Economies of Scope in the Agricultural Provision of Ecosystem Services: An Application to a High Cost Production Region

Verbundeffekte in der landwirtschaftlichen Bereitstellung von Ökosystemleistungen: eine Anwendung in einer Region mit hohen Produktionskosten

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Abstract

Joint production of agriculture commodities and environmental goods and services is a key attribute of multifunctionality. However, complex natural and economic interactions make a sound analysis difficult. In this regard, the concept of economies of scope provides a simple policy oriented indicator of jointness. Thus, the existence of economies of scope can be regarded as a precondition for the implementation of agricultural policies with respect to environmental goods and services. We apply the concept of economies of scope to the provision of ecosystem services in the Swiss lowlands using a spatially explicit economic-ecological programming model. Thereby, the consideration of non-agricultural competitors in the provision of ecosystem services allows a simultaneous assessment of economies of scope. A cost-effectiveness analysis shows the least-cost supplier of ecosystem services and spatial patterns in the supply for these services. Results imply the existence of economies of scope and hence strong jointness between agricultural production and the provision of ecosystem services. However, the potential for public cost savings due to structural change in agriculture is considerable. Moreover, the development of the second generation in biomass conversion technologies may enhance a non-agricultural provision of these services. Therefore, a continuous improvement in agricultural production efficiency is a precondition for strong jointness and thus multifunctionality.

Key words

economies of scope; strong jointness; ecosystem services; economic-ecological programming model

Zusammenfassung

Die Koppelproduktion (jointness) ist ein zentrales Element im Konzept der Multifunktionalität. Komplexe ökonomische und ökologische Zusammenhänge erschweren jedoch deren sorgfältige Analyse. Das Konzept der Verbundeffekte (economies of scope) kann jedoch als Indikator für die Koppelproduktion dienen. Das Vorhandensein dieser Verbundeffekten kann als Voraussetzung für die Implementierung von Politikmaßnahmen zur Bereitstellung von Umweltleistungen betrachtet werden. Der vorliegende Artikel untersucht, ob die Landwirtschaft in der Bereitstellung von Ökosystemleistungen Verbundeffekte aufweist. Mit Hilfe eines räumlich expliziten Optimierungsmodells wird die landwirtschaftliche Nutzung von Flächen einer industriellen Erzeugung von Energie auf denselben Flächen gegenübergestellt. Eine entsprechende Kosten-Effektivitätsanalyse zeigt den kostengünstigeren Anbieter von Ökosystemleistungen und ein räumliches Muster im Angebot derselben. Die Resultate zeigen, dass die Landwirtschaft über Verbundeffekte verfügt. Der im Modell implementierte Strukturwandel in der Landwirtschaft impliziert jedoch im Vergleich zur bestehenden Situation ein großes Einsparungspotenzial für zielgerichtete Direktzahlungen. Da die Entwicklung von Bioraffinerien der zweiten Generation diese Verhältnisse verschieben könnten, ist eine möglichst effiziente Landwirtschaft eine Voraussetzung für Verbundeffekte und damit auch für eine multifunktionale Landwirtschaft.

Schlüsselwörter

Verbundeffekte; jointness; Ökosystemleistungen; räumlich explizites Optimierungsmodell

1. Introduction

Agriculture produces both commodity and non-commodity outputs. Some of the latter exhibit the characteristics of externalities and public goods (OECD, 2001). Ecosystem services (ES), such as climate regulation, wildlife conservation or preservation of open space, are an important type of public goods provided by agriculture (WOLCOTT, 2006). Thereby, agricultural production can be complementary to or compete against environmental services, and is often associated with a bundle of multiple positive and negative services (HEAL and SMALL, 2002; HARVEY, 2003). In addition, the jointness between agriculture and ecosystem services is often based on a combination of different sources and cannot be attributed solely to technical interdependencies, non-allocable inputs or allocable fixed inputs. Rather, interactions between agriculture and ecosystem services are complex. Moreover, societal demand varies in space and time even within small regions. This makes a sound analysis of the joint production between agriculture and ecosystem services difficult.

In recent years, several authors modelled jointness between agricultural production and non-commodity outputs. Using a partial equilibrium model, BRUNDSTAD et al. (2005) show that without support for agriculture, the levels of joint public goods such as food security and landscape preservation will fall short of the demand in high-cost countries such as Norway or Switzerland. However, the current level of support is out of proportion. The latter is supported by RODSETH (2008) who models the provision of cultural landscape in a computable general equilibrium framework for Norway. Efficient support would in this case transform the agricultural focus towards the provision of cultural landscape rather than the production of commodities. In the context of competitiveness between agricultural production and the provision of environmental services, PEERLINGS and POLMAN (2004) illustrate for Dutch dairy farms that milk production and the provision of wildlife and landscape services are substitutes. Based on an econometric profit model, they conclude that economies of scope exist only on a small proportion of farms. HAVLIK (2006) models the joint production of beef and grassland biodiversity in different environmentally sensitive areas on the basis of a mathematical programming model. The conclusion is that more targeted agri-environmental programs are necessary to ensure the desired environmental quality in the different regions. In addition, LECOTTY and MAHÉ (2008) demonstrate with a cost minimizing approach that jointness can be sensitive to the intensification level of the agricultural production.

These models provide helpful insights into the analysis of jointness between agricultural production and environmental services. However, none of them implicitly addresses the question of an alternative provision of these services. The consideration of non-agricultural competitor, however, adds an important aspect to the analysis of jointness, because the provision of environmental services with the same technology but without a joint market product will always be more costly than an agricultural production (WOSSINK and SWINTON, 2007).

The purpose of this paper is to show an application of the economies of scope concept to a district in Switzerland which represents a case study for a region with small agricultural structures and high production costs. We evaluate the jointness between agricultural production and ecosystem services using a spatially explicit economic-ecological programming model. Thereby, the consideration of non-agricultural competitors in the provision of ecosystem services allows a simultaneous assessment of economies of scope. A cost-effectiveness analysis for a study region in Switzerland reveals the least-cost supplier of ecosystem services and spatial patterns in the supply for these services.

Throughout the analysis of economies of scope in this study, the existence of societal demand for a certain environmental benefit is a precondition (WOLCOTT, 2006). Given a certain level of society's demand for ecosystem services, economies of scope represent a framework in order to reveal the least-cost supplier of these services.

2. Problem Statement

Agricultural production inevitably interacts with natural resources and the environment. Thus, there is always some kind of jointness present. This, however, does not mean that these services are inseparable from agricultural production per se (ANDERSON, 2000; OECD, 2001). Thus, if jointness is used as a justification for agricultural support, it is important to analyse whether a separate provision of ES would be more cost efficient.

In this context, the OECD framework on multifunctionality regards the concept of economies of scope as a policy oriented indicator for the jointness between agricultural production and positive environmental goods and services (OECD, 2003). Economies of scope occur if the joint production of two or more products is less costly than the sum of the costs of producing each product individually. According to this concept, three steps are necessary to identify economies of scope in agricultural provision of ES: a) assessment whether the provision of ecosystem services can be de-linked from agricultural production; b) if de-linkage is possible, the associated costs must be estimated; and c) these costs must be compared to the cost of agricultural joint provision.

When no economies of scope exist, the OECD framework uses the notion of weak jointness. In contrast, economies of scope in the agricultural provision of ES refer to strong jointness. In the latter case, targeted payments for an agricultural provision of these services can be justified (OECD, 2003). Four main problems emerge when this framework is applied to the Swiss lowlands:

Firstly, alternative providers of ecosystem services are currently still strongly related to agriculture. However, due to the recent development of new technologies in modern biomass conversion, industrial bio-energy production emerges as a new form of land-use. In our context, the production of bio-energy thereby obtains a new dimension: instead of competing with fossil resources, non-agricultural bio-energy producers could compete with multifunctional agriculture in the provision of ecosystem services (HUBER, 2008). Therefore, a non-agricultural provision in our study is represented by the production of electricity through biogas plants in combination with a biorefinery which produces insulation material. The difference between the provision of ES by agriculture and a non-agricultural provision by a bio-energy producer lies in the underlying structure. We assume that agricultural structures are related to family-based farms. In contrast, non-agricultural bio-energy producers can exploit large production units. This is a conceptual assumption in our modelling approach and does not exclude the possibility that farmers themselves produce energy or, that in countries with large production structures, farms can assume the dimensions of industrial biogas plants. For the assessment of economies of scope, however, this assumption is reasonable because it allows a comparison between different provision activities.

Secondly, the underlying jointness between agricultural production and ecosystem services is currently disguised by existing (large) support. In Switzerland, the Producer Support Estimate (PSE) amounts to 66% (OECD, 2007). The extent of agriculture's contribution to ecosystem services in an unsupported situation is unknown and cannot be evaluated empirically. However, economic assessment of jointness requires a reference to this basic situation in order to evaluate efficient provision schemes. Otherwise, the connection between agricultural production and ES may be (over-) underestimated. In addition, energy production from biomass is also subsidized. Without the reference to an unsupported situation our study would merely compare subsidies. Therefore, our analysis is based on a mathematical programming model using normative scenario techniques (NASSAUER and CORRY, 2004). In relation to property rights, a situation without support refers to the counterfactual position (HODGE, 2008): farmers will select type and intensity of their farming systems in the absence of agricultural policies. Thus, farmers have the right to produce irrespectively of society's demand for public goods. Starting from this outcome, farmers are forced to provide ES (or avoid negative impacts on ES) and can be remunerated for these efforts.

Thirdly, the main advantage of agriculture may lie in providing several ecosystem services simultaneously (FLURY and HUBER, 2008). Adding up the costs for providing ecosystem services based on separate evaluations can produce misleading results. Therefore, an integrated modelling approach is needed which combines economic activities with environmental outcomes. In this study, the assessment of economies of scope in the agricultural provision of ecosystem services is conducted with a spatially explicit sectoral supply model.

The spatial dimension of our model refers to the fourth problem in analysing the provision of ES. Spatial differences in demand and supply of ecosystem services play an important role in the assessment of jointness. Thus, spatial distribution of ecosystem services and returns for competing land-uses are essential when modelling the supply of ecosystem services (ANTLE and STOORVOGEL, 2006). If land heterogeneity and hence opportunity costs of provision of ecosystem services are not considered, a sub-optimal provision is likely to occur (FRASER, 2008).

3. Research Questions

To meet the four challenges formulated in the previous section, we address the question of economies of scope using a two step approach. Firstly, we deal with the consequences for agricultural production given a high reduction in support by focusing on the following questions:

- What consequences can be expected for agricultural production in high cost countries given a major reduction in support?
- What costs are associated with higher levels of ecosystem services in a specific high cost region?

In a second step, we analyse the consideration of a non-agricultural provision in our model framework. Thereby, we focus on the following questions:

- Given an industrial bio-energy production representing a non-agricultural provision of ES, how do agricultural economies of scope change subject to higher prices for bio-energy?
- What are the consequences for the interpretation of strong jointness and the justification of the support for agriculture?

The following application of the economies of scope concept refers to a rural region in the Swiss lowlands with favourable conditions for agricultural production.

4. Methodology

4.1 Economic-ecological Programming Model

For our research questions the agricultural allocation model S_INTAGRAL was adapted, which was originally developed for the economic evaluation of carbon sequestration potentials, agricultural GHG mitigation strategies and nitrogen reduction potentials in Switzerland (PETER, 2008; HEDIGER, 2006). S_INTAGRAL is a recursive-dynamic linear optimization model which maximizes the aggregate annual income (labour income plus land rents) of Swiss agriculture under consideration of cropping constraints, plant nutrient requirements, manure production, forage and fertilizer balances, as well as structural constraints. The model includes all important activities with regard to income generation, land- use, livestock as well as GHG and nitrogen emissions. The model proved to be valid and reproduces observable real world data within a range of +/-5%. Thus, the performance of the model is satisfactory (HARTMANN et al., 2009).

In order to address our research questions, we adapted the model in the following way:

a) The base model was originally divided into three major production zones (plains, hills and mountain area). For our study, zones are replaced with spatially explicit units of homogenous land. These units are defined by their natural and anthropogenic conditions, but are independent of property rights.

b) As the focus is on a situation without support – which cannot be observed in reality – the dynamic element was removed from the model. A static approach suffices for our research questions since the adjustment processes is not of primary interest but the comparison of different states of ecosystem levels. This, however, means that all stabling, machinery and production plants are newly built in the corresponding solution.

c) Production processes and structural parameters are based on average Swiss data. However, in order to permit structural change, and thus a decline in fixed costs, benchmark farms were introduced into the model based on German planning data (KTBL, 2006). For milk production, this corresponds to a farm with 100 cows and approximately 80 ha of agricultural land. Without the introduction of such benchmark farms, our modelling approach (normative programming model) would result in a complete cessation of agricultural production in our case study region due to the high production costs. In the long-term, however, open markets (i.e. European production prices) will lead to structural change and a decline in fixed production costs. The idea is that these costs approach the level of the closest neighbour. Thus, our approach permits the adaptation of competitive agricultural production structures in our model. The disadvantage of this procedure is straightforward: with new production possibilities and without a recursive element in our model, the results can hardly be compared to existing production structures because the differences would merely reflect our assumptions. However, the model represents agricultural and bio-energy production processes in a detailed and valid manner. Therefore, our model is suitable for the purpose of this article, namely the identification of the least cost supplier of ES giving consideration to non-agricultural bio-energy producers.

d) In addition, the model has been expanded with bio-energy production activities (production of electricity and insulation material). Since they represent a non-agricultural land-use, the focus is on industrial production plants with a capacity of more than 5,000 t of biomass (dry matter) a year (data: KTBL, 2006, and GRASS, 2004). This corresponds to land demand of approximately 500 ha per plant. Due to this size, we assume full working load for their machinery. Marginal production costs in bio-energy production are therefore assumed to be lower than in agriculture.

Table 1 presents model activities and its specifications. With respect to land-use, for instance, the model can chose between 13 different crops, 3 intensity levels and allocate them to 2,334 different parcels of varying size and production suitability. Plant and livestock production are the only agricultural activities. In contrast, energy and insulation material are produced by non-farmers.[1] Restriction sets over crop rotation, nutrient and fodder balance combine the four production categories.

Table 1. Model Activities

Production	Model activities	Specifications
Plant	Root crops (sugar beet, potatoes), cereals (wheat, barley, triticale), oil seeds (sunflowers, rape), maize, grassland (permanent, rotational)	Crops (13); yields per parcel based on soil and climatic suitability (2334); intensity levels (3); size of the parcel (2334).
Livestock	Milk (dairy cattle, rearing cattle, goats), beef cattle (sucklers, calves, bulls), meat (pigs, lamb, broilers), eggs (pullets, laying hens)	Animal type (13); housing system (13) and size (7); livestock efficiency (8); feeding system (4); free range management (5).
Energy	Biomass (maize, grass) Manure (semi-liquid manure, dung)	Substrate: plant production intensity (2); manure (4); plant size (3).
Insulation material	Biomass (grass)	Substrate intensity level (3)

Source: own representation

The model optimizes total regional income over all producers and land units simultaneously. Thus, the model allocates the land to the most profitable activity and producer.

As we assume a small open economy, agricultural production prices are taken exogenously. Given the counterfactual position in our approach, we assume European production prices for agricultural products. The price scenario for food products is based on prognoses of the OECD and FAO for 2016 (OECD and FAO, 2007). Spatial data is based on the geo-data of the Swiss government.

[1] There is the possibility in the model that farmers can produce energy on their farms. These energy plants, however, are smaller than the industrial plants and thus have higher production costs. As the model maximises the income, the model will always chose the activity with lower production costs.

Different levels of ecosystem services are obtained by changing existing (or introducing new) environmental restrictions in the model. The costs of reaching the different levels of ecosystem services are expressed through the reduction of the total regional income. Under the assumption of the counterfactual position (property rights are assigned to land-users), the difference in income can also be seen as a minimum amount of the required public support for the competitors to provide these services. These provision costs correspond to the opportunity costs of providing the ecosystem service.

4.2 GIS Model

The linkage between S_INTAGRAL and the geographical information is built on a Geographical Information System (GIS) model. Based on the existing land characteristics, the latter forms continuous land units which are homogenous in their agricultural production suitability. In addition these land units contain information on the climatic suitability, average slope and the suitability for biodiversity conservation. To achieve the corresponding land units, the GIS model processes the data in two steps.

Firstly, the GIS model dissects the landscape using existing natural and anthropogenic linear elements, such as traffic routes, water/streams and edges of settlement areas or woods. Thus the landscape is subdivided into continuous land units within which, however, levels of soil or climatic production suitability vary.

Thus, in a second step, more fragmented land units are generated by introducing agricultural suitability information covering a certain zone (data source: BLW, 2007a). Once again, this leads to a fragmentation of the land units. In addition to size and soil suitability, the GIS model adds further characteristics to each land unit:

- climatic suitability for agricultural production (data source: BLW, 2007b);
- average slope (data source: Digital Elevation Model in BFL, 2007);
- biodiversity index (BI).

Climatic suitability is not used for a further dissection of the landscape due to pragmatic considerations. While differences in soil can easily be identified, a climatic change within the constructed land units would be virtually imperceptible.

BI refers to the benignity of the parcel for biodiversity conservation. The proposition is that agricultural land units with a direct connection to natural habits are more suitable for biodiversity conservation than those which are separated or isolated.

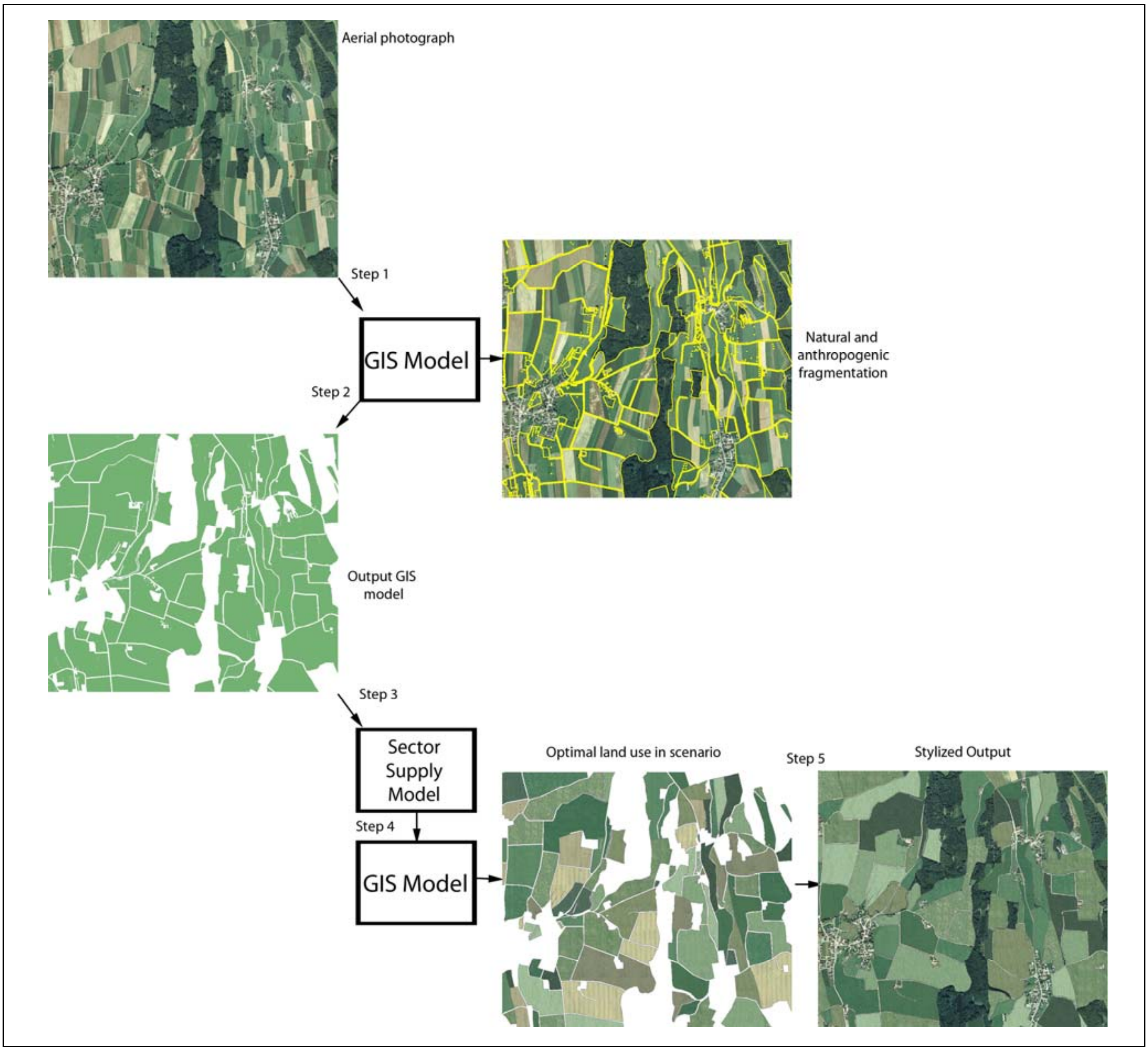
In the following step, land characteristics (soil, climate, slope and size) are integrated into the ecological-economic model. Soil and climatic information influence crop yields. Size and slope of the land unit affect cultivation costs. Information regarding the proximity to natural habits helps to assess effects on biodiversity. The GIS model does not take into account land tenure. Therefore, constructed land units are bigger than existing parcels. However, this is in line with the economic model which also does not account for individual farms.

4.3 Model Linkage

Figure 1 illustrates the model process with GIS maps and aerial photographs. Firstly, the GIS model processes the geographical data and calculates an optimal fragmentation of the landscape (step 1 and 2). Information for each land unit enters the sector supply model which optimizes the sectoral income (step 3). As one result, the economic-ecological model provides the optimal land-use for each land-unit. This information can be reimported into the GIS model (step 4). The resulting maps can be edited and rearranged in the aerial photograph (step 5).

The linkage between the economic-ecological model and the GIS data combines two different modelling approaches to land-use issues: given the static

Figure 1. GIS based Landscape Fragmentation



Source: own representation

character and the tendency of overspecialization in normative mathematical programming models, our approach is close to a land rent model. However, environmental and structural constraints enlarge the solution space and push the characteristics of the model closer to a normative agricultural regional farm type supply model (KUHLMANN et al., 2002).

5. Study Design

5.1 Study Region

The case study region (District Muri, LAU 1) is situated in the central part of the Swiss lowlands and has an agricultural area of approximately 10,000 ha. The region can be characterized as a peri-urban rural area. Agricultural structures are dominated by mixed farms (50%). 304 out of 536 farmers are milk producers. The number of cows amount to slightly more than 7,000 (13 cows per farmer). In addition, there is considerable pig and poultry production. Livestock units per ha (all animals) amounts to 1.9. One fifth of the farms have an agricultural area of less than 10 ha, 46% have 10-20 ha available for production and 34% cultivate an area bigger than 20 ha, whereby only 3% of these farm an area of over 40 ha. Average farm size is approximately 18 ha which is slightly above the Swiss average of 16.7 ha per farm. Still, average farm size must be characterised as very small. Land-use is dominated by grassland (57% of total area), cash crops (26%) and maize production (16%). The district lies in a valley in the bottom of which climatic and soil conditions are good. The hillsides are less suitable for agricultural production.

5.2 Indicators for Ecosystem Services

There are a number of slightly different classifications of ES. A first list is provided by DAILY (1997). With respect to agriculture, HEAL and SMALL (2002) describe in detail the complex interaction between agricultural production and ES. The common reference nowadays is the Millennium Ecosystem Assessment (MILLENNIUM ECOSYSTEM ASSESSMENT, 2005) in which ES are arranged with respect to supporting, provisioning, regulating and cultural functions. In our study, however, we refer to the classification of DE GROOT et al. (2002) because this explicitly mentions the habitat function. DE GROOT et al. group ecosystem services in information, habitat, regulation and production functions. In our model, ecosystem services are represented by selected indicators for the information, habitat and regulation function (table 2). The production function is represented by the agricultural output and does not need a specific indicator.

With respect to the information function of ES, open landscape and landscape diversity refer to the provision of aesthetic beauty and intellectual stimulation. In order to achieve higher levels of aesthetic beauty in our model, fallow land is restricted and the share of different crops must be increased on a certain percentage of the total area. In the model output, differences in the landscape patterns can be expressed by the Shannon-Index (in GIS models: LANG and BLASCHKE, 2007). The latter gives information on the occurrence of different land-use activities and the dominance of one of these. The Shannon-Index increases with a higher number of different land-uses and the evenness of the distribution of these land-uses.

Ecological compensation areas (ECA) and the quality of biodiversity are part of the biodiversity maintenance and thus belong to the habitat function. In our model, ECA's are represented by extensive grassland. A higher level of biodiversity maintenance is expressed by higher shares of ECA and a better accessibility from these compensation areas to bodies of water (lakes, streams) or woods (forests, trees, hedgerows).

Table 2. Model Restrictions in Scenarios

Scenario			Reference	Landscape	Ecosystem services
ES category	**Indicator for ES**		**Model restrictions**		
Information function	Open landscape	*[total land-use: % of the total area to be cultivated]*	-	100%	100%
	Landscape diversity	*[% crops in different sub-regions]*	-	26%	26%
Habitat function	ECA	*[% share of compensation area of total area]*	-	7%	14%
	Biodiversity	*[ECA accessibility of water and wood BI=1]*	-	-	100%
Regulation function	N-emissions	*[share of N-emissions in the reference scenario]*	100%	-	80%
	GHG emissions	*[share of GHG output in the reference scenario]*	100%	-	90%

Source: own assumptions

Nutrient balance and soil preservation belong to the ecosystem service category of regulation functions. Activities in the model lead to a degradation of these environmental services. Higher levels are expressed through a decline in nutrient runoff and enhanced crop rotation requirements. A reduction in greenhouse gas emissions (GHG) refers to the ecosystem service of air purification and climate regulation. Improvements are achieved by reducing CO_2 equivalents from the base solutions.

5.3 Scenarios

In accordance with our research questions, we initially calculate a basic scenario which represents a situation without direct payments and no protection above the EU level (i.e. predicted European production prices). This represents our *reference scenario*. Starting from this point, two different scenarios are constructed (*landscape* and *ecosystem services scenarios*) representing land-use systems with successively higher levels of ecosystem services (table 2).

In a second step, the production of energy from biomass is explicitly considered as an alternative to agricultural production in the provision of ecosystem services. In order to show the sensitivity of the model to different levels of energy prices, we vary the price for electricity from CHF 0.04 (which represents the producer price of electricity from a nuclear plant) to CHF 0.4 (representing the production cost for electricity from a small- scale agricultural production plant of 80 kW per year in Switzerland (PETER, 2008)). The actual average energy production tariff amounts to CHF 0.09 (AXPO, 2007).

The results reveal the least costs associated with a specific level of social preferences for ecosystem services over a range of electricity prices. At the same time, the spatially explicit approach reveals a pattern of agriculture and bio-energy production.

The scenarios consist of a combination of the ES indicators defined in the previous Section. Table 2 illustrates model restrictions and ES indicators for the three scenarios.

The *reference scenario* represents the prescriptions of the Swiss environmental laws but has no additional requirements relating to ecosystem services. For example there are no constraints concerning land-use. In principle, the whole area could be abandoned. Farmers do not have to set aside any compensation areas. In addition, there are no additional requirements concerning soil preservation through improved crop rotation or limits to nitrogen or GHG emissions.

The *landscape scenario* refers to a higher level of aesthetic beauty. Therefore, the total area must be cultivated, whereby the landscape must exhibit a pattern with different crops and a share of 7% of ecological compensation areas. A different pattern of land-use is achieved by restricting the crop rotation not to the whole area but to smaller sub-regions and introducing a minimal share of 26% crop production. The shares for these restrictions are related to the existing land use in this region.

In the *ecosystem services scenario*, additional requirements are introduced into the model. Nutrient in- and output must be balanced and the share of environmentally harmful nitrogen emissions must be reduced to a level of 80% compared to the *reference scenario*. The share of compensation areas is increased to 14%. This is an approximation to the assumed ecological optimal level in the Swiss lowlands (BROGGI and SCHLEGEL, 1989; BROGGI, 2007). GHG emissions are limited to 90% of the *reference scenario* level.

6. Results

The result section is divided into two parts. Firstly, we present the outcome of our calculations with the existing electricity tariff of CHF 0.09. In this case, our results imply that there is no bio-energy production in the optimal solution irrespective of the scenario. Thus, in the second section, we show the sensitivity to changing electricity tariffs. Thereby, table 3 gives an overview of the changing key characteristics in the scenarios with an increased level of ecosystem services compared to the *reference scenario*. The last column shows results of the *ecosystem services scenario* with electricity tariffs of 0.25 CHF per kWh. At this level, bio-energy production in connection with a biorefinery starts to displace agricultural production (section 6.2.).

6.1 Agricultural Provision of Ecosystem Services

Our results show static effects on land-use and farm characteristics in a long run perspective. The *reference scenario* refers to an optimal solution under complete rational economic behaviour and the stated parameters which does not represent actual values and structural conditions.

The regional income in the *reference scenario* consists of the returns on milk, meat and root crops

Table 3. Key Figures in Scenarios

	Unit		Reference	Landscape	Ecosystem services	
Electricity tariff	CHF		0.09	0.09	0.09	0.25
Sectoral income	m CHF		19.89	14.52	12.16	13.43
	%		100%	73%	61%	68%
Income per farmer	CHF		36,731	34,709	33,557	37,316
Provision cost per ha	CHF		–	585	841	703
Bio-energy plants			–	–	–	3
Milk production	bn kg		108	78	64	54
Dairy cows			12,023	8,635	7,155	5,962
Sheep			–	–	733	–
Livestock units			14,799	10,629	9,027	7,338
Livestock unit / ha			1.62	1.16	0.98	0.80
Import of fodder crops	kt TS		15.13	3.67	2.94	6.92
			100%	24%	19%	46%
Import of fertilizer	t		351	981	912	930
			100%	280%	260%	265%
Land use agriculture	ha	Root crops	172	463	445	581
		Cereals	0	1095	1199	1505
		Maize	968	698	579	474
		Oil seeds	0	832	746	304
		Grassland	1,695	2,445	685	1,826
		Permanent grassland	6,296	3,651	5,530	1,986
Total land use agriculture	ha		9,130	9,185	9,185	6,676
Land use bio-energy production	ha	Grassland	–	–	–	1,500
		Maize	–	–	–	1,009
Total land use bio-energy	ha		–	–	–	2,509
Fallow land			64	–	–	–
Ecological compensation areas	ha		0	639	1,282	1,282
		Agriculture	–	100%	100%	–
		Bio-energy	–	–	–	100%
N-loss	kt		0.91	0.86	0.73	0.73
	%		100%	94%	80%	80%
GHG emissions (CO2 equiv.)	kt		1,470	1,361	1,178	1,257
	%		100%	93%	80%	86%
Shannon diversity index	H		0.91	1.67	1.72	1.73

Source: own calculations

and amounts to CHF 19.89 million (table 3). Milk production dominates the overall income. Therefore, 87% of total area is used for grassland production which is the basic fodder in milk production. For additional feeding purposes, maize is cultivated on 11% of the area. However, a large part of concentrated feed needed for dairy production, is imported to the region. Production intensity is high on all land units. A small share of root crops is cultivated on land units with a high suitability for agricultural production. From the removal of support for agriculture, less than 1% of fallow land results. However, except for the provision of open space, the agricultural contribution to landscape diversity and biodiversity in the *reference scenario* is low. This is expressed by the low values of the Shannon diversity index (H) which can be attributed to dominance effect of the grassland. Results of the *reference scenario* reflect the comparative advantage of grassland based milk production in Switzerland.

For the *landscape* and *ecosystem system scenario*, the imposed model restrictions lead to a reduction of the sectoral income by approximately 30% and 40%, respectively. This corresponds to an amount of CHF 585 per ha in the *landscape* and CHF 841 in the *ecosystem services scenario*. The income loss in the *landscape scenario* comes from the changed landscape pattern which is assessed by the increased Shannon index. In relation to the *reference scenario*, farmers have to reduce the area for forage production (grassland) and increase the crop area in order to reach the same allocation as today (26% crop area). As a consequence, the number of animals is reduced and milk production decreases to 70% of the level in the *reference scenario*. Therefore, also livestock intensity per ha decreases. In addition, the produced wheat substitutes the imports of concentrate feed. The amount of imported fodder crops drops to 24% of the level in the *reference scenario*. In contrast, the amount of fertilizer imported to the region increases considerable (630 t) due to the reduced amount of manure and the changed nutrient requirements. On land units with high agricultural production suitability, cash crops are cultivated. Still, land use is dominated by grassland (67% of total land use). As a consequence of the reduction in the number of cows, GHG emissions and N loss are reduced to 93% and 94% compared to the reference level, respectively. Therefore, the results show that the introduction of constraints concerning land-use already reduces the amount of N-loss and GHG emissions. This indicates cost complementarities in the provision of our selected ecosystem services.

This is still more pronounced by the results of the *ecosystem scenario*. Additional requirements in this scenario further reduce income and the amount of work. But this decline is smaller than between the *landscape* and the *reference scenario*. The differences between the *landscape* and the *ecosystem services scenario* have two causes: a) the requirements concerning nitrogen loss and GHG emission lead to a reduction in the number of cows and b) the increased share of ECA involves sheep husbandry. The latter enters the solution as sheep can be fed with a higher share of extensive grass in their feeding ration whereas the intake of extensive grass for milk cows is restricted.

The reduction in animal production also leads to a decline in the need for the imports of fodder crops and fertilizer. In addition, the open space restriction impedes the abandonment of agricultural land. Without this restriction, farmers would abandon sensitive land units in order to minimize the income loss.

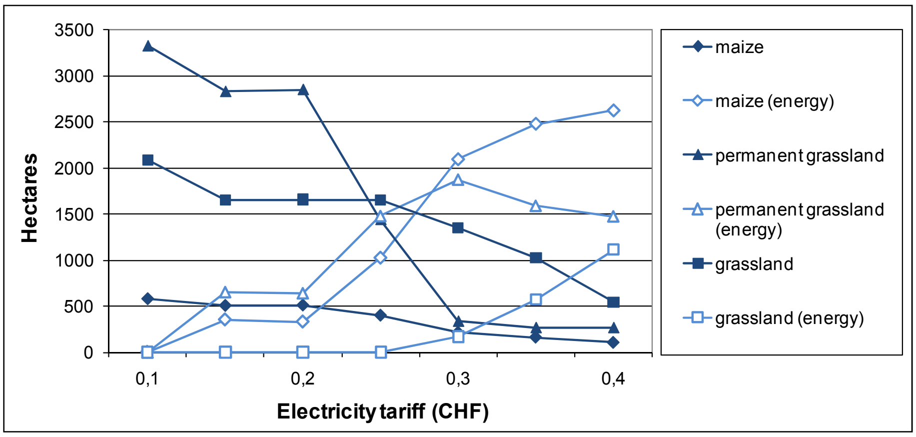
6.2 Bio-energy Production in the Ecosystem Services Scenario

Figure 2 shows effects on land-use with increasing electricity tariff. At a level of CHF 0.15 per kWh one bio-energy plant enters the optimal solution. At this price level, sheep husbandry is substituted with the production of electricity and insulation material. With a tariff higher than CHF 0.2, bio-energy substitutes further agricultural activities.

At a level of CHF 0.25 more permanent grassland is used for bio-energy than for milk production. In this case, 29% of the agricultural land is used for the production of electricity and insulation material (last column in table 3) whereby two third stems from grassland and one third from maize. Manure, on the other hand, is not used as a substrate in bio-energy production. The sectoral income and the income per farmer increase slightly compared to the *ecosystem services scenario*. The reason for this is that the extensive grass from the ECA is no longer fed to animals but can be disposed in the energy production. Due to the lower amount of grassland available for milk production the share of imported feed increases. In addition, bio-energy production leads to a further reduction in the nitrogen loss potential. Again, this results from lower livestock intensity. In contrast, GHG emissions increase due to CO2 emissions of the biogas plants. These emissions overcompensate the reduction in CH4 resulting from lower livestock intensity.

As mentioned above, existing market based electricity tariff in Switzerland is CHF 0.09. Therefore, a substitution of agricultural production by an industrial bio-energy plant would entail a triplication of actual electricity tariffs. This implies that agriculture still has lower costs in the provision of ecosystem services than non-agricultural competitors.

Figure 2. Land-use with Increasing Electricity Tariff



Source: own representation

This in turn can be interpreted as indication for strong jointness according to the concept of the OECD. Additional calculations without the production of insulation material in a biorefinery show that the trigger price at which non-farmers get competitive is increased at CHF 0.2. Substitution of farm activities beyond the provision of ECA starts at CHF 0.25. This indicates that without technological improvement in biomass conversion technologies, economies of scope in the agricultural provision of ES persist.

For illustrative purpose figure 3 shows a graphical representation of the *reference* (above) and the *ecosystem services scenario* with existing electricity tariff (middle) and with an elevated tariff of CHF 0.25 (below). The change in the landscape pattern from the *reference* to the *ecosystem services scenario* is obvious and depicts the increased Shannon index in table 3. In addition, figure 3 makes clear that a large part of the agricultural ecological compensation areas are used as substrate for energy and fibre and do not enter anymore in the agricultural production cycle. This indicates that under high electricity tariffs the industrial use of the extensive biomass may be a more efficient way to dispose the accumulated biomass than feed it to animals.

7. Discussion

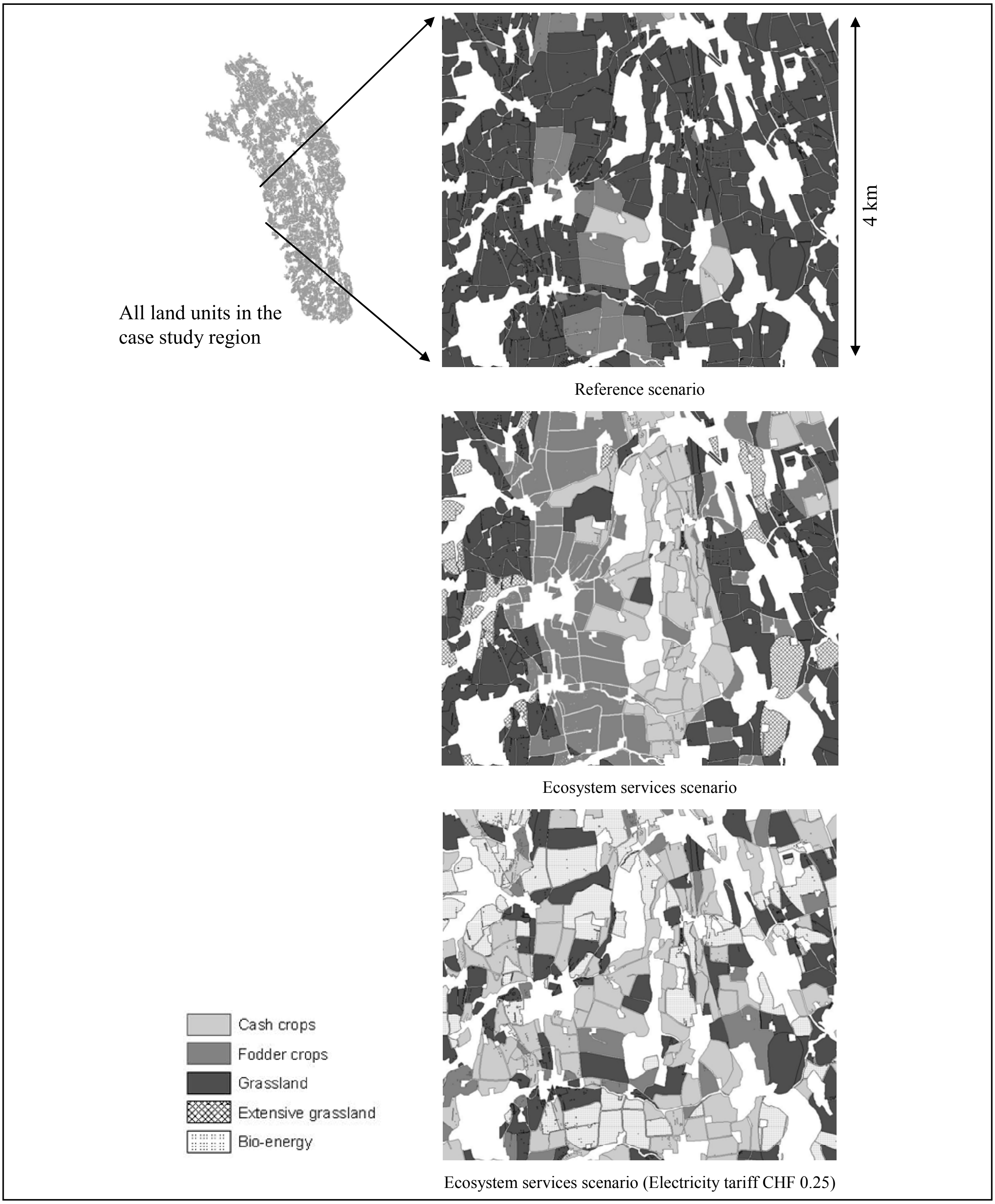
The modelling of Swiss agriculture with European production prices and no direct payments (*reference scenario*) shows considerable changes compared to existing agricultural production which is dominated by small mixed farms. This is not surprising since Switzerland still has the highest producer support estimate (PSE) worldwide (OECD, 2006). Given complete economic rational behaviour, farmers would concentrate on grassland based milk production. This is in line with other sector model results in Switzerland: MACK (2008) shows that a free trade agreement with the European Union would lead to a reduction in plant and an increase in milk production. Further results indicate that without direct payments, grain production would become unprofitable. However, the precondition for this development is a structural adjustment in the agricultural sector. Thus, the main challenge in milk production is an efficient transfer of resources between farmers leaving the sector and those wishing to expand production (DONNELLAN et al., 2009).

Agricultural contribution to ES in the *reference scenario* is low since farmers have no incentives to provide these services. Indeed, farmers provide open space by cultivating the agricultural surface. However, additional services (e.g. habitat or regulation functions) are neglected. This is consistent with current observations. FLURY (2005) shows that despite high payments for ecological compensation areas in the Swiss lowlands, the goals of reaching high quality land for biodiversity conservation is not attained. And the targets in N loss reduction are also missed. For the jointness between agricultural production and ecosystem services this implies a competitive relationship. This is also in accordance with the findings of PEERLINGS and POLMAN (2004) which show that only few farms exhibit economies of scope in the provision of milk and landscape services.

Through the provision of ecosystem services, agricultural income is reduced due to the imposed model restrictions. Targeted payments of approximately CHF 585 and 841 per hectare of land would offset these imposed costs in the *landscape* and the *ecosystem services scenario* respectively. This in turn corresponds at most to 77% of the actual decoupled area payment (CHF 1080) and 42% of average total direct payments per ha in the Swiss lowlands (approximately CHF 2000). The extent of these differences can be explained by the historical development of the actual payments, which are rather based on political income requirements of the farmers than on the provision costs of public goods. Therefore, the extent of actual support can not be solely attributed to the provision of environmental services. Hence, taking the structural change implemented in our model into account, the potential for cost savings in the provision of ecosystem services is considerable. This is in line with studies from Norway which is also a high-cost country for agricultural production. Their findings show a similar potential for cost savings in the provision of landscape services and food security (BRUNSTAD et al., 2005) as well as the provision of cultural landscape (RODSETH, 2008).

However, the level of the savings must be put into perspective. We are aware that the economic modelling approach (sector model) overestimates factor substitution which leads to an overspecializetion in our model. In reality different farm types have different provision costs for ES (for Switzerland HUBER, 2007). Costs may differ whether a high or low cost farm provide these services. This has spatial im-

Figure 3. Spatial Representation of the Scenarios



Source: own representation

pacts (HAVLIK et al., 2008) and ecological consequences (MUNIER et al., 2004). In addition, the nature of jointness (complementary or competitive) can change with the level of intensity in production of the farm (LECOTTY and MAHÉ, 2008). Our indicators for the assessment of ES, however, refer to a regional scale. Thus differences in ecological consequences on farm level (or on land units) are not assessed.

In addition, the spatial differences in the provision imply high expenditure for the implementation of targeted policies which are needed in order to achieve these savings. A flat rate payment scheme for ecosystem services which does not take into account the spatial differences would typically generate a suboptimal provision (FRASER, 2008). In the model, environmental goals are easily achieved by introducing constraints. But in reality, the achievement of these goals would depend on complex contracts between government and farmers. Whether these contracts would provide the expected ES needs to be assessed (HODGE, 2008). Thereby, the specific instrument chosen and the implementation of the targeted policy is a crucial task (OECD, 2008).

Moreover, the income level (compensation for labour) per fulltime farmer of the model calculations is low. This raises the question of whether farmers will remain in the agricultural sector since labour opportunity costs must be covered if the business is to be sustained (DONNELLAN et al., 2009). Therefore, there may be a need for additional policy instruments (e.g. income payments per farm household) in order to achieve acceptable levels of farm income irrespectively of the compensation for the provision of ES.

The differences between the *landscape* and the *ecosystem services scenario* show that livestock reduction leads to the highest sectoral income loss. Again, this can be ascribed to the comparative advantage of grassland based dairy production in Switzerland. Therefore, livestock is only reduced as a last option. This may hold for our scenarios in which different ES are combined as well as for the separate provision of ES, as NEUFELDT and SCHÄFER (2008) show for GHG mitigation in Germany and PETER (2008) for Switzerland. In addition, the small increase between the two scenarios refers to cost complementarities in the agricultural provision of our selected ES.

The introduction of non-agricultural competitors into the model shows that electricity tariffs must increase considerable in order to displace an agricultural provision of ES. This implies strong jointness between agricultural production and the provision of ES. However, the development of new types of biorefineries could alter this picture. The insertion of a side product (insulation material) lowers the trigger point at which the non-agricultural competitor gets competitive. Therefore, future technologies could weaken the jointness between agriculture and ES. Thereby, the development of the second generation of conversion technologies such as cellulosic ethanol production (FAAIJ 2005) is a crucial aspect. For example, TILMAN et al. (2006) show that a low input and high diversity biomass can be combined with the production of biofuels. This is of importance, since our results show that land which is used as ecological compensation areas enter the bio-energy production given a high electricity tariff. In this case, non-farmers would provide biodiversity conservation services combined with a reduced output of emissions on sensitive land-units.

With respect to multifunctionality and the exclusive support of agriculture, our results show the need for an efficient agricultural sector within a certain policy context. From an efficiency perspective, there is no reason why a farmer should be remunerated for the provision of ES, whereas biorefineries are not. If jointness is only based on economies of scope, the structural adjustment and thus the improvement of efficiency in the agricultural sector are crucial aspects of strong jointness and thus multifunctionality. Otherwise new technologies will substitute agriculture as the least cost provider. This would weaken the position of a multifunctional agriculture.

8. Conclusion

This study investigates agricultural economies of scope in the provision of ecosystem services in the Swiss lowlands. Results from a spatially explicit economic-ecological programming model show that under the stated parameters, output prices for non-farmers (electricity and fibre) would have to increase considerable in order to compete with agriculture in the provision of ecosystem services. Thus, agriculture still is the least cost supplier of these services. In relation to the concept of the OECD, the conclusion is that agriculture reveals a strong jointness regarding ecosystem services. However, new technologies will reduce the gap for non-farmers. As the results in this study imply, this is of particular interest for extensive used land-units. Therefore, a continuous improvement in agricultural production efficiency is a precondition for strong jointness and thus multifunctionality.

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