BIO-ENERGY –
A BY-PRODUCT OF RURAL LANDSCAPE MAINTENANCE?

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Paper prepared for presentation at the 47th annual conference of the GEWISOLA (German Association of Agricultural Economists) and the 17th annual conference of the ÖGA (Austrian Association of Agricultural Economists),
'Changing Agricultural and Food Sector',
Freising/Weihenstephan, Germany, September 26-28, 2007

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Abstract

Environmental goals play a crucial role in the economic assessment of bio-energy production, particularly in countries where the agricultural sector is less competitive. In addition to the reduction of CO_2 emissions, advanced biomass conversion technologies could contribute to the maintenance of landscape functions, such as the upkeep of rural scenery. From this perspective, energy production would be a by-product of the provision of environmental goods and services. This paper analyses, from a theoretical point of view, the consideration of alternative actors using biomass conversion facilities in connection with landscape maintenance and presents a case study from the Swiss lowlands. Results show that a societal optimal solution can be achieved with lower public expenditure and underlines the importance of technological development in bio-energy production.

Keywords: bio-energy, rural landscape maintenance, multifunctionality

1 Introduction

The two main functions of bio-energy production are seen in the substitution of fossil resources and the reduction of CO_2 emissions. Moreover in many countries bio-energy is regarded as a new income source for farmers and a possibility to foster rural development. In countries with a less competitive agricultural sector, such as Switzerland, a boost in support for energy from renewable resources is questionable because a) savings in fossil resources are small due to high production intensities, b) the reduction in CO_2 emissions would therefore also be marginal and c) generation of high costs for consumers and tax payers if, as anticipated in several economic studies (OECD AND FAO 2006), there is only a moderate increase in energy prices over the next 25 years. In this case, subsidies for energy production in agriculture would simply replace existing support for food production (cf. TANGERMANN AND VON LAMPE 2007: 15). Usually, the latter is justified by multifunctional benefits from agriculture.

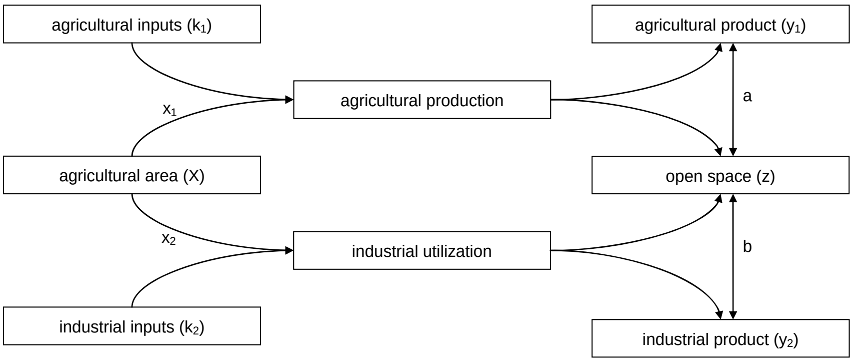
Landscape maintenance is a crucial aspect of multifunctionality in the densely populated Swiss lowlands. Societal demand for the upkeep of existing man-made landscapes have been verified in several studies (e.g. HUBER ET AL. 2007, SCHMITT ET AL. 2005). From an economic efficiency perspective, the corresponding landscapes must be provided by the least-cost supplier. 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. This would serve to strengthen important functions of bio-energy production, such as the closure of circular flows of biomass and a sustainable use of waste products. The inversion of perspective is analogous to that in agriculture: given societal demand and an adjustment of property rights (cf. BROMLEY 2000), the focus can be shifted to the provision of public goods in regions where food production is not competitive. The purpose of this article is a) to analyse, from a theoretical point of view, the consideration of non-agricultural actors using biomass conversion facilities in connection with landscape maintenance and b) to estimate their provision costs for landscape maintenance in the Swiss lowlands based on a case study. The combination of food and energy production as agricultural activities on farms is not subject of this article.

2 Consideration of alternative actors in the provision of open space: theoretical aspects

The main function of agriculture is the production of food and fibre whereas landscape maintenance is a by-product. On the other hand, alternative actors such as governmental institutions, farm contractors or machinery pools deal with the problem arising from landscape maintenance with biomass as a by-product. In a sustainable system with closed production cycles, the accumulated biomass ends up as industrialised products such as energy, chemical products, fuel, protein forage, manure or insulation material.

The following model analyses the consequences of integrating alternative actors in an optimal provision of cultivated landscapes. The analysis is restricted to open space aspects of landscape maintenance. The model consists of two inputs and outputs respectively. Private outputs (y_1, y_2) are conjoint with open space (z) due to the use of the common input land (X). This relationship is represented by the two arrows a, b in Figure 1.

Figure 1: Inputs and outputs in the provision of open space



The problem can be formulated as follows:

(1a) $$MaxU = U(y_1, y_2, z)$$

(1b) $$y_1 = y_1(x_1, k_1) \qquad y_2 = y_2(x_2, k_2)$$

(1c) $$z = z[v_1(x_1, k_1), v_2(x_2, k_2)]$$

(1d) $$X = x_1 + x_2$$

Functions (1a), (1b) and (1c) are concave and twice differentiable; z is positive because it represents a public good (open space); z smaller than zero would indicate a public bad emerging from this bundle of inputs (x_1, k_1). Function v corresponds to the relationship between inputs and the public good z. Further assumptions are: homogenous land, small food importing country, open economy and world market prices.

In a social optimum the value of the marginal product of an additional input must be equal in both uses. Thus, first order conditions with respect to land use are:

(2) $$\frac{\partial U}{\partial y_1}\frac{\partial y_1}{\partial x_1} + \frac{\partial U}{\partial z}\frac{\partial z}{\partial v_1}\frac{\partial v_1}{\partial x_1} = \frac{\partial U}{\partial y_2}\frac{\partial y_2}{\partial x_2} + \frac{\partial U}{\partial z}\frac{\partial z}{\partial v_2}\frac{\partial v_2}{\partial x_2}$$

The sum of marginal utilities from the private good (term 1) and the open space benefits (term 2) are equal in both uses. Moreover, the net marginal utility of land must correspond to the shadow price – the price at which another unit of land would be cultivated. In order to achieve an efficient solution the following optimisation problem for both farmers and the alternative actors emerge:

(3) $$Max\pi_i = p_{y_i} y_i(x_i,k_i) + p_z z\{\nu_i(x_i,k_i)\} - rx_i - C_{y_i}(x_i,k_i) \qquad \forall i$$

p_{yi} and p_z are the prices for the private and the public good respectively (p_z can be interpreted as societal marginal willingness to pay for open space areas); r is the rental price for land, and C_{yi} is defined as other production costs of the corresponding good. C_{yi} is strictly convex, therefore cost increase with higher input levels. Thus, the first order condition for an optimal allocation of the input factor x_i has the following form:

(4) $$p_{y_i}\frac{\partial y_i}{\partial x_i} + p_z\frac{\partial z}{\partial \nu_i}\frac{\partial \nu_i}{\partial x_i} = r + \frac{\partial C_{y_i}}{\partial x_i}$$

As long as p_z is zero, farmers and alternative actors would use land to the point at which marginal profits equal private marginal costs of the land. The latter contains two components: the rental price per unit of land and other marginal production costs per area. Given a low agricultural competitiveness, it is unlikely that the whole area could be cultivated in the case of a private optimum. In order to satisfy the assumed societal preferences, either the price for the private goods must be elevated by $p_z(\partial z/\partial y_i)$ or society must make an equivalent area payment. The latter would represent a direct reward for the delivery of open space benefits. Since open space areas are easy to monitor, low transaction costs can be expected and a direct payment would, in this case, be more efficient than a price subsidy (cf. VATN 2002). Therefore, in the following comparative static analysis, the internalisation of open space and its amenities are implemented via an area payment.

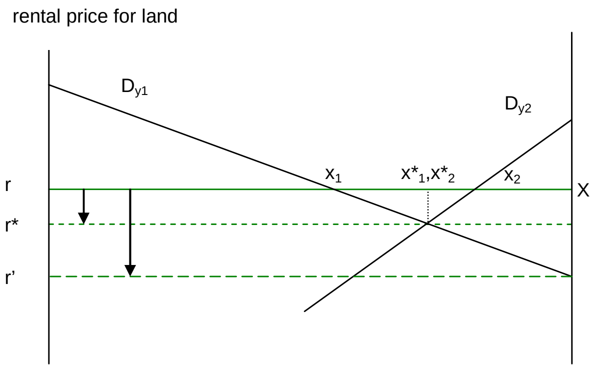
Under the assumption that $\partial z/\partial v$ is equal in both land uses, the same amount of open space is provided whether farmers or alternative actors cultivate the area. In this case $\partial z/\partial v_i * \partial v_i/\partial x_i$ can be set to 1 and equation 4a simplifies to:

(5) $$p_{y_i}\frac{\partial y_i}{\partial x_i} - \frac{\partial C_{y_i}}{\partial x_i} = r - p_z$$

If the contribution to open space would differ between the actors (or if the form of land use has an impact on the social benefits of z), an additional payment for the user with the higher marginal benefit would have to adjust these differences.

Figure 2 illustrates an optimal allocation of the input factor land. Dy_1 and Dy_2 represent the demand for area of farmers and non agricultural actors respectively. Under a given rental price r, agriculture and alternative actors would – in their private optimum – use the area x_1 and x_2 respectively and the area in between would not be cultivated (fallow land). The introduction of an area payment lowers the rental price for land and allows a societal optimal allocation of land (cf. equation 5). Considering only agriculture in the provision of open space, the condition at which a social optimum is achieved would be an area payment amounting to r-r'. At this point, farmers cultivate the whole area.

Figure 2: Optimal allocation of agricultural area between farmers and alternative actors



D_{y1}: agricultural demand for land

D_{y2}: demand of alternative actors for land

X: total area (societal demand for Open Space)

x_1: area used by farmers (no support)

x_2: area used by alternative actors (no support)

$x^*_1x^*_2$: optimal allocation of land

r*, r’: rental price for land with area payment

Taking into account both actors, equations (2) and (4) imply the efficiency conditions as follows:

(6a)
$$p_{y_1}\frac{\partial y_1}{\partial x_1}+p_z\frac{\partial z}{\partial \nu_1}\frac{\partial \nu_1}{\partial x_1}-\frac{\partial C_{y_1}}{\partial x_1}=p_{y_2}\frac{\partial y_2}{\partial x_2}+p_z\frac{\partial z}{\partial \nu_2}\frac{\partial \nu_2}{\partial x_2}-\frac{\partial C_{y_2}}{\partial x_2}=r^*$$

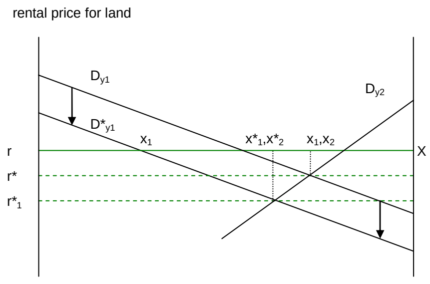
Social optimum is represented by the intersection point of the demand functions in Figure 2. A direct payment of $p_z\ (r-r^*)$ is required to reach this point:

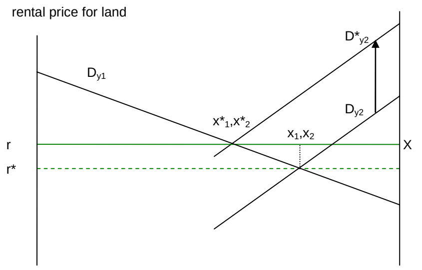
(6b)
$$p_{y_1}\frac{\partial y_1}{\partial x_1}-\frac{\partial C_{y_1}}{\partial x_1}=p_{y_2}\frac{\partial y_2}{\partial x_2}-\frac{\partial C_{y_2}}{\partial x_2}=r-p_z$$

Here, the social demand for open space is attained with a lower area payment than if only farmers are considered because both demands for land are taken into account.

This aspect is explored in more detail with a comparative static analysis in Table 1 and Table 2. The Figures show changes in the general conditions which strengthen (weaken) the position of alternative actors in the provision of open space.

Table 1: Relative strengthening of alternative actors (bio-energy)

Decrease in demand for land from agriculture • Decreasing prices for agricultural products; • Higher production costs in agriculture.	
A decrease in agricultural demand for land implies downward shift of D_{y1} to D^*_{y1} and the area in agricultural production moves to the left (x_1). Under the assumption that only an area payment would allow an socially optimal allocation in the first place (x_1x_2), this payment would have to increase by the amount of $r^*\text{-}r^*_1$.	

<table>
<tr>
<td>Increase in demand for land from alternative actors
• New (improved) technologies in biomass utilisation (e.g. biomass to liquid technologies);
• Increasing energy prices.</td>
<td>
</td>
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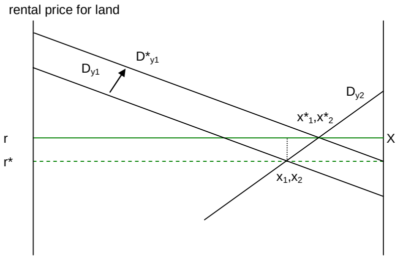
<tr>
<td colspan="2">An increase in demand from alternative actors can have two implications: a) if the increase in demand is smaller than the difference between Dy$_2$ and D*y$_2$, the amount of the area payment needed to reach an optimal solution falls; b) above D*y$_2$, the whole area is cultivated without direct payments. In this case alternative actors are even willing to lease out land from agricultural production.</td>
</tr>
</table>

Table 2: Relative weakening of alternative actors (bio-energy)

<table>
<tr>
<td>Increase in demand for land from agriculture
• Increasing prices for agricultural products;
• Productivity gains in agriculture (technical development, structural change).</td>
<td>
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<td colspan="2">A possible increase in demand from the agricultural side shifts the demand function from Dy$_1$ to D*y$_1$, and a bigger part of the total area would be cultivated by farmers. Again, two outcomes can be distinguished: a) if the increase in demand is smaller than the difference between Dy$_1$ and D*y$_1$, the area payment would decrease; b) a demand higher than D*y$_1$, farmers would be willing to lease out land from bio-energy production.</td>
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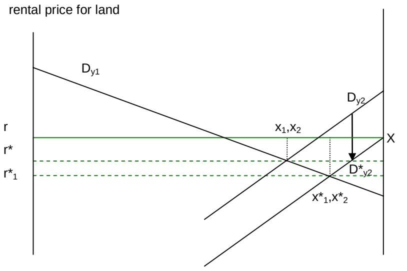
<tr>
<td>Decrease in demand for land from alternative actors
• No technological development and stagnating or decreasing energy prices.</td>
<td>
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<tr>
<td colspan="2">One possible emerging demand function in this case would be D*y$_2$. Again, the area in agricultural production increases, but in comparison to the initial situation, the area payment required would increase by $r^*-r^*_1$.</td>
</tr>
</table>

This comparative analysis has the following implications:

- The consideration of non-agricultural actors can lead to a more favourable provision of open space benefits and therefore lower cost in rural landscapes maintenance;
- The economic potential of bio-energy production depends on the demand of alternative actors. This non-agricultural demand for land is mainly influenced by a) advanced and new biomass conversion technologies; b) increasing demand for food and energy; and c) changes in agricultural competitiveness.

However, open space is only one part of landscape maintenance. This static analysis does not take into account any changes in agricultural production intensity, which can affect landscape elements negatively. If $\partial z/\partial v_i$ would have a negative sign, a tax instead of a payment would be necessary to restore optimality. Moreover, in reality, area payments also have insurance and welfare effects and can therefore change agricultural production intensity (OECD 2006). Another important restriction is the "small country case" assumption. Since the amount of food produced on the additional surface does not influence world market prices, feedback effects must not be taken in account (cf. LECOTTY AND VOITURIEZ 2003).

In the Swiss lowlands, current market price support and area payments for farmers generate a high demand for agricultural area. Thus an emergence of fallow land cannot be observed at the moment. Upcoming changes in Swiss agricultural policy could alter this picture and a change in the existing payment schemes would be necessary. In this context, the estimation of non-agricultural provision costs in landscape maintenance gives indication for the competitiveness of alternative actors in landscape preservation and represents an upper bound for direct payments for landscape maintenance.

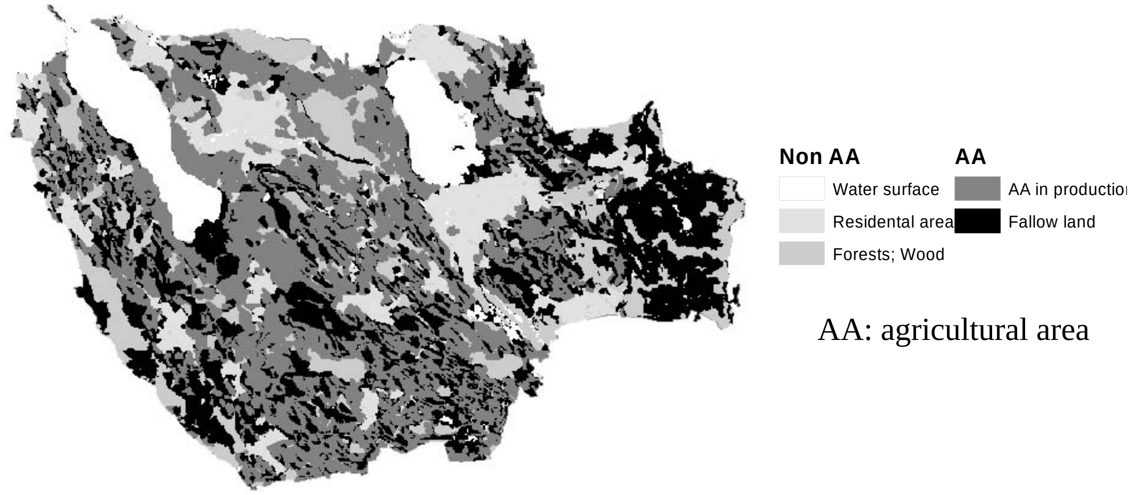
3 Case study

3.1 Case study region and reference scenario

The watershed of Lake Greifensee in the Canton of Zurich, with a total area of 15’579 ha, provides a basis for the case study region. Climate and surface conditions, which limit crop production to one fifth of the agricultural area, lead to a grassland dominated landscape. This area is suitable as a case study region because a) a previous research project in this region (cf. SZERENCSITS ET AL. 2004) provides well-elaborated (GIS-) data on existing land use, surface suitability and landscape aesthetics, and b) Lake Greifensee is an important local recreation area in the agglomeration of Zurich. Present demand concerning recreational and ecological amenities implies a certain willingness to maintain existing landscape in the future (SCHMITT ET AL. 2005).

In order to estimate the costs of non-agricultural actors in landscape maintenance, it is necessary to know what amount of area and landscape elements respectively must be provided in the case study region. This in turn raises the question of how much of the area would, without any support, still be used for agricultural production. The contribution to rural landscape maintenance which could be expected under (world) market prices is as yet unknown, because so far, the effects of large price reductions on agricultural structures have not been investigated. Therefore, the amount of fallow land is depicted in a reference scenario (Figure 3). To avoid duplicating provision costs, surface suitable for crop rotation (60% of agricultural area) remains in production due to food security aspects. In this way, estimated costs can be linked directly to landscape maintenance and are not confused with the other goals of multifunctionality in the Swiss constitution. It is assumed that surface less suitable for agricultural production is more likely to be abandoned under lower output prices. Therefore, the calculations are made stepwise: firstly, the costs are estimated for surfaces with low agricultural productivity before areas with a higher suitability are also abandoned. In doing so, the assumption of homogenous land in the theoretical concept is relaxed for the case study.

Figure 3: Assumed fallow land under world market prices in the case study region



Source: (modified) Szerencsits et al. 2004

3.2 Calculation set-up

Provision costs of landscape maintenance by alternative actors can be divided in two categories: costs for open space (per ha and year) and costs for the maintenance of landscape elements (per year). The former depend on the following factors: goal of the maintenance, type of grassland, necessary maintenance measures (mowing, mulching) and disposal costs of accumulated biomass. Total costs can be estimated by adding the cost per parcel and per surface suitability class consecutively. Costs for the maintenance of existing landscape elements are calculated for each surface suitability class, adding up costs per unit of trees, hedgerows and bushes as well as tree rows and crop fields (colour element).

In this case study, the goal of the maintenance is the preservation of existing landscape. Therefore, no additional actions for e.g. bio-diversity improvement are considered. The type of grassland varies with surface suitability, elevation, steepness of the parcel and existing use. Necessary annual maintenance measures are mowing and mulching in summer and in autumn respectively. Whether or not mulching is a suitable measure for maintaining abandoned farmland is part of an ongoing scientific discussion (e.g. Briemle 2004). Due to an elevated level of airborne nitrogen and the existing intensive land-use in the case study region, mulching is rejected as the sole maintenance activity and only possible in combination with mowing. Cost elements for the different activities are: labour, machinery, facilities and corresponding indirect costs. Mechanical and agricultural practices in landscape maintenance are comparable but can differ considerably with varying environmental and technical conditions such as scale effects by shifting from small to larger plots, higher engine power, increasing stand density in grasslands, steepness of plots and cost degressions due to wider machines. These aspects are also integrated into the calculation: scale effects are considered by a maximum workload of all machines, engine power and machine width varies with plot size in order to depict cost degressions. Different yield assumptions are used to make allowance for varying densities in grasslands due to environmental conditions (surface suitability). And finally, steeper plots are associated with higher maintenance costs. Data originates from a German composition of average costs in landscape maintenance (KTBL 2006) and, for a specification of landscape element costs, from various other German sources (Kapfer et al. 2003, Roth and Berger 1999). German data is used instead of domestic data because it is much more detailed and, under the assumption of world market prices, the provision costs in Switzerland would decrease due to structural changes. With regard to biomass disposal, four different possibilities are taken into consideration: burning in a waste incinerator (KVA), composting on fields, fermenting in a bio-gas plant or in a bio-refinery. The latter produces, in addition to energy, protein forage and insulation material (Grass 2004). Data for the disposal methods stem from different Swiss studies, which compare the efficiency of the different systems (Schleiss 1999, Oettli et al. 2004). Future developments concerning biogas plants and bio-refineries are based on the bio-energy vision 2020 of the Swiss Federal Office of Energy. Based on this scenario, a bio-gas plant and a bio-refinery are anticipated with a capacity of 3000 and 5000 tons of biomass utilisation respectively. A maximum of 5% of the accumulated biomass can be composted; the rest has to be burned in a KVA. Biomass disposal is a crucial task because the legal regulations concerning waste disposal are strict in Switzerland and there exist a rigorous waste disposal system throughout the country. It is therefore not possible to just build a landfill site in this region.

3.3 Results

Since the calculations are based on the addition of average costs and do not include any optimisation, the estimated costs must be considered as an upper limit. In the Greifensee region, costs of landscape maintenance by alternative actors amount to 4.8 million Euro (Table 3). Thereby an area of 3580 ha (43% of total area) is cultivated. Direct payments for landscape maintenance should not exceed this sum.

Mowing and mulching the corresponding area as well as the maintenance of landscape elements amount to one fifth of total costs (20 and 22% respectively). The highest percentage of total costs is generated by biomass disposal (58%).

Table 3: Cost of landscape maintenance of non-agricultural actors

surface suitability	extensive grassland	wet meadows	moderate suitable grassland	forage production preferred	land cultivated by alternative actors	total area
surface (ha)	246	168	1866	1300	3580	8357
% of total area	3%	2%	22%	16%	43%	100%
cost (Mio.€ per year)					total cost	% of total cost
maintenance	0.11	0.04	0.44	0.35	0.9	20%
biomass	0.19	0.14	1.49	0.95	2.8	58%
landscape elements	0.13	0.03	0.51	0.37	1.0	22%
total	0.4	0.2	2.4	1.7	4.8	
total cost per ha (€ per year)					1332	

There is only a small amount of marginal areas (extensive grassland, wet meadows) in this region. Therefore, the associated costs of landscape maintenance also remain low. However, they increase sharply if moderately suitable grassland goes out of agricultural production. Over the whole region, the average cost per ha amount to 1332 € per year.

The last column in Table 3 shows that more than three quarters of the total costs are linked to open space benefits (maintenance and biomass disposal). Additional sensitivity analysis of the calculations emphasises the key role of biomass disposal costs in landscape maintenance by alternative actors. Different scenarios in biomass disposal possibilities alter the total costs significantly, whereas the influence of alternative assumptions concerning hourly wages or machine workload is low. For example, if the whole biomass has to be burned (no additional technologies), provision costs rise 31%. In contrast, 20% higher machinery costs increase total provision cost no more than 5%.

Thus biomass disposal is the crucial factor in landscape maintenance by alternative actors in the Greifensee region and the competitiveness of these actors depends on future development in biomass disposal technologies. This conclusion is supported by the high average cost per ha (last row in Table 3). Additional calculations with a mathematical farm optimization model show that farmers in Switzerland – depending on farm types – would re-cultivate abandoned areas with costs between 220 and 1400 € (HUBER 2007). In this case many farmers would use the accumulated biomass in a more cost effective way.

4 Discussion

The main function of bio-energy production is the substitution of fossil resources. In addition, bio-refineries can contribute to environmental goals. This is particularly important for areas where the competitiveness of the agricultural sector is low. In this case, the production of energy and other marketable goods would be a by-product of a least-cost provision of environmental goods and services, such as rural landscape maintenance or biodiversity conservation. Non-agricultural actors using biomass conversion technologies would therefore compete with farmers, not only for agricultural surface, but also for direct payments. From a theoretical point of view, the consideration of non-agricultural actors is of economic interest because it could help reduce governmental expenditure for the provision of public goods. The development of the second generation of conversion technologies such as cellulosic ethanol production (FAAIJ 2005) is a crucial aspect for the potential of bio-energy production. In this context TILMAN ET AL. (2006) show that a low input and high diversity biomass can be combined with the production of biofuels. The case study in the Swiss lowlands underlines the idea that advanced biomass conversion facilities are the key to efficient provision of non-agricultural landscape maintenance. Alternative actors may have lower costs for mowing and mulching the corresponding areas due to scale effects, but without the development of new technologies (in this case a bio-gas plant and a bio-refinery), the integration into an agricultural production cycle is a more efficient way to dispose of the accumulated biomass. This is particularly applicable if, due to a high percentage of fallow land, the accumulated biomass exceeds non-agricultural disposal capacities.

The case study is only related to provision costs e.g. the supply of landscape maintenance. However, spatially differing demands for such public goods are critical for the potential of bio-energy. Above all, in recreational or tourist areas with a high demand for environmental goods and services, low input bio-energy production may be advantageous, because of scale effects in the provision costs and less negative externalities (noise, odour) compared to agriculture. This would lead to a spatial differentiation in the provision of public goods, analogous to that of agricultural commodities proposed by von Thünen. However, given a certain demand, the differences in prices would not originate from transportation costs but from the potential for economies of scale (bio-energy production) and economies of scope (agricultural production). In regions, where natural conditions make it possible to take advantage of scale effects in landscape maintenance, the production of bio-energy could therefore be an economic alternative to existing agriculture. However, all the positive and negative effects must be taken into account. The advantage of agriculture may be that it is possible to provide several environmental goods and services at the same time (economies of scope) which could offset economies of scale in a non-agricultural provision.

In addition to spatial aspects, further investigations into an economically efficient provision of landscape maintenance should include a simultaneous consideration of agricultural and bio-energy production cycles on a regional level. Such an analysis must also include bio-energy production as an agricultural activity on farms, an aspect which is not considered in this case study.

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