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Modelling and valuing ecosystem goods and services of multifunctional landscapes using GIS and remote sensing

Abstract: *Landscape change today is occurring more rapidly than in any other time in history. Among other influences such as global warming these changes are also driven by political decisions affecting ecosystem services. The overall research objective is to define how the European Union's political strategies implemented through rural development programmes and the Common Agricultural Policy (CAP) are influencing or changing ecosystem goods and services in the future. This contribution aims at outlining the research framework and especially focuses on a ground rent approach to model the spatially explicit distribution of subsidy cash flows on farm and parcel level. Experiments with changing political strategies and incentive payments were carried out in the Mondsee catchment (Austria) using GIS and remote sensing for facilitation. The results were visualised and show the dominant (inter-)national and regional funding programmes of this area. They further display the likely effects of changing political strategies on the monetary value of certain parcels and the overall farm-parcel balance. The validation of an aggregated set of funding measures reveals 15% deviation between the model framework and real subsidy payments. Thus, this model is suitable for estimating the impact of changed funding strategies at EU level and also supports farmers in indentifying the best economic income sources on parcel and farm level. Embedded in the overall research objective, the results constitute the basis for opening a discussion on how ecosystem services might change with political intervention strategies in rural areas and resulting landscape changes in the future.*

Keywords: *ecosystem goods and services, environmental eccounting, environmental economics, GIS, remote sensing, spatial planning, rural development*

Introduction

In the early period of the European Union, 80% of the EU's budget was used to finance the agricultural sector. Since then, European and national funding for sustainable land management is subject to a decline from 47% in the year 2001 (43.3 billion EUR total budget) to presently 38%. Due to the agricultural policy compromise adopted in October 2002 in Brussels, this trend is predicted to continue down to 32% in the year 2013 (Auswärtiges Amt 2006).

We argue that this forecasted decline of funding resources puts substantial pressure on landscapes. This pressure is, among other factors, caused by land abandonment, bush encroachment and afforestation which are the direct results of reduced labour effort spent on farming practices. These changes have also consequences for ecosystem goods and services associated with landscape scenery (i.e. recreation activities).

To maintain relevant services and to develop a landscape of tomorrow, it is necessary to create and establish an inventory of spatially explicit environmental goods and services (yellow, green and blue services) present in a landscape. This inventory postulates a comprehensive understanding of landscape complexity and should define which products are intangible and important for the prosperity and wellbeing of the local population. It should also identify which ecosystem processes and functions are necessary in order to provide specific ecosystem service products.

Further development of natural resources mandates the support of agricultural businesses by adequate payments in order to manage and maintain those ecosystem services demanded by society in the future. After all, landscapes comprise an economic value which needs to be captured besides food production. We frame the hypothesis that the value of ecosystem services we use is much higher than the subsidy payments disbursed for their maintenance. Unfortunately we cannot answer this question here but instead establish a framework within which it is possible to analyse and model past and present subsidy cash flows and forecast future developments based on specific assumptions for scenario building.

In response to this complex challenge, the overall research objective is to present a methodology developed for spatially explicit describing, modelling and classifying the impact of political decisions on ecosystem goods and services in the future using scenario techniques for visualisation. The authors propose a methodology combining Ernst Neef's School of Landscape ecological theory and land surveying techniques to capture the natural states, conditions and potentials of landscapes. Process-oriented classification methodologies and concepts for ecosystem analysis and assessment provide information on distinguishable functions working in landscapes (Bastian and Steinhardt 2002). The units derived from landscape analysis capture the multifunctional and multidimensional space of ecosystem services. Combined with theories and concepts from Economy and Social Science the value of functions for society can be determined and clustered at parcel level for the purpose of regional planning, landscape planning, nature conservation and environmental protection. These land use / land cover units are acquired from satellite imageries or aerial photographs using remote sensing techniques and change detection methods (Klug et al. 2007).

Economic-political guidance and control of financial resources is strongly recommended if we want to handle the limited resources that are available for society and environment to our best knowledge. This requires spatial explicit modelling of subsidies based on farm and parcel level. The results should reveal spatially explicit regional disparities based on changed funding structures. Based on new concepts and methodologies, this decision support tool predicts the likely consequences of future regulation and political decisions on the landscape of the Mondsee catchment study area. The two main objectives of this contribution are: 1) conceptualising a methodology that is able to capture scenarios of likely consequences of political interventions in regard to the agrarian funding system and 2) investigating the amount of subsidies employed by farmers and its share in the farmers' annual balance sheet.

Methods

This chapter outlines the overall concept and the materials used to facilitate the ground rent approach. The first section introduces a) a general approach of ecosystem goods and services (section 2.1) which b) results in an inventory of spatially explicit ecosystem services (section 2.2). The inventory aims at understanding the claimed natural resources and functions as a basis for a general discussion of the benefit of such a tool for society. With the inventory at hand we face the problem of environmental accounting in terms of money (section 2.3). This problem will only be discussed briefly, because it is not the focal point of the paper. However, the spatial units taken for service evaluation are necessary elements for the approach submitted here (section 2.4). Farmers receive subsidies from (inter-)national and regional funding bodies based on parcel level if they comply with the framework of cross compliance (VO [EG] Nr. 1782/2003 and VO [EG] Nr. 796/2004). Thus, the knowledge of available funding programmes triggers the cash flow of subsidies. The Mondsee catchment served as a case study area to model this proposed approach (section 2.6).

The concept of Ecosystem Goods & Services

Landscapes consist of a multitude of ecosystems. These ecosystems are based on a certain environmental structure which is reflecting imminent landscape processes. The processes shaping landscape structures are inherently complex and interrelated with certain ecosystem components (soil, water, relief, geology, flora and fauna) as well as human land use patterns. While taking advantage of these natural resources for human benefit, intervention is increasing with demand. As human populations grow rapidly, so do the resource demands.

Ecosystem services are, however, not invulnerable and infinitely available! Since society has realised that ecosystem services are not only threatened and limited, but also that pressure is rising, an evaluation of trade-offs between immediate and long-term societal demands is urgently needed. A landscape inventory system is required to capture these services, to estimate the relevance and sustainable use of this resource and to value the benefits of these resources in terms of money.

According to the Millennium Ecosystem Assessment (MEA 2005, p. xvi / 28) ecosystem services can be subdivided into five categories:

- provisioning services: e.g. the production of food and clean water
- regulating services: e.g. the control of climate and air quality and water flow regulation
- supporting services: e.g. as nutrient cycles and crop pollination
- ultural services: e.g. spiritual and recreational benefits
- preserving services: e.g. maintenance of diversity and good water quality

Inventory of spatially explicit environmental services

Provision of ecosystem services and their maintenance by farmers are not captured in commercial markets or politics nor are they adequately quantified; so far they have been given little attention in political decision making. Only when services are overexploited or stop working, re-active actions are denoted to turn back to previous conditions or to eliminate consequences induced (e.g. flooding due to decreasing retention areas).

It is argued that the neglect of valuing ecosystem services has consequences which ought to be considered today rather than tomorrow.

Ecosystem goods and services can be unitized into three categories:
1. *green services:* environmental and landscape services,
2. *blue services:* water resources services, and
3. *yellow services:* socio-economic services.

All three services are strongly interacting and partly superimposing. Capturing these services and the benefits for society enables one to identify those products that are intangible and important for a specific landscape. Impacts of anthropogenic use and abuse for these three service categories are becoming ever more apparent; – air and water quality and quantity are compromised, biodiversity is decreasing and partly genepools from vanished red list species decrease, deforestation and land amelioration is eliminating water retention possibilities and flood control around human settlements and pests and diseases such as the cow disease are extending beyond their historical boundaries. Guidance on general types of ecosystem services is given by the Millennium Ecosystem Assessment Report (MEA 2005, 165 et seqq) and de Groot et al. (2002).

Regional authorities or landscape stakeholders need to capture local services demanded by society. Public participation approaches identifying the requirements, needs and value of resources are a first step (Klug 2007a). Especially the valuation of ecosystem services needs such kind of approach since their economic value is associated with personal values and hence the respective stake considered. The main challenge of assigning economic values to natural units is prompting transdisciplinary shifts in the recognition and management of the environmental, social, economic and political responsibility and multidisciplinary opportunities of resources use.

The complexity of ecosystems poses a tough challenge for scientists as they try to understand how spatio-temporal relationships are interconnected with processes and functions (de Groot 2006). Therefore, understanding ecosystem services requires a strong foundation in landscape ecology, which describes the underlying principles and interactions of environment and people in a transdisciplinary way. Valuing these ecosystem goods and services relates to Environmental Accounting (EA). EA aims at measuring the contribution of natural capital to societal benefits and to document recent, present and future costs resulting from the overuse or damage to services provided by nature. The Intergovernmental Panel for Climate Change (IPCC) is for instance reporting effects of climate regulation due to an increase of CO2 in the atmosphere (IPCC 2007). While contributions to account ecosystem services on a global level (Costanza et al. 1997) are necessary and strongly supported by the authors of this article, practised methodologies reveal conflicts at larger spatio-temporal scales:

- Ecosystem services (ES) work at a certain spatial and temporal scale. Interpreting ecological information collected at a certain reference scale cannot necessarily be transferred to another scale.
- ES do not carry the same value in the world but are changing locally due to their fundamental anthropocentric character. Demands on ecosystem services spatially vary among countries, regions as well as social and ethical groups.
- ES retain a disparity between actual and perceived values. This relates possibly to peoples' limited acknowledgment of the interrelatedness of societies and the natural environment.
- ES depend on the local properties of land use / land cover, soils, water distribution, geological underground, climate / air, and relief.
- The services might change periodically or in a certain time period (seasonal changes).
- The preconditions to provide certain ecosystem services strongly depend on the natural background of a region.

According to Farber et al. (2002) six major methods for valuing ecosystem services in monetary terms include:

1. Avoided Cost: ecosystem services allow society to avoid costs that incur in the absence of those services (e.g. water purification in the absence of nutrient filtering infrastructure in the landscape)
2. Replacement Cost: ecosystem services can be replaced with man-made systems (e.g. restoration, maintenance or build up of structures in the catchment cost less than the construction and permanent use of a water purification plant)
3. Factor Income: established and maintained ecosystem services provide enhancement of local incomes (e.g. improved water quality increases tourism which in turn provides income for local shops, hotels, bars, etc. and the local fishing industry)
4. Travel Cost: ecosystem service demand may incur travel costs e.g. the toll roads (e.g. high mountain recreation - based on the value of people willing to pay to get there)
5. Hedonic Pricing: ecosystem service costs might be reflected by a specific location (e.g. houses with castle view or near the shoreline of a lake are more costly than houses in remote areas)
6. Contingent Valuation: ecosystem service can be valued according to presently used and passive values (not used) (e.g. asking people how much they are willing to pay for a specific service)

Despite the value of these six methods for environmental accounting we did not apply them because our question is: „How much is presently paid in subsidies to maintain ecosystem goods and services?“ This question leads to the question which spatial units are available for calculating present payments in order to maintain ES.

The spatial units

A Land Accountancy System (LAS) specifically attempts to interpret natural properties and their changes in terms of processes that transform one service to another. This is enabling the assessment of subsequent changes. These changes are based on spatial locations. Spatially explicit units need to be combined with economic valuation practices mentioned in the previous chapter. As an emerging field, spatial econometrics is combining GI-Science with Economics including findings from Environmental and Social Sciences. Valuation in this respect refers to the process of giving a monetary value to a particular unit that is representing one or more ecosystem goods and services (Farber et al. 2002, p. 376).

When trying to apply monetary values to certain landscape units we need to determine how these units should be framed. They can either be based on locations determined by the natural or by administrative boundaries. The latter can be equivalent to farm parcels which play a crucial role in EU agrarian funding schemes. According to the Common Agricultural Policy these units need to be captured in an Integrated Administration Control System (IACS) if EU subsidies want to be claimed. In Austria, the Agrar Market Austria (AMA) is providing the IACS service including a huge amount of spatially explicit information (e.g. land use, crop rotation system, intensity of use, subsidy measures taken for each field). These administrative units refer to the farm owner and those people who are shaping and embossing the landscape with their business. Farmers can be entitled the ecosystem service providers (ESPs) receiving money from the EU and national funding bodies to maintain the services provided.

Spatial decision support

The main driver of applied Geoinformatics in the field of environmental economics is the effort to inform decision-makers of present versus future costs and about the benefits of certain spatial resources. This involves a) defining the ecosystem service relevant for a region, b) translating scientific knowledge from several natural and social science disciplines and c) organizing the knowledge into economic values of comparable spatial units.

Understanding the dynamics of political decisions and their ecological and economic effects relative to the ecosystem services is essential when assisting political decision makers. Thus conceived, the basic notion of value that guides political decision is inherently anthropocentric, or instrumental. To the decision maker „value" is equivalent with the contribution of politics to the goal „satisfaction". While this value is related to the use of a specific thing (maize crop) or object (parcel), the actual determination of a value price requires some objective measure if one should be able to estimate the degree to which the thing or object improves income benefits and services for society. In a finite world of available financial resources politics are interested in economic and environmental forecasts and strategies of incentive implementation. While economists have developed an extensive theory of how people behave in the presence of political constraints and incentives (Varian 1992), GIS can help to spatially explicit model this behaviour using scenario techniques. The working hypothesis in our study case is that farmers make decisions in order to optimize satisfaction. Satisfaction is referring to maximizing income and/or reducing work load. This optimization process always takes place in the presence of certain constraints, such as present income of the farm, time resources available, local resource supply and many others. In this respect, optimization yields a deterministic set of possible decisions relevant for most real-world situations. This hypothesis is reflecting the fact that when constraints (subsidies or incentives) change, so do decisions. A deterministic set of decisions enables the modelling approach to reflect and respond to changes in a predictable fashion. This allows forecasting certain political strategies and to intervene in the European agricultural funding system in order to manage sustainable natural resources.

A set of relevant criteria is important for this spatially explicit approach: fair distribution of resources among member states and regions as well as an efficient allocation of available resources (Daly 1992).

Considering the requirements for decision support by stakeholders and politicians we apply a ground rent model on farm and parcel level helping to balance the a) costs allocated for certain regions, b) for the annual farm balance, and c) single parcels of a farm. This model framework has been applied to the case study area of the Mondsee catchment.

The Mondsee case study area

The catchment area of lake Mondsee is about 30 km northeast of the city of Salzburg and has an area of 248 km² (Figure 1). The majority of the study area lies in the Alpine foreland and it is politically divided by the Austrian Federal States „Upper Austria“ in the East and „Salzburg“ in the West. The area is characterized by its hilly appearance; only the south of the study area is dominated by the northern edge of the limestone Alps (Klug 2007b). The catchment is small structured by meadows and pastures and some smaller remaining areas of arable land. Of the 414 farmers (mainly cattle farms) more than half (232) are working on a small farm scale of 10 to 20 ha (Asamer and Klug 2008). According to the data collected by Statistics Austria (www.statistik.at) the years 1981 to 1991 show a trend in decreasing labour force in the primary sector (approx. -30%) causing a trend from full time to part time farming practices (Oberösterreichische Landesregierung 2004).

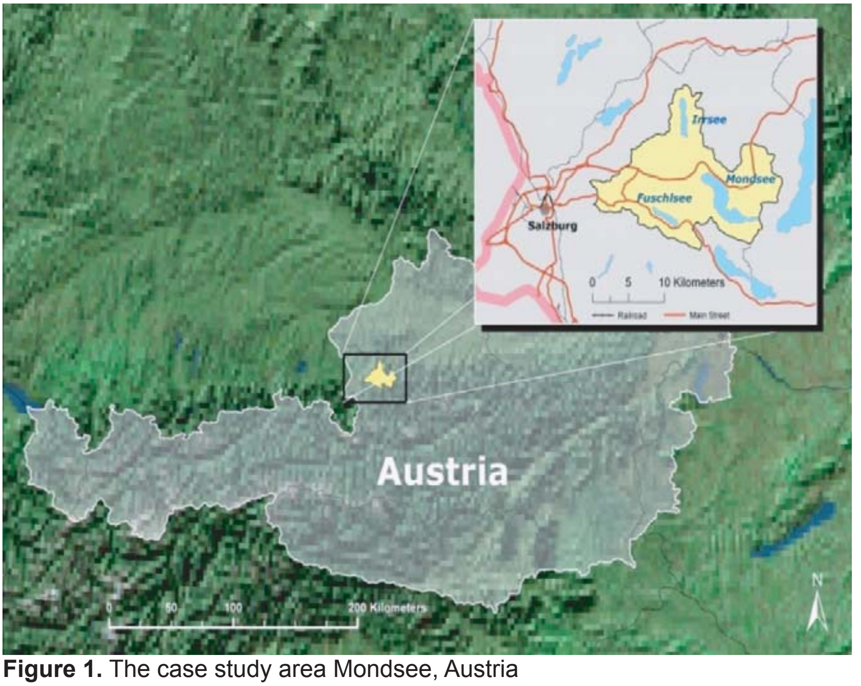

Figure 1. The case study area Mondsee, Austria

Supporting decision makers with problem tailored modelling tools means to assist politicians in finding solutions for emerging problems. Solutions can be framework directives, obligations, subsidies or incentives making a specific direction of development more attractive for people than another. Beside environmental, social, and economic aspects, politics must be included in the process of valuing ecosystem services.

Since the farming system in Austria is not economically viable per se, key subsidy payments are necessary to retain agricultural practices. These payments are coupled with the Common Agricultural Policy (CAP) which has been implemented by the EU to guarantee a stable price system for producers and to preserve our rural heritage and ecosystem services. The CAP is based on the Cross Compliance where both regulations (VO (EG) Nr. 1782/2003 and VO (EG) Nr. 796/2004) are mandatory in order to be eligible to receive subsidy payments since the beginning of January 1, 2005. The company Agrar Market Austria (AMA) is legally obliged to promote agricultural marketing and thereby coordinates the funding payments in Austria. AMA employs an Integrated Administration Control System (IACS) to register the subsidy payments based on the farmers' parcel and farm level. This spatially explicit inventory serves as a validation dataset for modelling.

The developed model is founded on collected information on all subsidy programmes of international, national and regionalised agreements which can be employed by farmers in the Mondsee catchment. Here, the national Austrian Agri-Environmental Programme (ÖPUL) is of significant importance to the farmers. We complemented this database by the farmers' real-life experiences for e.g. fuel, pesticides and nutrient costs or yield gained per hectare to capture their income and expenditures.
The ground rent approach employed after von Thünen (1826) is based on the theory that spatial context and present place conditions matter for the net income of farmers. The model tries to systematize the economic principles of location based factors such as income and expenditures and maps them spatially explicit with Formula 1 (see Schroers 2006).

Formula 1: $LR = ((y * (pf + iv) + sv) - (sc + nc + pc + lc + pc + mc + tc + rc)$

LR: land rent; y: yield; pf: production fee; iv: improvement value; sv: subventions; sc: seed costs; nc: nutrient costs; pc: pesticide costs; lc: labour costs; pc: production costs; mc: machine costs; tc: transport costs; rc: rental costs

Together with the previously mentioned database on funding programmes we developed a scenario for the year 2005 at parcel and farm level to assess the economic balance. We used ESRI‘s ArcGIS 9 with the Model Builder and Python scripts to semi-operate the model framework. In this framework we coupled the spatial explicit dataset from IACS with the developed funding database. In a first step we modelled income (e.g. subsidies, yield) and expenditures (e.g. fuel, work labour, seeds) at farm and single parcel level. In a second step, we compared the modelled farm balances with real payments farmers received from AMA for validation. In a third step we employed a possible short term scenarios to get an idea what might happen in the near and mid future. The scenario is based on a statement of the Austrian ministry of the Environment. The ministry argues for a strong reduction in the subsidy payment to maintain an open cultural landscape (OFFENKUL, Table 1). Effects on possible landscape changes caused by the exchanged agricultural funding bodies are assessed on the basis of the Rural Development Programme from 2007 to 2013 and the draft of the following period 2013 - 2019.

Results

The result of this ground rent model approach is a general assessment system adapted to the regional, natural, cultural, political and economic conditions of the given case study area in the province of Salzburg and Upper Austria, Austria. As a first result, the goal oriented planning procedure is shown to be a useful tool to enhance communication, scenario development, and planning of potential land use developments. Especially the analysis of subsidy programmes and their frequentation by farmers give insights into present shares of funding compared to the overall income. Furthermore, likely changing subsidy programmes causing spatial explicit changes give decision makers indicators of rural disparities.

Subsidy programmes

The cataloguing and the analysis of funding programmes, their content and designations as well as the amount of subsidy payment per area are developed in a database. Table 1 shows that particularly programmes on grassland funding dominate the acquisition by farmers in this area.

Table 1. Used programme measures in the Mondsee catchment

Measures	**Participation [%]**
Baseline funding (GRUND)	100,00
Renunciation of silage (VERSIL)	77,29
Renunciation of yield increasing measures in grassland areas (VBG)	76,33
Maintenance of slopes (OFFENKUL)	65,46
Maintenance of valuable areas (WERTV)	31,88
Biological practices (BIO)	17,63
Salzburg regional project ground water protection and maintenance of grassland areas (REGSALZ)	10,63
Renunciation of yield increasing measures in arable areas (VBA)	8,21
Maintenance of orchards (ERHSTREU)	8,21
Others	40,82

Spatially explicit results

The development of a semi-operational GI toolbox helped to model the net yield for each parcel and farm. Considering Formula 1, income from agricultural yields and subsidies as well as expenditures (e.g. fuel costs, insurance, and seeds) could be established on a hectare basis. Referring to the balance information in Figure 2 (showing a part of the Mondsee catchment) one can see that the areas in green and yellow mark the highest yield per parcel whereas parcels in red have a negative or equal to zero balance.

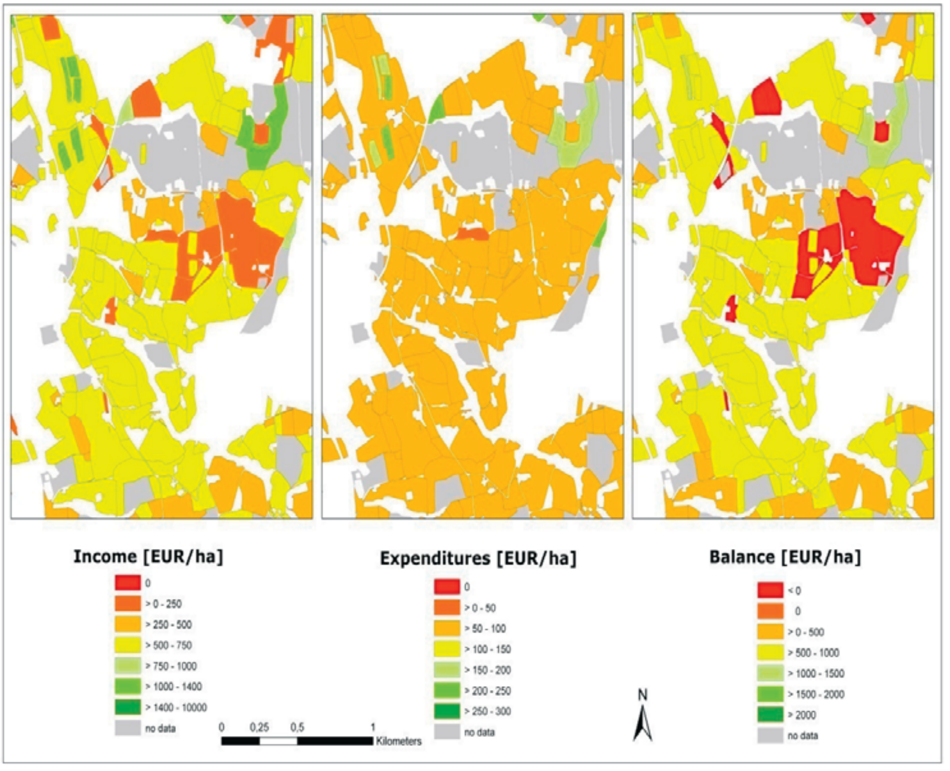

Figure 2. Calculation of the ground rent per hectare

Model validation

A comparison of the results of the ground rent model and the real payments from AMA is used for model validation (Table 2). Of the considered programme initiatives GRUND, VERSIL, VBG, and OFFENKUL an average level of 85% correctness is reached while some measures reveal more or less variance between modelled output and real payments.

Table 2. Comparison of model results and real payments from AMA in %

Measures	AMA [%]	model [%]	variance [%]
GRUND	17,05	11,11	34,81
VBG	32,64	32,64	0,00
VERSIL	47,04	37,67	19,92
OFFENKUL	3,27	3,36	-2,75
total	100,00	84,79	15,21

Envisioning the future

With a reduction of subsidy payments „maintaining an open cultural landscape“ (OFFENKUL) as forecast by the Austrian ministry, we demonstrated that the annual balance for some parcels in the case study area will definitely be negative. The farmers‘ expenditures are higher than their income. Hence, with decreasing funding the farming of land is not profitable anymore and can lead to abandonment of farming and ultimately the abandonment of land. This causes either a reduction of work labour in farming forcing the farmer to take on a second job or surrender farming all together or to retire. Especially parcels in remote areas and barren land with partly steep slopes are at particular risk of losing their cultural landscape characteristics which in turn has consequences for the tourism industry and biodiversity and hence important services in the Mondsee catchment are at risk.

Discussion

Present agrarian funding mechanisms at international, national and regional scale cannot be maintained in the future. There is a strong need to find strategies out of the dilemma of financing agricultural practices. According to our present knowledge, far reaching changes - especially in remote areas - are expected. If we cannot cope with these changes or compensate the decreasing financial payments with other funding strategies, landscape change will - without doubt - happen on high income parcels as well as low income parcels. This trend is still in process as outlined by Heißenhuber (2003) who reported the abandonment of parcels due to non-profitable yields. Furthermore, Silber et al. (2006) noted that since 1960 the forested area in Austria has increased by approx. 2700 km^2.

This approach cannot solve the problem of decreasing funding bodies, but the toolbox can offer help to identify the main areas at risk. It can be an instrument for stakeholders and decision makers to develop an action plan towards the maintenance of those areas. This model framework is able to run a monetary indicator system able to capture the basic characteristics of the spatially adapted distribution of financial resources.

To conclude, this model serves as a decision making tool for policy makers. Policy makers are able to predict the consequences of reduced subsidies for certain areas and can assess whether the instruments used and the policies implemented for rural development have an efficient and effective impact on rural areas in Europe.

Furthermore, this model serves as a tool for farmers and the farm advisory service. Applying this model can supply farmers with information regarding land use strategies which are financially feasible. This paper contributes to the development of tools supporting policy makers and farm advisory services in the implementation of Strategic Guidelines for Rural Development Policies.

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