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The Provision of Ecosystem Services by Agriculture – a Spatially Explicit DEA Approach

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Abstract

According to the concept of ecosystem services, agriculture not only provides commodities but also cultural and regulating services. While it is easy to value commodity production by market prices, the valuation of cultural and regulating services is complex because of their public good character. Non-parametric approaches such as the Data Envelopment Analysis (DEA) allow for estimating the contribution of agriculture to such services. However, it is not enough to know the extent of ecosystem services provided; it is also necessary to be aware of which farmers provide these services and where they are provided. In this paper, we suggest a plot-specific approach combining GIS analysis and DEA models. This allows a spatially explicit assessment of agricultural land use for different subject matters such as ecology and the contribution of a single plot to landscape diversity. The approach is undertaken in a marginal low-mountain region in Germany on 95 farms involving more than 5,800 plots. The results show the spatial distribution of externalities supplied by agriculture and the degree of segregation between "production areas" and "protection areas". The results also allow a deeper understanding of the spatial impact of policy measures on the provision of ecosystem services by agriculture.

Key words: Agricultural land use, data envelopment, environment-oriented technical efficiency, landscape-appearance-oriented technical efficiency.

JEL classifications: Q12, Q26, Q57

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1 Introduction

The major aim of agricultural enterprises is to gain income from commodity production in order to guarantee a certain standard of living for farmers and their families. But agriculture also has significant effects on the environment and landscape aesthetics, so-called external effects. For example, the application of mineral fertilizers can cause environmental damage to biodiversity or water quality – one example of a typical negative external effect. With respect to landscape appearance, agriculture forms the cultural landscape which is socially desirable, thus creating positive external effects.

Since agricultural land use is strongly linked to the single plot as location of production, a site-specific view of external effects is sought-after but has not until now been a common feature in the evaluation of externalities. For this study a number of significant variables are selected which cover a specific indicator function. The second major challenge in this context is the combination of data within geographic information systems (GIS) with non-parametric methods such as the Data Envelopment Analysis (DEA). This method seems to be a way to measure the performance of agricultural land use in producing (positive and negative) externalities.

This paper presents such an approach in the study region "Rhön" in northern Bavaria.

2 Material and methods

2.1 Study region

The study area "Rhön", located in the low-mountain range, is typical for low-yield marginal sites and thus for regions which are threatened by the withdrawal of agriculture. It is important to safeguard the farms in this region in order to continue the long-term preservation of a highly structured and – from a conservation perspective – valuable cultural landscape (Cooper et al., 2006). Geographically the study area is the northern section of the "Hohe Rhön", a tertiary basalt plateau with peaks in the range of 800 m a.s.l. The open areas of the hilltops are very low-yield sites. Agricultural use is restricted to pastures for sheep and cattle as well as extensive meadows, cut twice (Figure 1). Typical features are spacious, mosaic-like diverse meadow communities, large perennial matgrass meadows (*Nardus stricta*), mountain hay meadows, and valuable marsh meadows and several moor areas.

Figure 1. The open areas of the hilltops are being used as pastures and extensive meadows.

Figure 2. A mixture of forest and grassland areas is characteristic for the slopes.

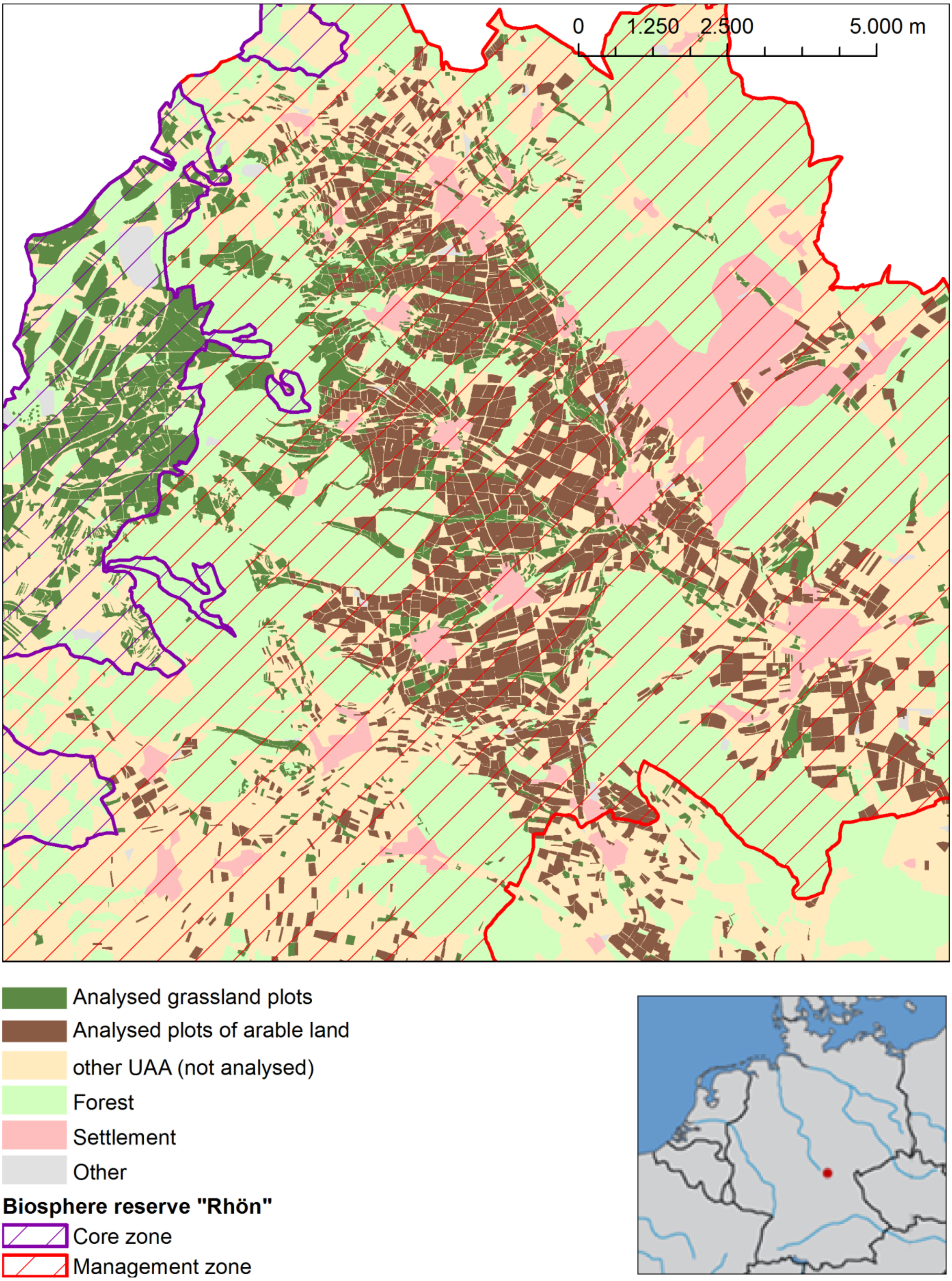

Figure 3. Overview on plot structure and land-use type of the study area “Rhön”.

The eastern slope falls steeply, approximately 300 m, to the valley bottom known as "Fladunger Mulde". These slopes are dominated by forest (Figure 2). Here the waters have cut deep, so that a series of wooded ridges and grassland valleys has developed. The forest-free areas in-between are used exclusively as a two- or threefold cutting meadow. The land-use pattern in the map in Figure 3 shows that the valley plains of the "Fladunger Mulde" are used almost entirely for arable farming. The sites can still be described as marginal. Shrubs along water bodies, hedges and orchards are the typical landscape structures.

The farms in the study area are generally small in size and form, with some exemptions, primarily a sideline income. The average livestock density is comparatively low at 0.5 livestock units (LUs) per hectare. Due to the occurrence of extremely rare species the area is a Fauna-Flora-Habitat-area (FFH) "Hohe Rhön", part of the European network Natura 2000. Furthermore, the region is also protected as biosphere reserve "Rhön", from which the "core zone" and the "management zone" are depicted in Figure 3.

2.2 Methodical approach of a spatially explicit DEA

For calculating the agricultural contribution to environmental services and to the benefits for landscape, the Data Envelopment Analysis (DEA) is used. DEA is a non-parametric mathematical programming approach enabling the comparison of the efficiency of production performances.

2.2.1 Suitability of the DEA approach

By using the DEA approach, it is possible to consider multiple inputs and outputs which can have different units. Consequently, even factors which cannot (or only at great expense) be expressed in monetary units can be included in the assessment (see e.g. Kantelhardt and Eckstein, 2007). Thus, this technique allows integrating multiple environmental aspects such as the avoidance of soil erosion, the prevention of nitrate leakage and the conservation of biodiversity.

The production performance is rated by calculating the output-to-input ratio of the respective production processes; the less input required for producing a given output or the more output produced with a given input, the higher the efficiency score. Our study is based on analysing single plots. The final efficiency score is derived within a DEA by benchmarking the output-to-input ratio of an individual plot against the output-to-input ratio of those plots with the best performance (see Cooper et al., 2006). Thus, DEA compares single plots not to the average of the sample, but to the best ones.

At farm level, DEA has been already conducted in several studies to measure environmental efficiency. For instance, Reinhard et al. (2000) calculated the environmental efficiency of Dutch dairy farms and De Koeijer et al. (2002) measured the sustainability effects of Dutch sugar beet growers by taking into account the ecological efficiency. Dreesman (2006) analysed the productivity and the efficiency of agricultural farms, taking into account not only production inputs and outputs but also environmental effects. Kantelhardt and Eckstein (2007) and Kantelhardt et al.

(2009) measured the economic as well as the environmental efficiency of farms dependent on their participation at agri-environmental programmes.

Certainly the quality of environmental services is often plot specific, depending on the single plot management, the specific site conditions or the adjacent area. In our study, we conduct a DEA-efficiency analysis at plot level to investigate the spatial difference of provided ecological services or the contribution to landscape benefits. Thus, the decision is made as to what types and quantities of input (e.g. fertilizers, pesticides) are used and what types and quantities of output are produced at plot level.

To calculate plot efficiencies, the ordinary Charnes-Cooper-Rhodes (CCR) model is used (Cooper et al., 2006). DEA offers the choice between input- or output-oriented value calculations. For our analysis, the output-oriented model was used, which means that the input variables are held constant while DEA tries to maximise the output (Coelli and Rao, 2003). The rationale for doing so is that agricultural production (e.g. yield) should be optimized simultaneously with the provision of environmental goods in our 1st DEA-analysis and the contribution to landscape appearance in our 2nd analysis. According to Kantelhardt and Eckstein (2007), for the provision of agri-environmental services, no economies of scale is assumed. The linear programming (LP) problem to be solved for each plot is as follows:

$$\max_{\phi,\lambda} \phi \tag{1}$$

$$\text{s.t. } -\phi y_i + Y\lambda \geq 0$$

$$x_i - X\lambda \geq 0$$

$$\lambda \in R_+$$

where ϕ is a scalar, λ is a (N x 1) vector of weights, X is a (N x K) matrix of input quantities for all N plots, Y is a (N x M) matrix of output quantities for all N plots, x_i is a (K x 1) vector of input quantities for the ith plot and y_i is a (M x 1) vector of output quantities for the ith plot. Note that the technical efficiency, abbreviated as θ, in this paper is defined as $1/\phi$.

DEA makes assumptions that all objects of investigation are comparable in the case of available means of production and available resources (inputs) and the potential output of products and services (Dyson et al., 2001). As at plot level, the management of arable land and grassland is totally different; we separate the sample of plots into these two main types of cultivation. This means that we calculated two different types of efficiency for grassland plots and two different types of efficiency for arable plots respectively: the environment-oriented technical efficiency, (environmental efficiency) θ_{env} and the landscape-appearance-oriented technical efficiency (landscape efficiency) θ_{land}. For both efficiency values (θ_{env} and θ_{land}) and for both land-use types (grassland and arable land), only the surface area of the plot is used as a single input variable (see Table 1). For calculating the θ_{env}, the total nitrogen application, the nitrogen surplus, the value of biotopes and environmentally sound land-use methods are considered as output variables. On grassland, the yield level was incorporated as additional output variable, in the sense that a high yield potential stands for a high intensity of use. On arable land the use of plant-protection products (PPP) as well as the share of erosion-prone crops was additionally introduced in the calculations.

Table 1

List of considered variables

		Environment-oriented technical efficiency θ_{env}		Landscape-appearance-oriented technical efficiency θ_{land}	
		grassland	arable land	grassland	arable land
input	area	x	x	x	x
output (undesirable)	PPP		x		
	total nitrogen application	x	x		
	nitrogen surplus	x	x		
	grassland yield	x		x	
output (desirable)	landscape elements			x	x
	circumference			x	x
	value of biotopes	x	x	x	x
	share of erosion-prone crops		x		
	crop-rotation elements				x
	environmentally sound land use	x	x		

For calculating θ_{land}, the extent of landscape elements, the circumference of the plot and the value of existing biotopes serve as output variables. Additionally, for the calculation of the θ_{land}-score, the grassland yield is considered for grassland and the number of crop-rotation elements is considered on arable land.

A shortcoming of DEA is that outputs are interpreted as something clearly desirable; consequently, higher output levels result in higher efficiency values. In fact, some of the chosen outputs which affect the environment resources or the landscape appearance represent typical negative external effects. For instance, excess nitrogen application and the application of pesticides are such undesirable outputs considered in our study. Therefore, undesirable and thus negative outputs had to be reversed, in order to be correctly interpreted by DEA (c.f. Scheel, 2000).

2.2.2 Assignment of input and output variables

Our study is conducted by analysing data of the integrated administration and control system (IACS-data) and digital field maps of about 5,800 plots with a unique field identifier (FID) belonging to 95 farms. As object of investigation, the single plot is chosen. Area-specific information sources such as the biotope mapping of the state of Bavaria, the register of protected areas and the land-cover map complete the GIS-Data system. For example, habitats and landscape elements were projected into the parcel map and the respective FID assigned. In addition to the IACS-Data, economic, socioeconomic and environmental indicators at plot level such as yields and N-surplus are calculated from standard data, taking into account the land use and production scheme of the farms, as well as regional statistics and site-specific attributes. In the following, the utilized variables are described *en detail*.

Plant-protection products: The use of PPP is taken from the recommendations by the Bavarian State Institute for Agriculture (LfL and ILB, 2010). For the calculations of the PPP-needs, the appropriate average crop rotation on arable land of the farm is assumed out of the IACS-Data; thus the yield level was taken into account. The amount of PPP is presented in € per hectare, so relative differences between crops are represented.

Nitrogen surplus: The N-surplus refers to the potential nitrogen surplus on agricultural land and provides an indication of potential water pollution due to nitrogen leakage. Water pollution by nitrates is one of the main problems from agricultural activities, because nitrate is well soluble and can easily pass through the soil or via surface runoff into water bodies. For the study, the nitrogen surplus is determined in form of a simplified farm gate balance by calculating the difference between the total need of nitrogen, depending on the cultivated crops and the yield level and the total amount of applied nitrogen (Formula 2)[2].

$$Nbal_{\mathrm{FID}} = (Nsup_{\mathrm{FID}} - Ndem_{FID}) \quad (2)$$

Nitrogen supply: The nitrogen supply is calculated as the total amount of organic (N_{org}) and mineral nitrogen (N_{min}) applied (Formula 3).

$$Nsup_{FID} = N_{org} + N_{min} \quad (3)$$

The amount of N_{org} applied results from the animal husbandry of the farms (see Formula (6) in the Annex), assuming that during application an estimated 60 % is utilized only. The amount of applied N_{min} results from the crop-specific needs in addition to the amount of N_{org}, while leakages as well as the cultivation of legumes are taken into account (Formula 7 in the Annex)[3].

Grassland yield: The input factor yield at harvest constitutes a natural disadvantage of the productivity of the soil and is therefore an expression of the agricultural usability of a parcel. The value is obtained from the Land Registry for each single plot. The calculation basis is the outcome of the soil evaluation mapping of the respective area.

Share of landscape elements: An important aspect for biodiversity is referring to the environmentally significant landscape elements such as border structures, hedges, etc. The basic idea is that a higher incidence and a higher density of structural elements will increase the biodiversity in the landscape. A landscape element is hereby only considered if it is mapped within the IACS database. Not included are, for example, stands of fruit trees and single trees, which are not registered. The indicator describes the area of the landscape element(s) on the single plot.

[2] For detailed calculation steps see Formulas (4) to (9) in Annex I.

[3] Excess quantities of N_{org} are assumed to be distributed pro rata to the farm areas. Where there is a difference between organic fertilizers, accrue and demand is balanced with mineral nitrogen, of course, with the exception of organically producing area.

Circumference: The appearance of a cultural landscape is dependent on the typical structures of the agricultural fields. For example, the image of a landscape with big field sizes is quite different from the appearance of a landscape with fields divided into small sections. Furthermore, some ecologically beneficial landscape elements, such as water trenches or a heavily indented forest edge, prolong circumferences of agricultural plots.

Value of biotopes: Small-scale landscape elements worthy of protection, such as biotopes, are to be included in the evaluation of agricultural environmental benefits. This is especially true since biotopes act as refuges and are important for re-colonization of land after crop rotation or harvest (Riecken et al., 2006). The biotopes were obtained in GIS-format from the Bavarian biotope mapping programme (LfU, 2010). Since the nature-conservation value of a biotope varies in the same habitat type, depending on the local appearance or the species present, the site conditions were further valued according to the habitat types from Annex I species of the FFH-directive.

Crop-rotation elements: Another important aspect of landscape appearance is the diversity of agricultural land management. On arable land an extended crop rotations stand for the improvement of the environment and a varied landscape. To show these benefits, the number of rotation elements is evaluated for arable land.

Environmentally sound land-use methods: Pollutants and nutrient loads of water and soil, as well as biodiversity losses, are - besides other stress factors - rooted in the agricultural land use, with different agricultural practices having varying effects. Agricultural practices which are characterised by a largely sustainable use can contribute significantly in reducing material and structural losses and can strengthen the positive impact on the cultural landscape. The importance of environmentally sound farming practices is underpinned by the support from the public sector in form of AEPs. These programmes promote land-use management practices, following the aim of preserving, maintaining and improving ecologically valuable habitats for rare and endangered species. Participation in AEPs is therefore representative of selected nature-friendly farming methods in the region, e.g. minimum tillage, mulch seeding on arable land or the acceptance of mowing-date obligations or stocking limits on grassland. The selection focuses on popular and the most ecologically effective measures in the region, e.g. the protection of field breeder. In Table 7 in Annex II those farming practices considered environmentally sound and AEPs are summarised. The extent is based on the financial premiums remunerated in current AEP listings[4].

2.2.3 Statistical analysis

To characterise the study area we conduct a statistical analysis of relevant indicators used for the DEA. Furthermore, we analysed some political and social framework conditions in the context of the efficiency results obtained. In particular, we test if there is an influence on the efficiency values whether the plots are located inside or outside different protection zones of the

[4] Current compensation tables from the Bavarian Cultural Landscape Programme ("KULAP") and Contractual Nature Conservation Programme ("VNP / EA") for the year 2010.

biosphere reserve area “Rhön”. Since the analysed data sets were not displaying normality, we applied the non-parametric Kruskal-Wallis H-Test.

Furthermore, we analyse the influence of the compensatory allowance on environmental or landscape benefits. We complete our statistical analysis by a correlation between the obtained efficiency values; θ_{env} and θ_{land}.

3 Results

3.1 Statistical analysis of data

Table 2 summarises the results of the statistical analysis of the chosen input and output variables. One can see that in general the plot size is very small in the study region. This is due to the mountainous topography and the unfavourable land tenure. With an average plot size of 1.3 ha on arable land and only 0.9 ha on grassland, the fragmented characteristic of the landscape becomes imaginable. The ratio between circumference and plot size highlights the unfavourable production conditions but is also an expression of the high potential of the area for biodiversity and landscape values.

Table 2

Statistical description of input and output variables

variable		grassland	arable land
number of plots		2,994	2,844
plot size (ha)	mean	0.9	1.3
	SD	1.56	1,42
circumference per plot size (m/ha)	mean	928	587
	SD	733	340
PPP – plant-protection products (EUR/ha)	mean		62
	SD		33
nitrogen use (kg/ha)	mean	48	123
	SD	88	59
nitrogen surplus (kg/ha)	mean	53	26
	SD	263	100
grassland yield (dt/ha)	mean	45	
	SD	16	
agri-environmental measures (€/ha)	mean	180	25
	SD	473	154
number of cultivated crops	mean		6,8
	SD		1,9
share of erosion-prone cultures (%)	mean		0.07
	SD		0.12
value of biotope (points)	mean	1.45	0.23
	SD	1,61	0.43
landscape element (ha)	mean	0.007	0.003
	SD	0,040	0.018

In general, due to the bad growing conditions, the use of PPP and nitrogen is at a low level. Remarkably, although the total application of nitrogen is higher on arable land, on grassland there is a larger surplus. This indicates even worse growing conditions on grassland, which can be confirmed by an average yield of only 45 dt/ha grassland. The remuneration for participation in AEP is considerably higher on grassland than on arable land. This is because the requirements for the grassland measures are comparatively higher, as the use of mineral fertilizer is totally prohibited and a limit of livestock units must be complied with.

On arable land, the number of cultivated crops is an indicator for landscape diversity. One can see that with an average of seven different crops and a share of erosion-prone cultures – e.g. corn or turnips – of only 7 %, the level of production is generally not very intensive. As regards the structural richness, on both field-types there are only a few landscape elements, but on the grassland, the biotope-value is higher.

3.2 General efficiency results

3.2.1 Environment

The mean environmental efficiency θ_{env} for grassland and arable land are quite similar, reaching 0.58 and 0.46 respectively. However, it is remarkable that the spread of efficiency scores seems to be much wider on arable land than on grassland. In particular the probability for the occurrence of very low efficiency values is higher on arable land. Possibly, the wide range of intensive farm management on the one hand and the participation in AEP on the other hand becomes visible in the spread of efficiency scores on arable land. In contrast, the range of efficiency scores on grassland is narrower, because the possible grassland management regimes are, due to their low site quality conditions, similar in their intensity.

Table 3

Environment-oriented technical efficiency θ_{env} of land-use type

	grassland	arable land
mean	0.58	0.46
min/max	0.09/1.0	0.00/1.0
SD	0.17	0.20

The spatial distribution of the environmental efficiency values is presented in Figure 4. Regarding the grassland plots, which are mainly located in the western part of the study region, the minor heterogeneity of θ_{env} is typical. This indicates that the site conditions, as well as the management of the grassland plots, are of lower diversity. Only a few plots are noticeable in the sample for high environmental services. By analysing the share of plots which reach efficiency scores above average, it becomes clear that only 35 % of the plots are above average. This emphasizes the outstanding performance of only a few plots which provide environmental services.
In Figure 4 one can see a bigger heterogeneity in environmental efficiency scores θ_{env} on arable land in the form of a patchwork of different scores side by side. This indicates that on arable land a wider range of production intensities – depending, for example, on crop rotation – have

external effects. The analysis of the environmental efficiency date shows that on arable land 44 % of the plots are above average. This reasonably high amount demonstrates that on arable land, other than on grassland, there are some quite badly performing plots which reach only relatively low efficiency scores.

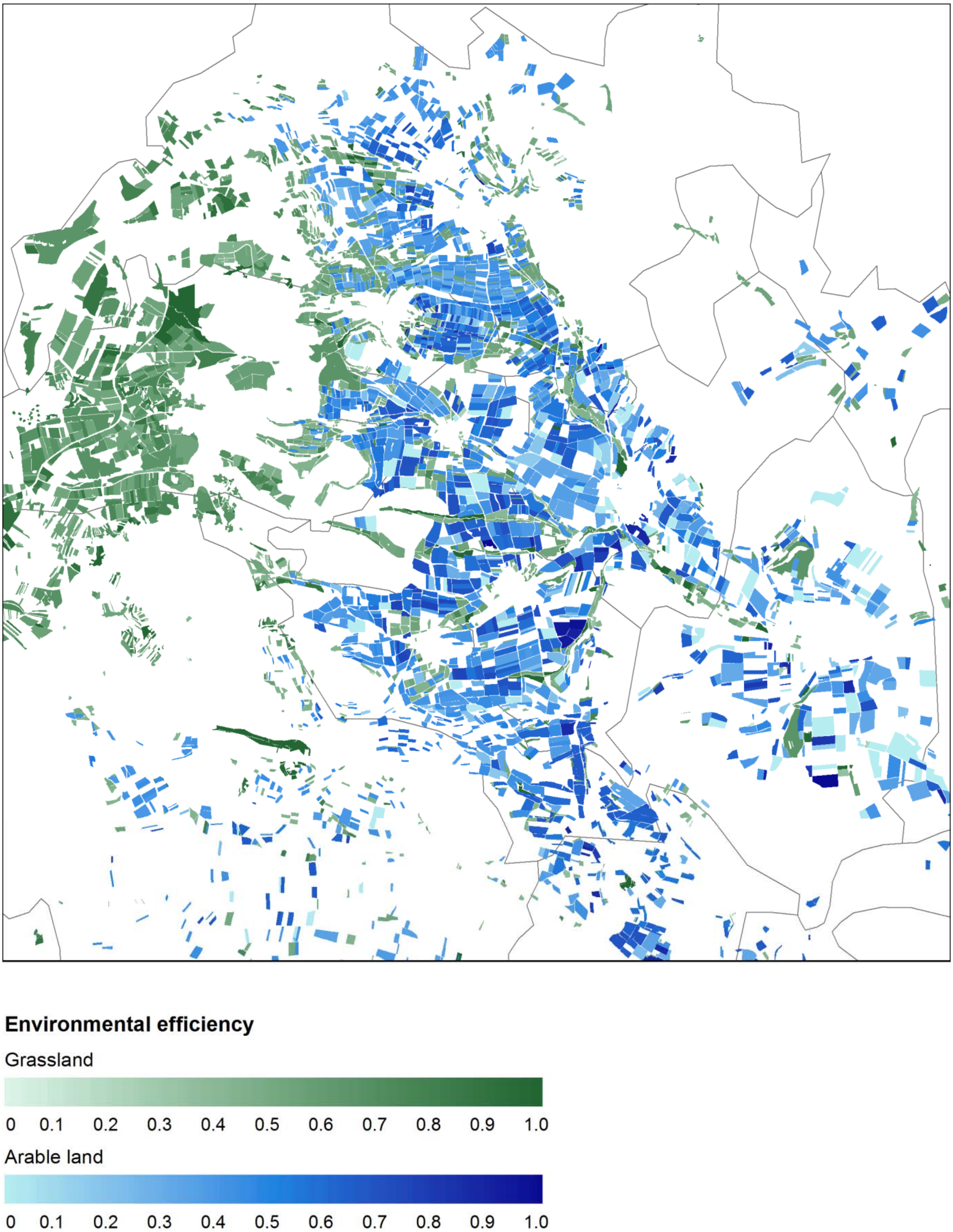

Figure 4: Environment-oriented technical efficiency values in the study region “Rhön”.

3.2.2 Landscape

The mean landscape efficiency values θ_{land} are shown in Table 4. Here the mean efficiency of the two land-use types is quite different. While the mean efficiency on grassland is about 0.42, on arable land only a score of 0.16 is reached. The very low mean efficiency scores on arable land

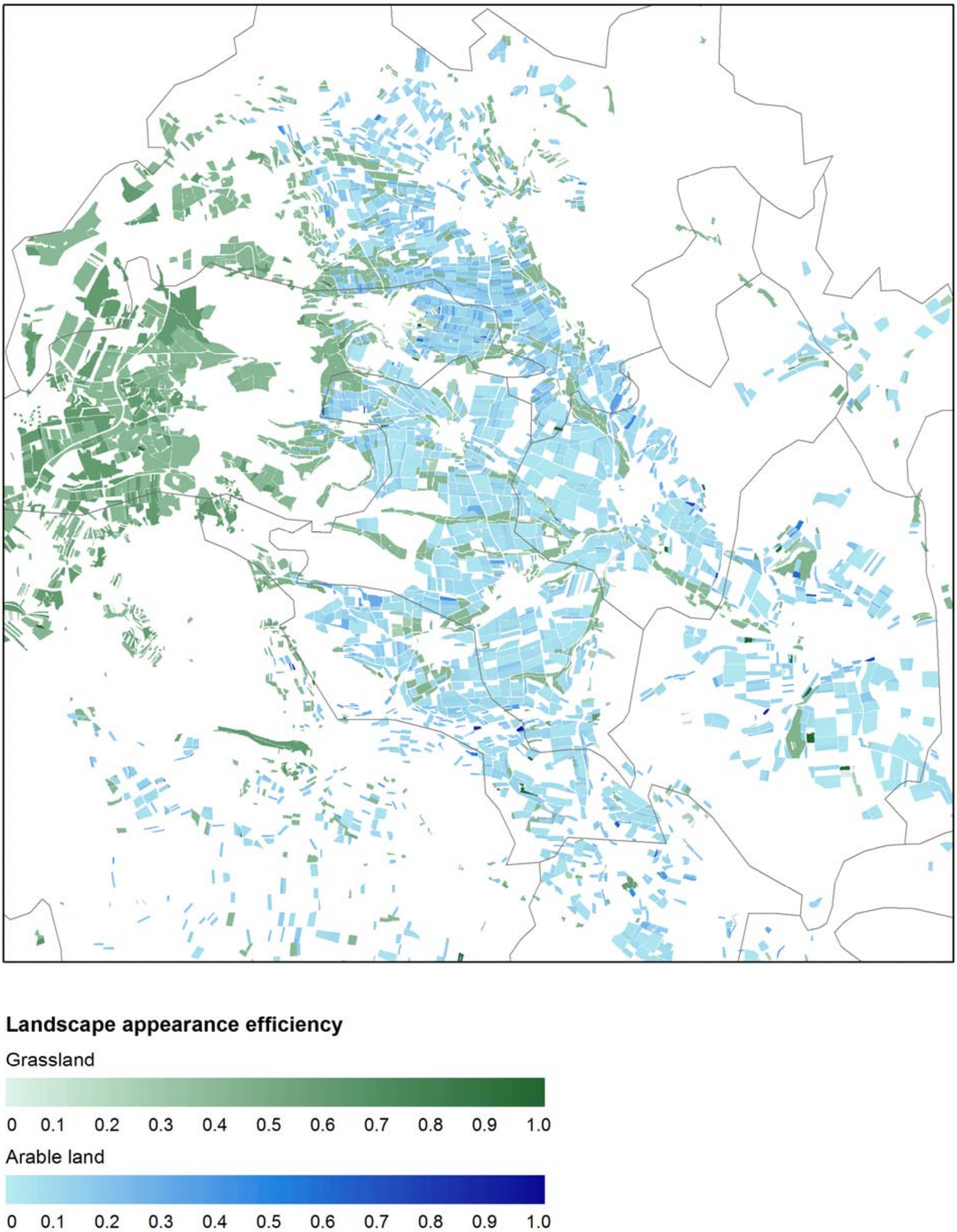

Figure 5. Landscape-appearance-oriented technical efficiency in the study region "Rhön".

show the low potential of getting landscape-improving services on arable land. This is due to the fact that only a few plots reach high landscape efficiency and therefore set the benchmark. However, the majority of the plots cannot reach such levels of efficiency as some of their attributes;, like circumference-area ratio and share of landscape elements, cannot be influenced by the farmer. Consequently, "normal" plots of arable land cannot reach high efficiencies. On grassland, the more homogeneous situation of site specifications and quality reveals that improvements in production conditions are less important, especially on grassland with only low frequency of use because of the low yield potential.

Table 4

Landscape-oriented technical efficiency θ_{land} of land-use type

	grassland	arable land
mean	0.42	0.16
min/max	0.03/1.0	0.03/1.0
SD	0.14	0.11

Figure 5 presents the spatial distribution of the landscape efficiency scores on grassland and on arable land. The comparison shows that there is only little heterogeneity in landscape efficiency scores for both land-use types. On arable land there is a share of 39 % of the plots above average, which is not surprising as the average is at a very low level. On grassland only 18 % of the plots are above average. Here only a few plots seem to reach very high efficiency scores, whereas the majority of the plots reach a mean performance.

3.2.3 Influence of political and social conditions

In the following detailed analysis, the influence of protective areas on environmental and landscape efficiency is analysed first. For this, the efficiency results in three protection zones are compared. These are: the area outside the biosphere reserve area, the management zone and the core zone of the biosphere reserve area[5].

The results show that on grassland there is indeed a gradient of efficiency values in ascending order from the outside of the biosphere reserve to the core zone of the reserve. This is true for both the θ_{env} and θ_{land} and these results are statistically significant (Table 5). In this study area, the grassland of high ecological quality concentrates in reserve areas. For their maintenance agricultural land use is necessary but often of low profitability. Ecologically and site-quality specific payments might contribute to assuring a low-intensive land use in ecologically sensitive areas. In the case of arable land, in both efficiency values there seem to be only a few differences between outside and the management zone of the biosphere reserve area, a fact which is not significant. This might be a consequence of rather low legal restrictions in the management zone.

[5] It should be noted that, in the core zone of the biosphere reserve area, there is no arable-land cultivation.

Table 5

Efficiency scores in different zones of the biosphere reserve area

	Environment-oriented technical efficiency θ_{env}		Landscape-oriented technical efficiency θ_{land}	
	grassland	arable land	grassland	arable land
outside	0.50	0.45	0.34	0.15
management zone	0.57	0.46	0.42	0.16
core zone	0.65		0.47	
mean	0.58	0.46	0.42	0.16
p-value*	0.000	0.459	0.000	0.060

Notes: * Kruskal-Wallis H-Test

The study region represents a typical remote rural area suffering from depopulation and decline. Natural handicap payments should enforce farmers to continue the use of agricultural land use and in such areas in order to assure a sustainable development of maintaining the countryside. Therefore an analysis of the influence of natural handicap payments on agricultural land use makes sense. Table 6 shows the results of the non-parametric correlation tests:

Table 6

Correlation between efficiency scores and natural handicap payments

	Environment-oriented technical efficiency θ_{env}	Landscape-oriented technical efficiency θ_{land}
grassland	0.205**	0.227**
arable land	-0.038*	-0.654**

Notes: * correlation significant on 0.05 level, ** correlation significant on 0.01 level

One can say that on grassland the correlation between natural handicap payments and environmental, as well as landscape efficiency, is very weak. This means that according to our plot sample, natural handicap payments only have a small influence on the provision of environmental services.

Regarding arable land environmental efficiency and natural handicap payments do not correlate. However, there is clearly a negative correlation between natural handicap payments and landscape performance of -0.65. This means natural handicap payments encourage a farmer to keep marginal agricultural land in use and avoid abandonment but do not enforce a diverse landscape, e.g. by a less intensive use and a wider crop rotation.

In this context one has to be aware that the whole study region can be characterised as very marginal. If the sample were also to include high-yield sites, the results might differ.

3.2.4 Correlation of environmental and landscape efficiency

Environmental services and a pleasant landscape appearance are requirements of society which are assumed to occur together. Although the occurrence of both together is likely in small structured areas like the "Rhön", one cannot deduce that a plot contributes to both at the same level of intensity. In the following analysis we investigate the spatial distribution of those plots which contribute to only a single efficiency value, to both or to none of the calculated efficiency scores.

Figure 6 shows the distribution of the plots which are classified in the following four categories: (a) landscape efficiency and environmental efficiency above average; (b) landscape efficiency above average; (c) environmental efficiency above average; and (d) both efficiency values below average.

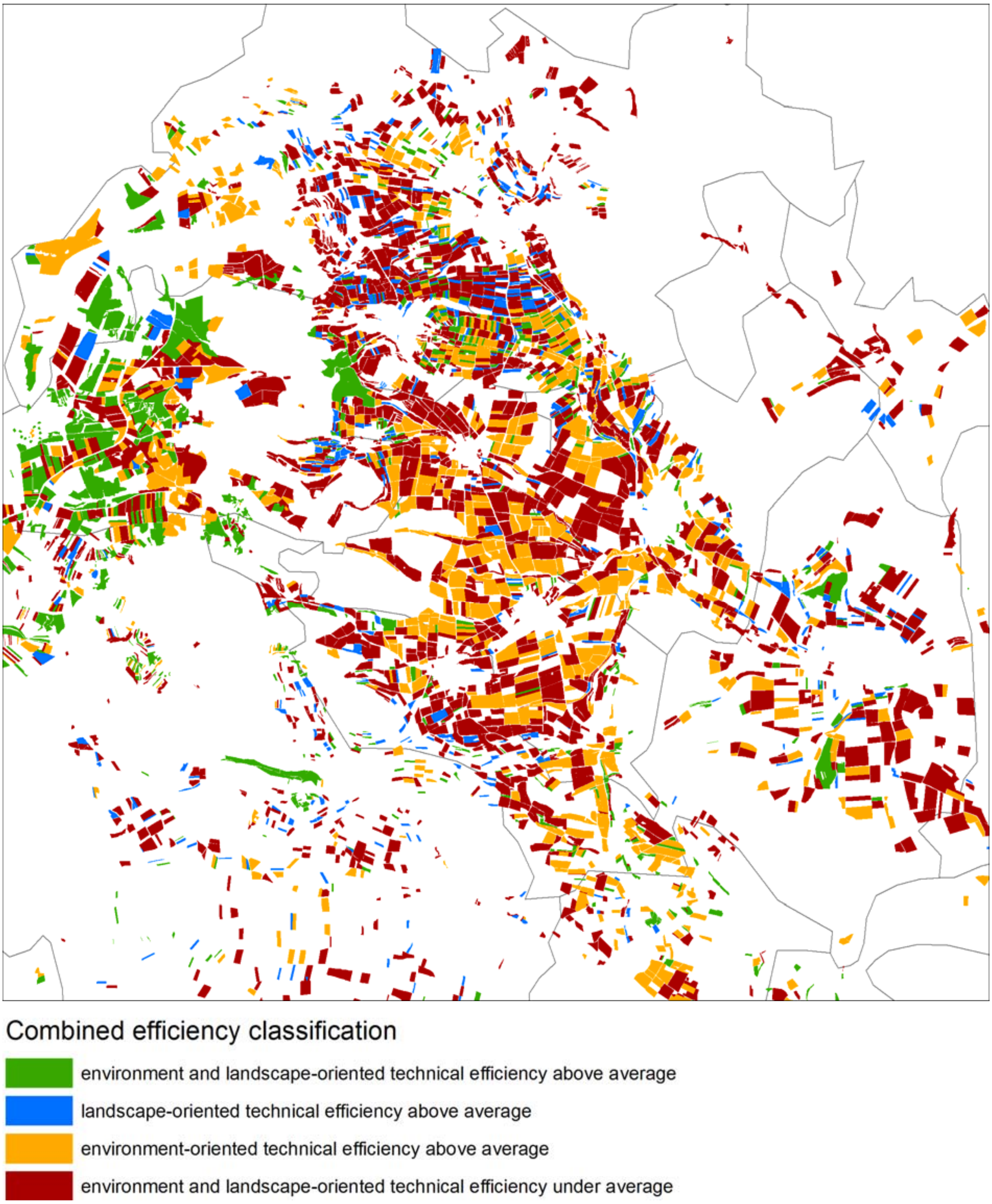

Figure 6. Combined efficiency classification in the study region “Rhön”.

It becomes clear that the plots which are in (a), i.e. both categories above average, are mainly located in the western part of the grassland dominated biosphere reserve area. The plots which are in (d) are mostly arable land. There are only few plots which are solely above average in landscape efficiency and not in environmental efficiency, as those two performances are often correlated with each other. A high correlation index of 0.529 between environmental and landscape efficiency can be seen especially on grassland plots. In contrast, plots with solely above-average environmental efficiency are widespread in arable land as well as on grassland.

4 Conclusion

First of all, the calculated environmental efficiency values θ_{env} on grassland plots are significantly higher than on arable land. However, on arable land there seems to be a much wider range from very low to very high values. This leads one to the conclusion that there is more potential for improvements of the θ_{env}. on arable land. The already well-established θ_{env} on grassland needs to be at least maintained at the current levels.

Secondly, in the core zone of the biosphere reserve, "Rhön" grassland sites reach higher effectiveness, both in terms of environmental and landscape efficiency, as the analysis of variance has shown. The results also show that the higher the reserve status, the higher the environmental efficiencies and the landscape efficiencies, at least on grassland. This result highlights the distinct relevance the establishment of protected areas, particularly as a non-economic tool for grassland conservation. Agriculture must thereby become an integral part of the protection plan, as the cultural landscape is obtained only by a consistent land use. It should even be thought about how the positive externalities for nature and landscape could be internalised even better. However, targeted support would go way beyond current AEP and therefore requires careful examination and appropriate integration into existing programmes.

Another approach to support those areas of high environmental and landscape quality is currently discussed in respect of the future of the direct payments. The results of our study support the efforts by the EU to bind direct payments more strongly to the specific provision of positive external effects for the environment and landscape.

With regard to the methodical approach, it must be mentioned that the choice of relevant variables of input and output depends one hand on the availability of data. On the other hand it is important to be aware of the state which is socially desirable. This is especially true for the landscape-oriented efficiency. The choice of the variables which are taken into account must be oriented on the desirable appearance of the considered landscape. For example, if there are many fallows which are overgrown with bushes and trees there seem other variable suitable than in an area with an emptied and monotone landscape.

In general, our single-plot approach allows seeing the influence of the natural conditions which typically vary from region to region or even from plot to plot. Thus, the unequal agricultural production conditions which are outside the farmers' responsibility are taken into account. Furthermore, it becomes possible to analyse the spatial distribution of the supply of externalities, so it is possible to work out "production areas" and suitable "protection areas". This could be a basis for a number of applications and further methodological developments.

5 Literature

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Annex I

The derivation of variable $Ndem_{FID}$(total nitrogen demand) for each single plot is done via the nitrogen requirement of crops cultivated and the respective yield level.

$$Ndem_{FID} = \sum A_{FID} \times (Sh_{PV} \times Y_{PV,FID} \times cN + \begin{cases} 30\ wennif(PV <> Legume\ or\ ext.grassland \\ 0\ other \end{cases} \quad (4)$$

$Ndem_{FID}$	N-demand of plot in kg
Sh_{PV}	share in type of crop production on the total area of field plot
A_{FID}	area of field plot in ha
$Y_{PV,FID}$	yield of production method on field plot in dt/ha Y_{PV}, *FID=f (LSK, yield statistics)*
cN	N-content in harvest in kg N / dt (for legumes N from symbiotic N-fixation is accounted for)
PV:	Type of crop

$$orgNsup_{FID} = \frac{orgNsup_{BNR} \times A_{FID}}{A_{BNR}} \quad (5)$$

$orgNsup_{FID}$	organic N-supply in kg
A_{BNR}	area of farm in ha

$$orgNsup_{BNR} = \sum Q_{Hus} \times orgN_{HUS} \times (1 - SL) \quad (6)$$

$orgNsup_{BNR}$	organic N-supply in kg of the farm
Q_{Hus}	quantity husbandry each animal species , yearly average
$orgN_{HUS}$	organic N from husbandry per LU in kg
SL	storage loss (15 %)

$$minNsup_{FID} = \begin{cases} 0\ if\ organically\ farmed\ or\ orgNsup_{FID} \times (1 - FL) \times OR > Ndem_{FID} \\ Ndem_{FID} - orgNsup_{FID} \end{cases} \quad (7)$$

$minNsup_{FID}$	mineral N-supply on field plot
FL	field loss (10 %)
OR	occupancy rate (plant availability) org. N (70 %)

The $Ndem_{BNR}$ (N-demand) of each farm was calculated as in Formula 8.

$$Ndem_{BNR} = \sum Ndem_{FID} \quad (8)$$

$Ndem_{BNR}$ N-demand of farm in kg

The remaining emissions of nitrogen to the soil, groundwater and surface water, as well as into the air, are taken into account in the form of a static loss rate. This also includes losses in the form of ammonia. The biological nitrogen fixation by legumes and the atmospheric deposition are left aside for the calculation, in particular, since atmospheric deposition of nitrogen results partly from the non-agricultural sector.

$$Nsup_{FID} = minNsup_{FID} + orgNsup_{FID} \quad (9)$$

$Nsup_{FID}$ N-supply in kg on field plot

Annex II

Table 7

Impact ranking of environmentally friendly farming practices from low to high associated costs

Arable land management	Grassland management
- Slurry injection (1.50 €/m3; 28 €/ha) - Winter greening (80 €/ha) - Mulch seeding (100 €/ha) - Reseeding and maintenance of 10 to 30 m wide green belts along water bodies (110 €/ha) - Agro-ecological agricultural use flowering areas (200 €/ha) - Extensive cropping for field breeders and segetal plants (275 €/ha) - Conversion of cropland to grassland along waterways and other sensitive areas (400 €/ha)	- Summer grazing for cattle (30 €/LU; 39 €/ha) - Mowing date after June 1st (85 €/ha) - Mowing date: later than 15. June (50 €/ha) - Extensive pasture use (110 €/ha) - Abandonment of mineral fertilizers max. 1.76 LU/ha principal forage area (150 €/ha) - Implementation of agro-ecological approaches to grassland (150 €/ha) - Mowing date after August 1st (175 €/ha) - Abandonment of mineral fertilizers max. 1.40 LU/ha principal forage area (180 €/ha) - Mowing date after September 1st (220 €/ha) - Extensive use of grassland along waterways and other sensitive areas (abandonment of fertilizers & PPP), (350 €/ha) - Mowing meadows on steep slope 35 – 49 % (400 €/ha) and above 50 % (600 €/ha)

Notes: LU = livestock units