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Do farmers provide agri-environmental services efficiently? – An economic analysis.

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Abstract

Agricultural land use does not only concern farmers, but also has a large number of social and environmental effects. Consequently, it is to be assumed that farmers have to use financial resources as well as labour in order to provide these services. Using the nonparametric method of Data Envelopment Analysis (DEA), we calculated the economic as well as the ecological efficiencies of farms and examined whether farms are able to succeed in combining ecological and economic efficiency. In addition to this analysis, we studied the driving factors of the respective efficiencies. The study was carried out in four typical production regions in Bavaria which vary in their proportions of grassland as well as their yield potential; thus, the study regions reflect a gradient of agricultural land use which is typical for Southern Germany. In all regions, a farm survey was conducted covering a total of 122 farmers.

Key words

agricultural land use, data envelopment analysis, ecological efficiency, economic efficiency

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Introduction

Agricultural land use affects the quality of environmental resources in various ways. For instance, it influences the quality of abiotic resources such as soil and water and plays a vital role in the shaping of cultural landscapes (c.f. HEIßENHUBER et al. 2003; 2004). Agri-environmental services are, in most cases, coupled to conventional agricultural production processes. Nevertheless, the provision of these services often involves financial expenditures for the farmers. For instance, in order to maintain landscape elements, farmers have to bear a higher working load as well as economic disadvantages because of not being able to use the most modern technology (c.f. KAPFER et al. 2002; 2003).

One can conclude that farmers who attach great importance to agri-environmentally sound production cannot use their financial as well as their labour resources exclusively for conventional production but have to also invest them in the provision of agri-environmental services. It is assumed that the performance of the respective farms would be reduced if an efficiency assessment were exclusively limited to conventional indicators and did not consider environmental aspects. Consequently, various authors demand that conventional efficiency calculations are complemented with environmental indicators (c.f. LATACZ-LOHMANN 2004).

A suitable method with which such an economic-ecological assessment can be conducted is the Data Envelopment Analysis (DEA). This technique allows integrating economic as well as environmental aspects and helps to distinguish between efficient and less efficient farms. Furthermore, DEA can be applied to identify model farms which may be useful in understanding how environmentally sound land cultivation can be promoted.

The central aim of this study is to analyse to what extent the provision of non-market goods influences the economic efficiency of farms. In particular, we investigated if farms are able to succeed in combining ecological and economic efficiency. In addition to this comparison, we analysed potential driving factors for the respective efficiencies (farm size, regional dependencies, and full-time/part-time farming). In order to answer these questions, we applied a two-step approach. In the first step, we calculated the overall, the ecological and the economic efficiencies of farms using a data envelopment analysis (DEA). In the second step, we analysed our results from a statistical point of view.

2. Using DEA for agricultural land use assessment

DEA is a nonparametric mathematical programming approach enabling the comparison of production performances of so called Decision Making Units (DMU). Their performance is rated by calculating the output-to-input ratio of the respective production processes; the less input a DMU requires for producing a given output or the more output it produces with a given input, the higher is the efficiency of the DMU. The final efficiency score is derived within a Data Envelopment Analysis by benchmarking the output-to-input ratio of an individual DMU against the output-to-input ratio of all best working DMUs. These DMUs are part of an envelope forming a reference frontier for the benchmark process (c.f. COOPER et al. 2007). Thus, DEA compares single DMUs not to the average DMU, but to best practise DMUs.

When DEA is applied to agriculture, the DMUs are represented by farms. Here the decision is made as to what types and quantities of input (e.g. fertilizers, pesticides, machines or working units) are used and what types and quantities of output are produced. In the literature, there are a number of studies analysing the efficiencies of farms. For instance, BALMANN and CZASCH (2001) calculated and compared the economic efficiencies of East German farms. REIG-MARTINEZ and PICAZO-TADEA (2004) estimated the economic efficiencies of Spanish citrus farms in order to identify best practice farms. Numerous studies also consider agri-environmental aspects. 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.

From the point of view of an agri-environmental assessment, a notable strength of DEA is that it allows for the consideration of multiple inputs and outputs while not requiring identical units. Consequently, even factors which cannot (or only at a high expense) be expressed in monetary units can be included in the assessment. A shortcoming of DEA concerning environmental assessments is that outputs are interpreted as something clearly desirable; consequently, higher output levels result in higher efficiency values. However, environmentally relevant outputs of agricultural production activities are frequently undesirable from a human point of view. For instance, the emission of carbon dioxide, methane and nitrous oxide contributes to global warming; soil erosion endangers agricultural productivity. In order to enable a proper integration of negative environmental outputs into DEA calculations, the literature discusses two main approaches (c.f. SCHEEL 2000). The first approach is of an indirect manner; the formal structure of the DEA model is not changed, yet undesirable outputs are interpreted by changing the mathematical sign or by integrating it into the model as an input. In contrast to the indirect approach, the direct approach alters the DEA model; in effect, it assumes that undesirable outputs are only weakly and not strongly disposable.

In addition to methodical problems regarding the proper integration of environmental aspects, DEA makes further assumptions with fundamental relevance for land use analysis. DEA assumes that all DMUs are engaging in similar activities and producing comparable products or services. Furthermore, it expects all units to have a similar range of available resources (DYSON et al. 2001). Both assumptions are not fully accurate in the context of agricultural land use, particularly in the case of the latter assumption. It should be emphasized that the natural conditions typically vary from region to region or even from plot to plot. This leads to unequal agricultural production conditions, resulting in a significant variability in farm efficiency which is beyond the farmers' responsibility.

3. Method

3.1 Methodical approach

In order to calculate farm efficiencies, we use the ordinary Charnes-Cooper-Rhodes (CCR) model (c.f. COOPER et al. 2007, p. 42). This DEA-model can be either input- or output-oriented. In the input-oriented case, DEA defines the frontier by seeking the maximum possible proportional reduction in input usage, with the output levels held constant. In the output-oriented case, the input levels are held constant while DEA tries to maximise the output (c.f. COELLI and RAO 2003). In accordance with COELLI and RAO (2003), we selected the output-oriented CCR model, since the main goal in agriculture is generally to maximize the output rather than to minimize the input. However, it should be emphasized that with either output or input orientation the technical efficiency scores will be the same unless variable returns to scale are assumed.

The linear programming (LP) problem to be solved for each farm is as follows:

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

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

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

$$\lambda \in R_+ ,$$

where ϕ is a scalar, λ is a Nx1 vector of weights, X is a NxK matrix of input quantities for all N farms, Y is a NxM matrix of output quantities for all N farms, x_i is a Kx1 vector of input quantities for the i-th farm and y_i is a Mx1 vector of input quantities for the i-th farm. Note that the technical efficiency θ applied in this paper is defined as $1/\phi$.

Using this model, we calculated different types of efficiencies: the overall efficiency θ_{All}, the ecological efficiency θ_{Ecol} and the economic efficiency θ_{Econ}. In case of θ_{All}, we considered all categories of input and output activities as shown in Figure 1. On the input side, this includes the land input X_{Land} and the economic inputs X_{Econ}, which basically summarizes all resources the farmer needs to run his farm, as well as the undesirable environmental inputs X_{Ecol}, which consist of negative environmental effects of agricultural activities. On the output side, we consider economic outputs Y_{Econ} as well as desirable environmental outputs Y_{Ecol}.

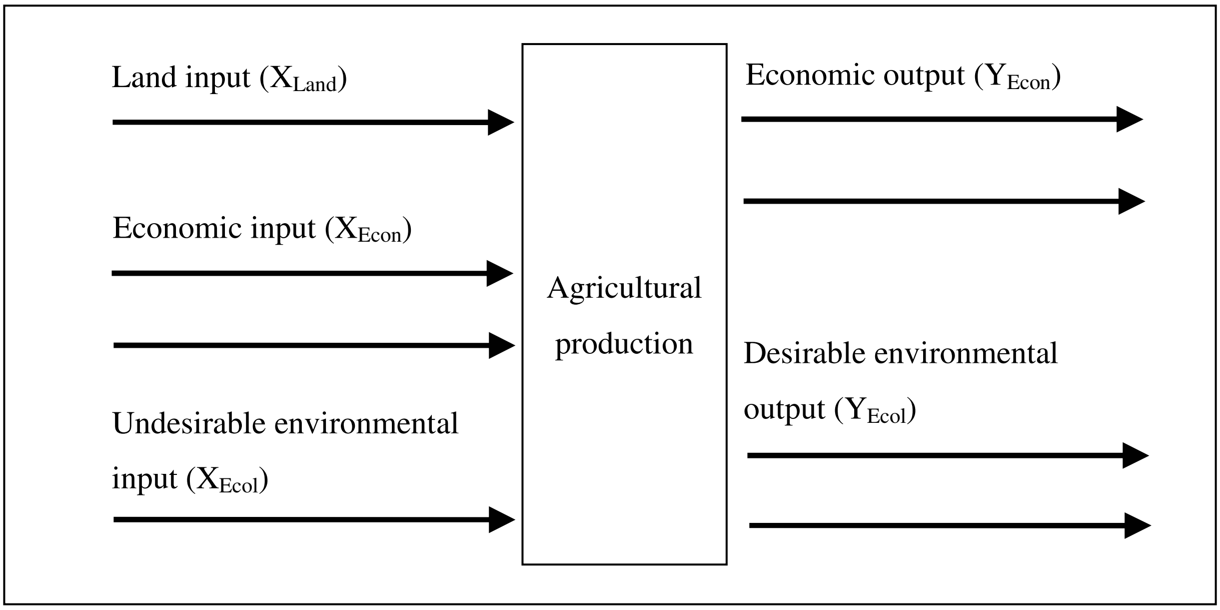

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Figure 1: Schematic depiction of output and input categories

In case of the ecological efficiency θ_{Ecol}, we excluded the economic factors from our calculations and focused on ecological aspects. Thus, we included the undesirable environmental input X_{Ecol}, the desirable environmental output Y_{Ecol} and land input X_{Land}.

When calculating the economic efficiency θ_{Econ}, we considered only the land input X_{Land}, the economic inputs X_{Econ} and the economic outputs Y_{Econ}. Undesirable environmental inputs and desirable environmental outputs were not included in this calculation.

In addition, in the case of economic efficiency, we calculated the Banker-Charnes-Cooper (BCC) model (c.f. COOPER et al. 2007), which incorporates size effects by modelling variable returns-to-scale (VRS). The corresponding model θ_{Econ_vrs} is defined as follows:

$$\max_{\phi,\lambda} \phi \tag{2}$$

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

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

$$e\lambda = 1$$

$$\lambda \in R_+ ,$$

to which is formula 1 with the added constraint $e\lambda = 1$ is added. Again it should be noted that also in this case the technical efficiency θ is defined as 1/ϕ.

The efficiency measure θ_{Econ_vrs} was calculated exclusively for the economic measure, since relevant size effects are only expected within the field of agricultural production and not for the provision of agri-environmental services such as low-intensity use areas and landscape elements.

In the second step of our analysis, we analysed our results from a statistical point of view. In particular, we tested if there were differences in efficiency between groups of farms. As criteria for determining such groups we used the affiliation to study regions, size classes as well as part-time/full-time farming. Since the analysed data sets were not displaying normality, we applied non-parametric tests. These are in case of more than two groups the Kruskal Wallis test and in case of only two groups the rank-sum test of Mann and Whitney.

3.2 Selection and description of input and output variables

A fundamental requirement regarding the set of input and output variables is that they should cover the full range of resources used. Moreover, all relevant activity levels and performance measures should be captured (DYSON et al. 2001). However, the number of input and output variables is to be kept at a distinctly smaller level than the number of DMUs. Otherwise, too many DMUs will appear efficient and no relevant conclusions are possible. DYSON et al. (2001) suggest in this context that the number of DMUs should be at least twice the product of the number of input variables and the number of output variables.

The selection of variables is often limited due to missing data. This applies in particular to environmental data, where a pragmatic definition of input and output variables is often necessary. For instance, there are no generally accepted indicators for the measurement of landscape aesthetics or biodiversity with a reasonable input of effort. A pragmatic way to assess these aspects is e.g. to measure the density of hedgerows and other landscape elements (c.f. KANTELHARDT et al. 2003).

Table 1 gives an overview of the selected input and output variables. The table furthermore shows to which categories and efficiency measures the variables have been assigned to. Altogether nine variables have been chosen. As discussed before they are classified into land input, economic input, undesirable environmental input, economic output and desirable environmental output.

Table 1: Selection of indicators and assignment to categories and efficiency measures

Category	Indicator	Assignment to efficiency measures		
		θ_{All}	θ_{Ecol}	θ_{Econ}, θ_{Econ_vrs}
Land input	Land (ha)	x	x	x
Economic input	Labour (Hours per year)	x		x
	Capital (EUR)	x		x
	Operational Cost (EUR/year)	x		x
Undesirable environmental input	Nitrogen (kg N)	x	x	
	Crop-type factor	x	x	
Economic output	Revenue (EUR/year)	x		x
Desirable environmental output	Low intensity use area (ha)	x	x	
	Landscape elements (ha)	x	x	

Source: own figure

The utilized agricultural area was chosen as the land indicator. The indicator as well as the method to calculate it is briefly presented in the following statement:

- The factor UAA sums up both classes of **utilized agricultural areas** of arable land A_{AL} and grassland A_{GL}; it includes leased and non-leased land:

$$UAA = A_{AL} + A_{GL.}$$

As indicators for the economic input, labour, capital asset and operational costs were chosen. These indicators sum up all the basic inputs required to run a farm:

- The factor C summarizes the **capital costs** arising on a farm. In order to reflect the yearly expenses, the values of the capital assets are depreciated (c.f. BALLMANN et al. 2001). The formula for calculating C is

$$C = C_M + C_B \ , \tag{3}$$

where C_M is the depreciated capital value of machinery and equipment and C_B the depreciated capital value of buildings. The depreciation periods are 10 years for machinery and equipment and 20 years for buildings, respectively.

- The factor O covers all **operational costs** which arise on a farm in the short-term:

$$O = O_{Energy} + O_{PP} + O_{Fert} + O_{Fodder} + O_{HMach} + O_{Animal} \ , \qquad (4)$$

where O_{Energy} stands for energy costs (fuel and power supply), O_{PP} for plant protection, O_{Fert} for fertilizers, O_{Fodder} for purchased fodder, O_{HMach} for hired machinery and O_{Animal} for purchased animals.

- L summarizes the **labour** rendered by the farm family L_{Fam} and employees L_{Emp} in one year:

$$L = L_{Fam} + L_{Emp} \ . \qquad (5)$$

Hired machine work is not included in this factor.

As indicator for undesired environmental input, we used the farms' nitrogen input and the crop-type factor:

- N considers mineral and organic **nitrogen**:

$$N = N_{Min} + N_{Org} \ , \qquad (6)$$

where N_{Min} summarizes the nitrogen input by all types of mineral fertilizers, while N_{Org} is calculated on the basis of the prevailing stocking rate of the farm. In the narrow sense, N indicates the risk of water pollution (by nitrogen) and air pollution (by nitrous oxide). In the wider sense, N stands for the general land use intensity and potential pollution risks.

- CF shows the potential risk of soil erosion. It is calculated in dependence of the proportion of erosive crops in crop rotation, measured by the **crop-type factor** of the universal soil loss equation (c.f. SCHWERTMANN et al., 1987). It is:

$$CF = C_{AL} * A_{AL} + CF_{GL} * A_{GL}$$

where CF_{AL} is the crop-type factor of the specific crop rotation on the farm, A_{AL} the area of arable land, CF_{GL} the crop-type factor of grassland and A_{GL} the area of grassland.

On the output side, there is one economic indicator, the yearly revenues achieved by a farm:

- R summarizes the **revenues** achieved with animal R_{Animal} and crop R_{Crop} production:

$$R = R_{Animal} + R_{Crop} + R_{AEP} + R_{DP} + R_{LFA} \quad (7)$$

R furthermore considers subsidy payments granted to the farm. This includes the payments for agri-environmental programmes R_{AEP}, as well as the less-favoured area payments R_{LFA}. In addition, the direct payments R_{DP} of the European Union are included in R, since these payments had not been decoupled at the moment of the farm survey and are thus of extraordinary importance for the organization of the farms.

As the environmental indicators on the output side, we selected the low-intensity use area and the area covered by landscape elements:

– The factor LI covers all **low-intensity use areas**:

$$LI = LI_{Al} + LI_{Gl} \ , \quad (8)$$

where LI_{Al} is the total amount of arable land which is cultivated with all cereals except wheat, winter barley and triticale. It may be cultivated with grain legumes, peas, clover or ryegrass or may be set-aside. LI_{Gl} is the total amount of low-intensity use grassland, such as meadows and pasture with a maximum of two yields per year.

– The factor LE considers the endowment of the farm with **landscape elements**. In detail, LE summarizes the area covered by hedges and groves LE_{Hedge}, wetlands LE_{Wet} such as ponds and reed and other landscape elements LE_{Oth} such as fringes and stone cairns:

$$LE = LE_{Hedge} + LE_{Wet} + LE_{Oth} \quad (9)$$

Finally, it should be emphasized that none of the chosen indicators were expressed in relation to an area unit such as ha. The uniform standard for comparison was chosen to be the farm level.

4. Study areas and material

4.1 Study regions

Bavaria can be divided into six areas characterised by largely uniform agricultural production conditions (Figure 2). The northern parts of Bavaria are predominately small-structured. The Jura as well as the northern Bavarian hill area provide comparatively unfavourable conditions for agriculture due to low water availability (Jura and northern Bavarian hill area) and low temperatures (Jura). In contrast, the Tertiary hill area and the loess area have the distinction of exhibiting largely favourable (Tertiary hill area) or excellent (loess area) production conditions.

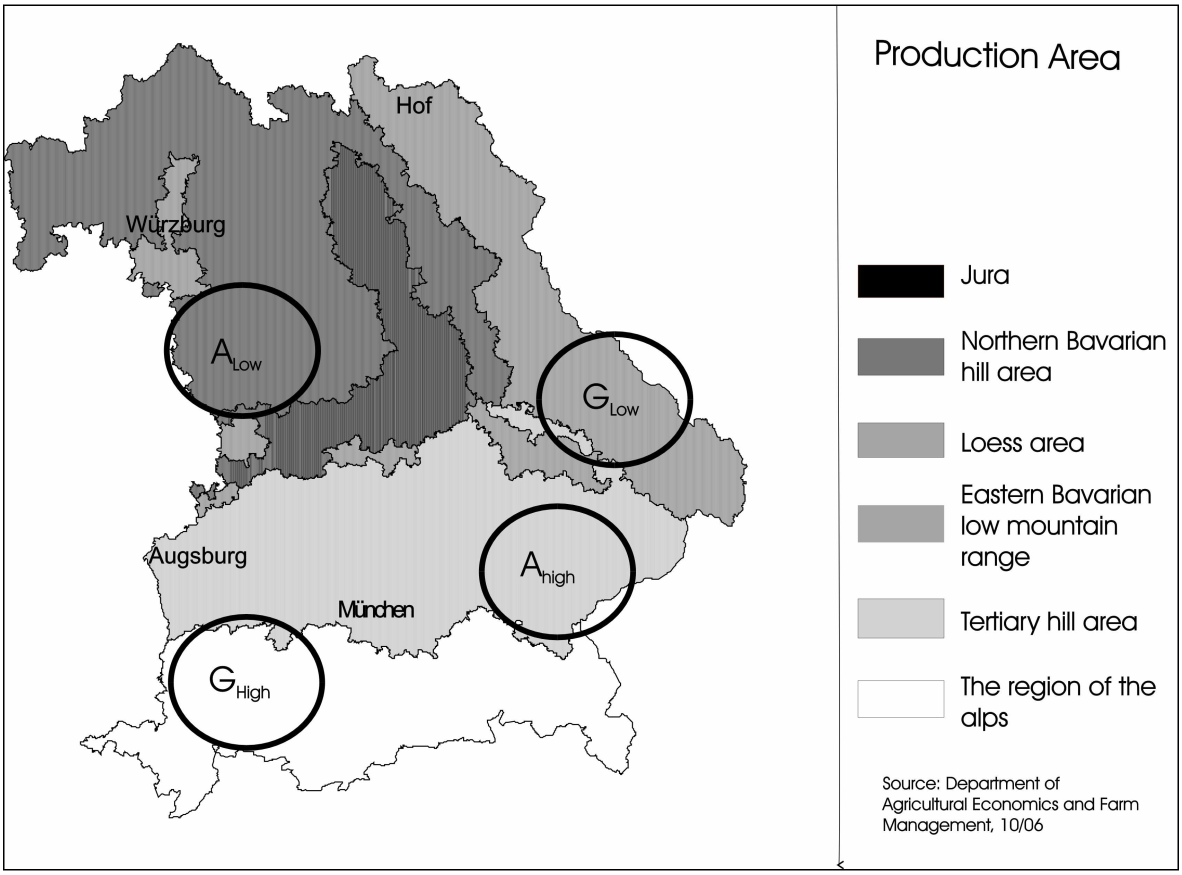


Figure 2: Agricultural production areas in Bavaria and study regions

The alpine region in southern Bavaria and the eastern Bavarian low mountain rage are both dominated by grassland. However, the production conditions are more favourable in the alpine region, since here – at least in the lower situated areas – the duration of the cultivation period is longer than in eastern Bavaria.

Overall, the conditions for agricultural production are very heterogeneous in Bavaria. Consequently, the agricultural land use ranges from low-intensity grassland use up to high-intensity arable land use. In order to consider the most relevant conditions for agricultural land use, four study areas have been selected. These are located in the eastern Bavarian low mountain range, the northern Bavarian hill area, the Tertiary hill area and in the alpine region (Figure 2):

- The low-yield Grassland (G_{Low}) area which has a low potential for agricultural yield and is predominately cultivated as grassland. The area is located in the eastern Bavarian low mountain range.

- The high-yield Grassland (G_{High}) area which has a high potential for agricultural yield and is predominately cultivated as grassland. The area is located in the alpine region;
- The low-yield Arable (A_{Low}) area with a high percentage of arable farming and a low potential for agricultural yield. This area is located in the northern Bavarian hill area;
- The high-yield Arable (A_{High}) area with a high percentage of arable farming and a high potential for agricultural yield. This area is located in the Tertiary hill area.

4.2 Farm survey

A survey of farmers was conducted in all study areas. In total, 122 farmers were interviewed (c.f. ECKSTEIN ET AL. 2005). The aim of the study was to generate individual farm-based input and output variables. Accordingly, the farmers were questioned regarding various aspects of production such as land cultivation, animal husbandry and the purchase and sale of products. Furthermore, the farmers were asked to provide details regarding their sales revenue, the inventory of machinery and buildings as well as their working hours. Of interest was also the presence of special habitat structures.

Table 2 gives an overview of selected characteristics of the studied farms. The indicators are shown on a regional and an overall level. The average farm size is 32 ha. It should be noticed that the average farm size is lower in grassland regions than that it is in the arable land regions. Furthermore, a division between grassland and arable land can be identified in the A_{Low} region, while in A_{High} most of the area is used as arable land.

Table 2: Characteristics of the study regions and analysed farms

		G_{Low}	G_{High}	A_{Low}	A_{High}	overall
Land use						
agricultural land	mean	24.0	25.6	38.0	42.5	31.8
	min/max	3.8 / 73.4	6.3 / 62.6	5.0 / 95.7	4.3 / 105.9	3.8 / 105.9
grassland	mean	21.0	25.6	14.4	8.8	17.3
	min/max	3.8 / 71.0	6.3 / 62.6	0 / 36.3	0.3 / 23.0	0 / 71.0
arable land	mean	3.0	0.0	23.2	33.5	14.4
	min/max	0 / 13.2	0 / 0.2	0 / 60.5	0 / 95.6	0 / 95.6
Magnitude						
< 15 ha	quantity	17	7	7	8	39
15 - 35 ha	quantity	12	14	9	6	41
> 35 ha	quantity	7	7	13	15	42
Production style						
full time	quantity	16	24	16	23	79
part time	quantity	20	4	13	6	43

Source: InVeKoS (2004)

Regarding the distribution of farm sizes in the specific study regions, we can see that in G_{Low} only a small number of farms is bigger than 35 ha. This is the same in G_{High}. However, in this region also the group of farms smaller than 15 ha is of minor importance. In contrast, most of the farmers cultivate more than 35 ha in the arable used regions.

With regard to the full-time/part-time farming distribution, most farmers work as full-time farmers in both regions with a high production potential (G_{High} and A_{High}). In the regions with low production potential (G_{Low} and A_{Low}), the proportion of part-time farmers is accordingly higher.

5. Results

5.1 Statistical analysis of the study regions

Table 3 shows the statistical analysis of the input and output variables. In the low-intensity use grassland region G_{Low}, most parameter values are low, since the farms in this area are comparatively small. One exception exists regarding the depreciated capital assets, which amount for more than 11,000 Euro. On the other hand, the low production potential of the region is expressed in the low nitrogen input, which on average amounts to 4,000 kg per farm. Regarding the high-intensity use grassland region G_{High} it should be emphasized, that the farmers manage with a comparatively low amount of operational costs and capital assets. Due to the extraordinary production conditions, this region shows a very small amount of low-intensity use area.

Table 3: Occurence of the input and output factors in the study regions

Variables		G_{Low}	G_{High}	A_{Low}	A_{High}	overall
Agricultural land [Hectar]	mean	24.0	25.6	38.0	42.5	31.8
	min. / max.	3.8 / 73.4	6.3 / 62.6	5.0 / 95.7	4.3 / 105.9	3.8 / 105.9
	SD	19.3	15.2	25.7	30.7	24.6
Capital (C) [1,000 Euro]	mean	11.4	9.8	8.6	9.2	9.8
	min. / max.	0 / 53.9	70 / 36.9	0 / 62.9	0 / 33.5	0 / 62.9
	SD	14.6	9.5	12.5	9.2	11.8
Operational Costs (O) [1,000 Euro]	mean	17.9	16.3	25.0	40.6	24.6
	min. / max.	0.5 / 95.7	0.5 / 69.3	1.6 / 104.1	0.8 / 168.3	0.5 / 168.3
	SD	23.0	16.3	24.6	39.3	28.3
Labour (L) [1,000 hours]	mean	4.3	5.3	4.2	5.5	4.8
	min. / max.	0.5 / 14.6	0.6 / 10	0.5 / 8.9	0.3 / 11.9	0 / 14.6
	SD	3.2	2.3	2.8	3.3	3.0
Nitrogen (N) [1,000 kg]	mean	4.0	4.4	6.0	8.7	5.7
	min. / max.	0 / 16.9	0.6 / 11	0 / 23.7	0.1 / 25	0 / 25
	SD	4.0	2.6	5.3	7.2	5.3
Crop-type factor (CF)	mean	122	26	481	622	304
	min. / max.	4 / 695	7 / 63	5 / 2,137	4 / 2,671	4 / 2,671
	SD	188	15	502	720	498
Landscape elements (LE) [Hectar]	mean	0.1	0.3	0.5	0.3	0.3
	min. / max.	0 / 0.5	0 / 2.5	0 / 4.2	0 / 2	0 / 4.2
	SD	0.1	0.5	0.9	0.4	0.6
Low intensivly utilized area (LI) [Hectar]	mean	3.7	2.5	9.1	5.9	5.2
	min. / max.	0 / 19	0 / 11	0 / 34	0 / 19	0 / 34
	SD	3.4	3.5	8.8	4.8	5.9
Revenue (R) [1,000 Euro]	mean	68.3	75.8	81.8	97.9	80.3
	min. / max.	0.8 / 293.5	4 / 177	0.9 / 262.8	1.5 / 310.6	0.8 / 310.6
	SD	78.4	51.1	72.6	78.9	71.7

Source: own calculations

In A_{Low} region we find an above-average amount of low-intensity use areas and landscape elements. The farmers in the A_{High} region have comparatively high input values, but gain also above-average amount of revenues. The high production intensity appears in the high nitrogen and crop-type factor values, which is typical for the usage of arable land.

In general, it can be said that the farmers in the two grassland areas have a comparatively low amount of operational costs. Furthermore, it should be noted that the factor "labour" hardly varies among the regions in contrast to the other factors.

5.2 General efficiency results

In the first step, we analysed the general efficiencies, which were calculated on the basis of the overall farm sample (table 4). As efficiency measures we used the overall efficiency θ_{All}, and the partial efficiencies θ_{Ecol} and θ_{Econ} and θ_{Econ_vrs}. On average, the overall efficiency θ_{All} was calculated to have a value of 0.81. The partial efficiencies account for 0.25 in the ecological case, for 0.64 in the economic case and for 0.73 in the Econ_vrs case.

Table 4: Overall efficiencies

overall	θ_{All}	θ_{Ecol}	θ_{Econ}	θ_{Econ_vrs}
mean	0.81	0.25	0.64	0.73
SD	0.19	0.28	0.24	0.23
Minimum	0.24	0.00	0.06	0.11
percentage of efficient farms	34%	4%	9%	24%

Source: own calculations

It should be noticed that the ecological and economic efficiencies largely sum up to the overall efficiency. Thus the partial efficiencies can be interpreted as indicators of the relative weights which the farms are assigning to the respective efficiencies. The clear gap between the economic and ecological efficiencies can be explained by the fact that the optimisation of economic outputs (revenues) is a goal for most farmers. This stands in contrast to the provision of ecological outputs (low-intensity use areas and landscape elements) which is in many cases not of interest in agriculture. By calculating the variable return to scale model (θ_{Econ_vrs}), one can see a clear improvement of the mean efficiency value. This can be explained by economies of scale effects.

Table 5 shows the mean partial efficiencies of the respective regions. One can see that in particular the high-intensity use grassland region G_{High} differs from all other regions. This region shows an outstanding economic efficiency combined with a significant below-average ecological efficiency. This finding is valid for both types of economic efficiencies θ_{Econ} and θ_{Econ_vrs}.

Table 5: Regional efficiencies

region	θ Ecol	θ Econ	θ Econ_vrs
G_{Low}	0.28	0.61	0.73
G_{High}	0.13	0.78	0.82
A_{Low}	0.32	0.58	0.65
A_{High}	0.26	0.59	0.74
p-value	*0.006***	*0.002***	*0.060*

Source: own calculations: significance level: * <0,05;** <0,01;***<0,001
Kruskal-Wallis-H-Test

Altogether, the results show that the regional conditions seem to have a significant influence on the efficiencies. It should be noted that this finding is supported by a tobit-regression analysis which also indicates a significant influence of site quality parameters (percentage of arable land and production potential).

5.3 Efficiency results on a regional level

Due to the importance of the regional conditions for agricultural production, we decided to expand our analysis to the regional level. In doing so, we can ensure that the homogeneity conditions, a necessary precondition for a Data Envelopment Analysis, are fulfilled. Consequently, the following analyses are based on efficiency calculations, with exclusively regional farm groups. In the first step, we studied the relationship between the different partial efficiency measures and selected criteria, specifically the farm size and part-time/full-time farming.

For the analysis of the influence of farm size on the efficiency results, we defined three groups of farm sizes (table 6). The results indicate that the smallest farm size class appears to differ from the other farm size classes. This class in general shows a comparatively high ecological mean efficiency θ_{Ecol}. With regard to the economic efficiency, the result is more ambiguous; small farms have a comparatively low economic efficiency if we apply θ_{Econ}. In contrast, small farms perform better in some regions if we take into account potential size effects and apply the efficiency measure θ_{Econ_vrs}.

Table 6: Size efficiencies on regional level

	θ_{Ecol}	θ_{Econ}	θ_{Econ_vrs}
G_{Low}			
<15	0.52	0.55	0.72
15 - 35	0.14	0.89	0.89
>35	0.09	0.98	0.99
p-value	*0.016**	*0.001***	*0.011**
G_{High}			
<15	0.55	0.82	0.98
15 - 35	0.29	0.91	0.93
>35	0.48	0.95	0.97
p-value	*0.182*	*0.244*	*0.135*
A_{Low}			
<15	0.62	0.52	0.84
15 - 35	0.21	0.67	0.68
>35	0.26	0.70	0.79
p-value	*0.012**	*0.496*	*0.173*
A_{High}			
<15	0.69	0.75	0.94
15 - 35	0.28	0.83	0.85
>35	0.25	0.86	0.89
p-value	*0.016**	*0.637*	*0.659*

Source: own calculations; significance level: * <0,05;** <0,01;***<0,001
Kruskal-Wallis H-Test

It should be emphasized that the significance of these findings is clearly limited. Significant differences between size groups can be observed with regard to the ecological efficiency, except of the G_{High} region. In the case of economic efficiencies there are only in the G_{Low} region significant differences.

Analysing the criteria of part-time/full-time farming, we found a higher significance (table 7). An exception is the A_{Low} region, where neither the economic nor the ecological efficiency measures show significant correlations. Part-time farmers have, in general, a higher ecological efficiency θ_{Ecol} and a lower economic efficiency θ_{Econ}. This applies in particular to the two grassland regions G_{Low} and G_{High}. With regard to the arable regions, the differences between the respective groups are smaller, in particular in the case of the economic efficiency. Once again, the results concerning the economic efficiency are to be questioned and the alternative efficiency measure θ_{Econ_vrs} should be applied; in this case, part-time farmers perform in some regions better from an economic point of view.

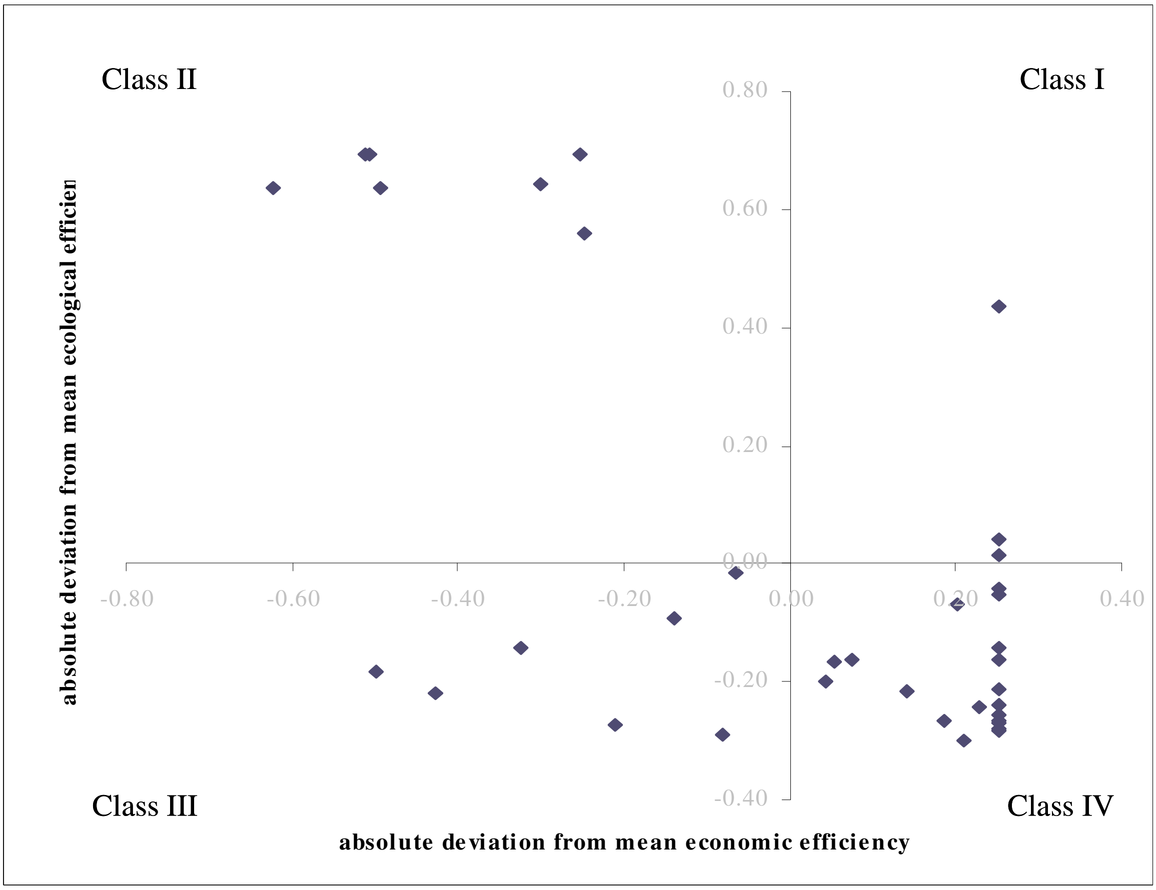
Table 7: Part-time efficiencies on a regional level

	θ_{Ecol}	θ_{Econ}	θ_{Econ_vrs}
G_{Low}			
full time	0.11	0.90	0.91
part time	0.47	0.62	0.77
p-value	*0.008***	*0.009***	*0.095*
G_{High}			
full time	0.34	0.93	0.95
part time	0.82	0.73	0.96
p-value	*0.019***	*0.070*	*0.635*
A_{Low}			
full time	0.31	0.67	0.77
part time	0.35	0.62	0.76
p-value	*0.914*	*0.475*	*0.948*
A_{High}			
full time	0.27	0.84	0.87
part time	0.79	0.75	0.97
p-value	*0.003***	*0.813*	*0.071*

Source: own calculations; significance level: * <0,05;** <0,01;
***<0,001; Mann-Whitney-U-Test

In the next step, we analysed to what extent farms succeed in combining economic and ecological efficiencies. For this analysis, we used the two partial efficiencies θ_{Ecol} and θ_{Econ}.

Figure 3 explains the analysis by using the G_{Low} region as an example. All farms located in this specific region are rated with regard to their economic and ecological performance. As a result of the analysis, the farms are classified into four classes. Class I contains all farms which show an above-average economic efficiency as well as an above-average ecological efficiency. These farms may be viewed as best-practice farms with regard to both economic and ecologically efficiency. Class II farms still have a comparable high ecological but only a below-average economic efficiency, whereas for Class IV farms the opposite holds. Class III farms finally neither show an above-average economic nor an above-average ecological efficiency.



Source: own calculations

Figure 3: Scatterplott $G_{Low:}$ Deviation from mean efficiency scores

Within the G_{Low} region, most farms are located in class IV, which is characterized by an above-average economic efficiency and a below-average ecological efficiency. Class I farms, which are above average concerning both criteria, are comparatively rare. This finding can be generalised; also, in the other regions class IV is the most important class and class I – even if in the case of G_{High} and A_{High}, comparatively more farms share this class – is of lower importance (table 8).

Table 8: Percentage of farms in the different classes

class	θ Econ	θ Ecol	G_{Low}	G_{High}	A_{Low}	A_{High}	overall
I	+	+	8%	25%	10%	17%	15%
II	-	+	19%	18%	28%	17%	20%
III	-	-	19%	21%	24%	21%	21%
IV	+	-	53%	36%	38%	45%	43%

Source: own calculations

6. Conclusions

According to the results of our study, there are substantial differences in the economic and ecological performance of farms. Analysing these differences, it seems important to consider regional influences. In our case this applies in particular to the high-intensity use grassland region, which differs significantly from the other regions. Reasons for this may be the extraordinarily high land use intensity with regard to economic efficiency and the typical low endowment with landscape-elements with regard to ecological efficiency.

Due to the significant impact of the regional conditions on the efficiency results, it seems necessary to base efficiency analyses on regional data. On the regional level we find that in particular part-time farms seem to provide agri-environmental services efficiently. These part-time farms, however, show a lower economic efficiency on average. The same results apply in general to small farms. However, when analysing the respective differences between farm groups we did not find in all cases significant results. Though the group of farmers is comparatively small, our analysis furthermore shows that some farms succeed in combining ecological and economic efficiency. These farms could serve as best practise farms. Thus, it would be interesting to analyse their techniques and strategies more detailed on a farm level.

However, most farmers focus exclusively on one efficiency component or perform below average with regard to both efficiencies. From the point of view of society, the group of farmers which displays an above-average performance concerning the ecological efficiency and a below-average performance concerning the economic efficiency is of particular importance. With regard to these farms, a further analysis of the economic viability seems important, since our results indicate that the above-average ecological performance of these farms is at risk due to their poor economic performance. This result is supported by a study of GANZERT et al. (2006), who analysed farm behaviour with regard to common welfare and management capabilities and found similar results: they identified a group of farmers who provide an above-average amount of social services but are at the risk of abandoning farming due to comparatively poor management capabilities.

Finally, some methodical aspects shall be mentioned. A decisive characteristic of the standard DEA technique, which we used, is that each single DMU can choose the weights of input and output variables without any restrictions. Thus, a DMU can exclude variables from the efficiency calculations which are from its point of view “unfavourable”. Consequently, a DMU may be efficient even if it achieves excellence in only one specific aspect. This, however, appears to be problematic from the point of view of an agri-environmental assessment. In this field, a more holistic approach seems necessary since it makes no sense to, for example, protect soil quality but spoil groundwater. Another problem is posed by the restricted data concerning environmental indicators. In addition, it appears necessary to develop new indicators to measure and evaluate environmental aspects more appropriately.

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