ecosystem services analysis in a mountain region	Visp	A1, A2, B1, B2	ALUAM, LandClim

3.1. Assessing the impacts of economic and climate changes on land-use in mountain regions: A spatial dynamic modeling approach

This first publication in 2012 provides a detailed description of the model framework and applies the model to the case study region Visp (Valais) using two different climate change scenarios (A1FI and B1). The combined impact of climate as well as economic changes result in significant land-use changes and land-cover shifts in our case study region. The two main effects are (a) a reduction of cropland and (b) less intensive grassland production. Our results imply that yields on alpine pastures are increasing but the additional biomass will not be consumed without a corresponding increase in the number of animals. Such an expansion of animal production, however, is not profitable even under current economic conditions. As a consequence, least profitable parcels will be abandoned and converted in managed or unmanaged forests. In the assessed region, however, this process is only triggered if climate change exceeds a certain level, i.e. changes as assumed for the B1 scenarios are not strong enough to induce these changes. This result illustrates one example of a possible threshold effect in climate change impacts in mountain regions.

3.2. Evaluating the relative impact of climate and economic changes on forest and agricultural ecosystem services in mountain regions

In this study, the same climate and land-use change scenarios as in Briner et al. (2012) were divided in i) the direct biophysical impacts of climate change, ii) climate mediated land use change, and iii) socioeconomic driven changes in land use (Briner, et al., 2013a). We evaluated the impact of these driving forces on the provision of forest and agricultural EGS. Results imply that forest EGS will be strongly influenced by the direct impact of climate change, but that changes in land use will have a comparatively small impact. The simulation of direct impacts of climate change affects forest ES at all elevations, while land use changes can only be found at high elevations. In contrast, changes to agricultural ES were found to be primarily due to shifts in economic conditions that alter land use and land management. The direct influence of climate change on agriculture is only predicted to be substantial at high elevations, while socioeconomic driven shifts in land use are projected to affect agricultural ES at all elevations. This study exemplifies the large heterogeneity of climate and land-use change impacts in mountain regions, even in a small case study area.

3.3. Trade-Offs between Ecosystem Services in a Mountain Region

In this contribution, we assessed the relationships between forest and agricultural EGS in the case study region Visp (Briner, et al., 2013b). Based on the concept of jointness in production, we evaluated trade-offs and synergies among food provision, biodiversity conservation, carbon sequestration, and protection against natural hazards. Results show that increasing the provision of a focal ecosystem good or service in a mountain region may result in alternating trade-offs and synergies, depending on the interaction of economic and technological interdependencies. Thus, management schemes aiming to increase the provision of one focal service have to consider not only the technological or biological nature of interrelationships, but also the economic interdependencies among different EGS. Trade-offs and synergies from these interactions strongly depend on the underlying structural and environmental conditions driven by socioeconomic and climatic developments. These simulations emphasize the importance of trade-offs between different ES in the assessment of future sustainable land-use.

3.4. Modeling Social-Ecological Feedback Effects in the Implementation of Payments for Environmental Services in Pasture-Woodlands

For the case study region in the Jura, the ALUAM framework was expanded with agents that represent individual farmers and their decision making (Huber, et al., 2013a). In addition, the model was coupled to WoodPaM (Peringer, et al., 2013). We used this extended ALUAM model to simulate the effect of different payments for environmental services (PES) on typical silvopastoral landscapes. The probability of a successful implementation of these PES schemes were assessed using a policy network approach (Hirschi, et al., 2013). Modelling results show that concomitant climatic and socioeconomic changes advance the loss of open grassland. This would, in the longer term, deteriorate the historical wooded pastures in the region, which fulfil important functions for biodiversity and are widely considered as landscapes that deserve protection. Payment for environmental services could counteract this development while respecting historical land-use and ecological boundary conditions. The assessed policy feedback process reveals that current policy processes may hinder the implementation of PES, even though a payment for the upkeep of wooded pasture would generally enjoy the backing of the relevant policy network. To effectively support the upkeep of the wooded pastures in the Jura, concomitant policy changes, such as market deregulation, must

also be taken into account. This publication highlights the importance of feedback effects in the assessment of mountain EGS.

3.5. Combining Policy Network and Model-Based Scenario Analyses: An Assessment of Future Ecosystem Goods and Services in Swiss Mountain Regions

In this contribution, we combine a model-based scenario analysis with a policy network analysis in the case study regions Jura and Valais (Hirschi, et al., 2013). Analysing the structure of the policy network and taking into account the policy preferences of the individual network actors allows us to assess the feasibility and likelihood of policy developments as derived from scenario-based modelling assessments. Our results show that a production-oriented agricultural policy still has strong political support and, consequently, a status-quo protection scenario is very likely. In contrast, a more environmentally friendly agricultural policy is unlikely if it leads to extensive new regulations for agricultural production. Even with a greening scenario performing best within a set of ex-ante model-based assessments of future policy options, our policy network analysis suggests that changes in agricultural policy would have to reconcile the support of the provision of nonmarketable ecosystem goods and services with market deregulation policies in order to become politically feasible. This article emphasises the importance of interdisciplinary approaches in studying EGS.

3.6. Inter- and transdisciplinary perspective on the integration of ecological processes into ecosystem services analysis in a mountain region

In this article, all four scenario storylines were used for the assessment of climate and land-use change impacts in the case study region Valais (Huber, et al., 2014). The simulation results summarize four key aspects which had been elaborated on in the other publications. First, we show the high spatial and temporal heterogeneity of EGS provision even in a small case study region. Second, we find that climate change impacts are much more pronounced for forest EGS, while changes to agricultural EGS result primarily from shifts in economic conditions. Third, our modeling results reveal the complex trade-offs associated with the different scenarios. Fourth, simulations illustrate the importance of interactions between environmental shifts and economic decisions.

4. Conclusion and policy implications

Our simulation studies imply that thresholds; heterogeneity; trade-offs, as well as feedbacks are key characteristics of our mountain case study areas. These results suggest that an institutional framework focusing on three aspects is essential for maintaining and strengthening important EGS in mountain regions. Firstly, integrative approaches (‘policy integration’) to strengthen cross-sectoral coordination should be supported. These approaches would allow for a more effective provision of mountain EGS in the presence of heterogeneity and thresholds. Secondly, network management and steering (‘network governance’) to strengthen multi-level governance would permit an adequate integration of (local) stakeholders in policy formulation and implementation processes. Spatial planning instruments and methods addressing heterogeneity, trade-offs and feedbacks provide important policy alternatives in this context. Thirdly, the integration of stakeholders would permit a focus on capacity building. This is important to reduce vulnerability to changing climate conditions, socio-economic developments and related risks that we identified in ‹Mountland›. With respect to the model development, the project aspires for a better integration of grassland and forest development in ALUAM and a spatial explicit validation of land-use intensities in the case study regions. This would further improve the robustness of results in our simulations.

5. Reference Section

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