Environmental Efficiency of Traditional Farming with Consideration of Grassland Biodiversity: Implication for the Ukrainian Carpathians

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Abstract

Land abandonment and/or agricultural intensification are the most probable scenarios which could be expected for remote mountainous areas in Eastern Europe. Both of them can be a threat to the situation existing in the rural areas of the Ukrainian Carpathians where a high degree of connectivity between farming activities and the ecosystem still exists. In the paper we argue that in this area certain agricultural practices are more conducive to biodiversity than others. Therefore we aim at building an economic-ecological model to evaluate the environmental efficiency of farming performance in this area with special consideration of such positive externality as biodiversity. The DEA (Data Envelopment Analysis) is considered as a suitable method for this evaluation and for identification of the farming management patterns which are most efficient from economic and environmental perspectives. The data from socioeconomic and geo-botanic surveys conducted in the Ukrainian Carpathians were used to show how the method can be applied to evaluate the farming efficiency at the research sites.

This paper is a contribution to the research on the influence of traditional farming on biodiversity and a trial to analyse economic and environmental performance of farming practices which produce such positive externality as biodiversity.

Keywords: Efficiency, Traditional Agriculture, Positive Environmental Externalities, Biodiversity

JEL code Q18, Q57

1. Introduction

Trends of land use change connected to land abandonment have been observed in many areas of Europe. This phenomenon appears more frequently in the less favourable areas (LFA) which have difficult geographical and climate conditions, in particular mountain regions (MacDonald et al. 2000, Dullinger et al. 2003). A common alternative scenario examined in literature is agricultural intensification or modernisation which can be observed in some relatively prosperous mountainous landscapes as a finalised process of land use change (Tasser & Tappeiner 2002). As opposed to this situation, the rural areas of the Carpathian Mountains are currently representing the state of the development where these processes have not been yet finalised but have already started (Nuppenau et al. 2011); to find indicators for this development and its direction is an important and exciting research topic.

The Ukrainian part of the Carpathians is still characterised to a certain and large extent by low-intensity traditional farming as well as still exhibits high biodiversity and has partly intact landscapes. Since the level of biodiversity is closely connected to the type and intensity of farming (Kleijn et al., 2009), we can argue that various farming practices have a certain impact on species diversity. Therefore, if we assume that there is a certain variation in farming intensity and in agricultural practices (even within the homogenous group of low-intensity farmers), the environmental performance might also vary. To measure these variations, it is important to include analysis of environmental performance (the level of grassland biodiversity in our case) into the evaluation of the farming efficiency. Although the concept of environmental (or ecological) efficiency is quite ambiguous and there are various approaches to its definition (Kuosmanen and Kortelainen, 2004; Reinhard et al., 1999), this kind of analysis is a suitable approach within the context of the current research.

In a nutshell we argue that traditional farming practices in the region of the Ukrainian Carpathians generate positive external effects on environment in form of rich grassland biodiversity. The main research questions are:

- How are certain farming practices influencing the level of grassland biodiversity?
- Are some practices more conducive to biodiversity than others?
- Which elements of traditional farming are the most crucial for biodiversity?
- How efficient are the farmers in the study region with consideration of biodiversity provision and if we can distinguish them according to economic-environmental performance?

The aim of this paper is to develop further the environmental efficiency approach which would allow to consider ecological and economic parameters simultaneously and to examine the question of possibilities to measure economic performance in agriculture with the consideration of positive environmental externalities. The implementation of such analyses in the area with traditional farming implies certain peculiarities in specification of inputs and outputs for the efficiency analysis.

The paper is structured as follows: after the introduction the section on theoretical background deals with the three issues important for the environmental efficiency analysis with consideration of environmental impacts of farming. First of all, environmental external effects are considered with the focus on positive externalities such as grassland biodiversity. After that the concept of HNV (High Nature Value) farming is briefly introduced as a conceptual framework which connects the low intensity traditional farming and the provision of nature. Finally the section deals with the notion of efficiency (in particular environmental efficiency) and the suitable approaches to consider the efficiency of multi-input and multi-output production.

The third section focuses on the methods and the data. The first part introduces the main features of the DEA-method used for the environmental efficiency analysis. The next part describes the most important characteristics of the study area which are important to consider for the analysis and for the methodology. The main sources of data are introduced. The last part of this section is dealing with the specification of the model: the structure of the objective function and the constraints is defined and the inputs and outputs included into the model are described.

The fourth section of this paper presents the efficiency evaluation of the farming in the Ukrainian Carpathians. The possible reasons for differences in environmental and economic performance of different farms are analysed.

This paper is a contribution to the research on the influence of traditional farming on the biodiversity and at the same time a trial to develop the environmental efficiency approach for the evaluation of economic and environmental performance of farms with consideration of positive environmental externality.

2. Environmental efficiency: Theoretical background

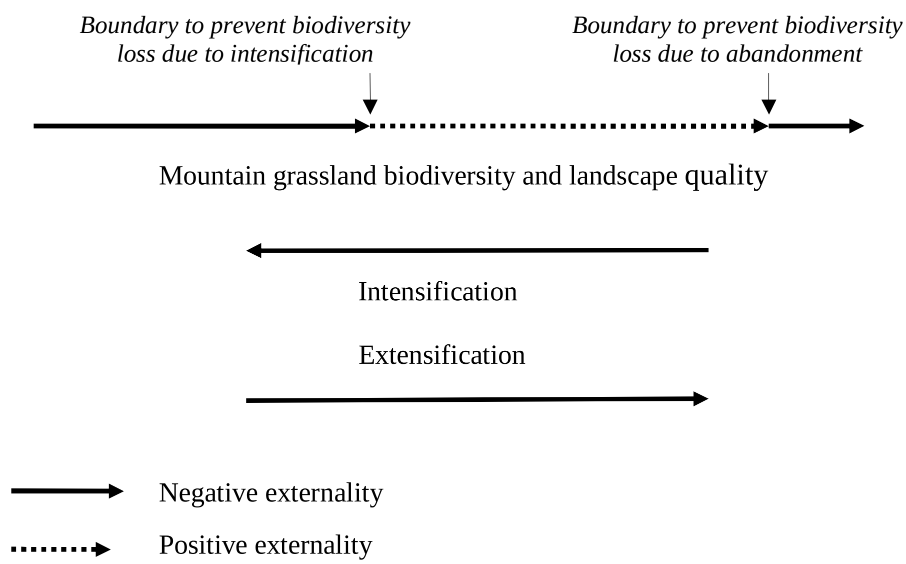
This section deals with the three issues important for the understanding of the approach to environmental efficiency. Three parts of this section will introduce environmental external effects with the focus on positive externalities such as grassland biodiversity, the concept of HNV (High Nature Value) farming, and the notion of efficiency (in particular environmental efficiency) respectively.

2.1 Environmental external effects of farming and grassland biodiversity in the Ukrainian Carpathians

There are various approaches to analyse the impacts of human activities (for instance, agriculture) on the nature. Usually they are treated as environmental external effects. The notion of externality implies in this case that the impacts of production on the nature influence not only the producer but also other society members causing additional costs (in case of negative external effects) or benefits (positive external effects) (Schader, 2009, p.9). Among various challenges of this approach is the differentiation between environmental “goods and bads” especially for the case of agricultural production when positive and negative externalities are mixed (Van Huylenbroeck and Whitby, 1999, p. 26). In other words we need benchmarks for the environmental external effects.

The focus of our research is the main habitat type of conservation interest in the Ukrainian Carpathians - mountain hay meadows or mountain grasslands. Most of them are still managed using traditional practices which contribute to the maintenance of high level of grassland biodiversity. This low-intensity farming system is facing two possible alternatives (intensification or abandonment), which would lead to various scenarios for grassland biodiversity in the region. Intensification of agricultural activities would cause biodiversity loss (negative environmental externalities), whereas extensification would act in the opposite direction (positive environmental externalities) (Kleijn et al., 2009, Van Huelenbroeck and Whitby, 1999). At the same time we should be aware of the thresholds (Fig. 1): for instance abandonment which is often connected to inability to adapt the land management to social and economic pressures (MacDonald et al., 2000), is a significant threat. Main impacts of this trend on the environment are usually straight connected to biodiversity losses and changes in landscape mosaic (MacDonald et al., 2000, p.56). This is one of the problems for the Ukrainian Carpathians. The reason for the fast loss of grassland species is that the meadows in the sub-alpine level of the Carpathian Mountains are the result of human activity and were converted from forest. As soon as farming activity is stopped, the forest steps in. This leads to several further problems: loss of unique meadow biodiversity, loss of sources for fodder which are based on the remaining livestock which could possibly lead to complete disappearance of farming in the region, disappearance of multifunctional heterogeneous landscapes, decline in diversification of income through tourism (Solovyeva et al., 2011).

Figure 1: Possible benchmarks for positive and negative externalities.



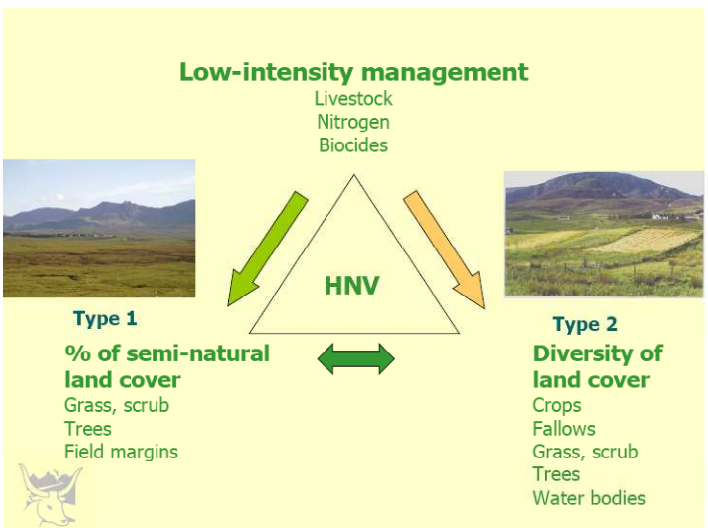
Source: own representation based on Huelenbroeck and Whitby, 1999, p. 27

Biodiversity and landscape in the broader sense play a critical role in the region. We can argue that various traditional farming practices in the Carpathian Mountains have influence at the wider scale, that means for the landscape and biodiversity on the whole. In this sense, traditional farming practices which are part of biodiversity and landscape management are regarded in this paper explicitly as a community activity. They are linking nature provision (e.g. biodiversity, landscape appearance) to the human activities. Therefore we can argue that the farming system in the Ukrainian Carpathians can be referred to as HNV (High Nature Value) farming.

2.2 HNV (High Nature Value) farming

The concept of HNV (High Nature Value) farming is rather new (Beaufoy et al., 1994; Beaufoy, 2007, Andersen et al., 2003); though it covers well-established conceptual approaches in farming system and landscape analysis (such as extensive farming, farming with nature provision). The concept was developed for different landscapes, within which one still finds an intact nature and ecological values are ranked high (Fig. 2). HNV farming applies to situations in which nature co-exists and coincides with the farming activities as well as in situations where farming is supportive for higher biodiversity in semi-natural landscapes.

Figure 2. Characteristics of HNV farming



Source: Beaufoy, 2007, p.5.

The purpose of this concept is to contrast extensive farming systems to farming systems that do not care for nature or even degrade nature. The aim is to link the three components, ecology, farming, and public policies, in such a way that they get "equal" recognition and management concepts, which promote HNV, can be developed (Beaufoy, 2007).

As we can see, the concept of HNV farming is based, first of all, on the idea of low-intensity farming and more importantly on the concept of a holistic system of extensive land use practices which includes the notion of connectivity between farming and nature (Solovyeva and Nuppenau, 2012). Therefore HNV agriculture provides the public good of biodiversity conservation as well as other environmental amenities and facilitates increased ecosystem provision. As will be shown in part 3.2, the farming system in the Ukrainian Carpathians has definitely the features of HNV farming. In our paper this concept is used to emphasize the specific conditions of this area which should be considered within the approach to the efficiency analysis.

2.3 Concept of environmental efficiency

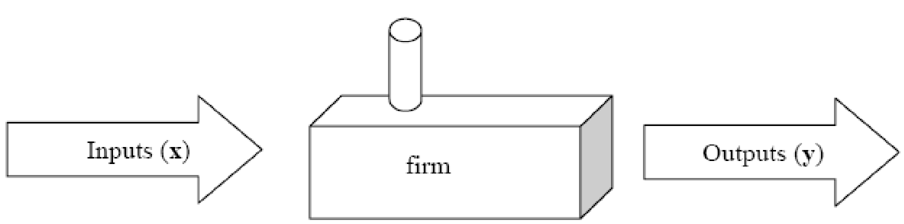
Ecological economics offers another approach to the environmental externalities by using the concept of joint production. This concept considers the environmental external effects as by-products (or outputs) of the production process (Baumgärtner et al., 2003). This brings us to the point where we can incorporate these impacts on the nature into the efficiency analysis of production.

The measurement of production efficiency is usually based on physical and monetary inputs and outputs. The traditional setting of production economics (see Fig. 3) implies that "a firm consumes inputs (e.g., labor capital, materials, energy) to produce economic outputs (i.e., goods and services)" (Kuosmanen and Kortelainen, 2004, p.3). Technical efficiency of this firm implies that its input-output combination lies on the boundary of the set of all possible inputs and outputs which represents technology (Kuosmanen and Kortelainen, 2004, p.4). A commonly used measure of efficiency is a ratio in form of:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

Although many other measures (such as, for instance, relative efficiency) are used (Cooper et al., 2002, p.1, p.5, Boussofiane et al., 1991, p.1), it lies at the core.

Figure 3. The traditional setting of production analysis



Source: Kuosmanen and Kortelainen, 2004, p.3

The notion of environmental efficiency provides many possibilities for economic evaluation of environmental impacts. However modelling approaches differ. Environmental efficiency is defined either as "the ratio of minimum feasible to observed use of an environmentally detrimental input" (Reinhard et al., 1999, p.48) or as the ratio of economic value added to environmental pressures (Kuosmanen and Kortelainen, 2004, p.18). Quite often it is modelled as a technical efficiency of production with inclusion of environmental components (Sipiläinen et al., 2008; Areal et al., 2012).

There were various attempts to include environmental externalities into the efficiency analysis in order to provide more complete representation of production technology, however most of these studies were performed within the framework of negative environmental externalities (Färe and Grosskopf, 2004; Lauwers and Van Huylenbroeck, 2003; Reinhard et al., 1999; De Koeijer et al., 2002; Kuosmanen and Kortelainen, 2004; Reinhard et al., 1999). However there are also attempts to model positive externalities as well (Sipiläinen et al., 2008; Areal et al., 2012). The methodological challenge of this approach is the consideration on how these externalities can be incorporated into the efficiency model: as an input or as an output.

It is important to point out that an incorporation of environmental externalities into efficiency analysis provides a more complete representation of production technology. At the same time the omission of environmental effects may create biases in evaluation of production techniques and to underestimate the environmentally friendly technologies (Sipiläinen et al., 2008, p.2). The methodological challenge of this approach is the consideration on how these externalities can be incorporated into the efficiency model: as an input or as an output.

There is a certain number of research papers which elaborate on the consideration of environmental impacts of production in the efficiency analysis. The majority of these sources is dealing with negative externalities. Some authors assume that negative environmental impacts are technically outputs and therefore argue that environmental externalities should be modelled as an undesirable output (Färe and Grosskopf, 2004). Another group of researchers sees it as a conventional input; they justify this, for instance, by the fact that undesirable environmental effects as well as inputs incur costs to the firm (Kuosmanen and Kortelainen, 2004, p.14, Lauwers and Van Huylenbroeck, 2003, Reinhard et al., 1999, De Koeijer et al., 2002). However there are also attempts to model positive externalities which are considered as non-marketed output or as desirable by-product (Sipiläinen et al., 2008, Areal et al., 2012).

3. Methods and data

3.1 DEA-method

DEA (Data Envelopment Analysis) method has been often used for evaluation of environmental impacts of human activities (e.g. De Koeijer et al., 2002, Reinhard et al., 2000, Sipiläinen et al., 2008, etc.). Here we briefly describe the method and consider some of the characteristics which make this method attractive especially for dealing with environmental issues.

DEA is an approach to compare efficiency of various organizational units (farms) with multi-input and multi-output production options (Sipliläinen, 2008, p.9). Efficiency is calculated for relatively homogenous set of decision making units (DMUs). DEA constructs the efficiency frontier (the most efficient combinations of inputs and outputs performed by some of the DMUs in the set) and calculates the distance to this frontier for the DMUs which are not situated at the frontier and therefore are less efficient (De Koeijer et al., 2002, p.12). "DEA does not require the user to prescribe weights to be attached to each input and output... and it also does not require prescribing the functional forms" (Cooper et al., 2002, p.1). So minimal prior assumptions are made and the approach lets the data "speak for themselves" (Kuosmanen and Kortelainen, 2004, p.7). This is especially beneficial for the case of environmental evaluation since subjective assessment of weights for the aggregate level of environmental impacts is quite a challenging procedure (Kuosmanen and Kortelainen, 2005, p.64). Moreover DEA is using LP models which are solved for every DMU.

Considering the attempts to evaluate the performance at the farm level, we can argue that DEA is a suitable method to measure the efficiency of farms' performances with consideration of environmental impacts. On the one hand it allows consideration of multiple environmental effects (Reinhard et al., 2000), on the other hand it also gives an opportunity to model positive as well as negative externalities (in the form of outputs and inputs respectively). In addition DEA results can be practically used in many other ways, for instance, to ascertain how the DMUs can become more efficient, to form peer groups, to identify efficient operating practices and strategies, to allocate resources, etc. (Bousofiane et al., 1991, p. 4). The aim is now to use DEA for evaluation of farm performance.

Despite all the positive features it is obvious that the approach also has some limitations. DEA is based on certain assumptions such as resource disposability, convexity and absence of statistical errors in the data set. In fact “the extensive data requirement” is usually mentioned as the main limitation of this method (Kuosmanen and Kortelainen, 2005, p.70). Since the efficiency frontier is built simultaneously and no prior assumptions are made, the data should be accurate and reliable. Another problem within DEA, which should be mentioned, is connected to the simultaneous evaluation of multiple positive and negative environmental impacts. First, a clear framework should be elaborated which accommodates the environmental effects and groups them into two groups according to their positive or negative impact. It should be also decided how these impacts are defined – as inputs or as outputs. Secondly, the interdependencies between these environmental effects should be also considered (Kuosmanen and Kortelainen, 2005, p.60).

3.2 Study area and data

Before specifying the model for our analysis, it is important to introduce the study area and the sources of the data so that all the details could be considered in the model.

The area under study consists mostly of semi-natural landscapes which are dependent on the human activities such as hand mowing, and the mountain grasslands are an important habitat of conservation interest. Due to various factors the situation which so far has balanced the farming activities and environmental parameters is under threat. We can argue that the drivers of the land use change in this area, in particular of land abandonment, are mostly exogenous to the ecosystem (Lambin & Meyfroidt 2010): (1) outmigration after the collapse of collective system, (2) following labour shortages, (3) low incomes, (4) generally poor socioeconomic situation, and (5) bad infrastructure. However some other reasons for change are connected to the region’s environmental conditions: (6) special geographical and climate conditions which give less opportunity for intensification, and (7) limit the agriculture in the region to labour-intensive extensive farming. At the same time those who stay are very dependent on the ecosystem and in particular on the mountain grasslands which provide valuable fodder for their livestock, medicinal plants, landscape amenities, etc. It is important to mention that culture and traditional knowledge of certain farming practices may be regarded as an important integrating force which still helps to conserve farming in the region of the Ukrainian Carpathians (Nuppenau et al. 2011, Solovyeva et al. 2011). The study area is associated with Hutsuls – one of the three ethnographic groups typical for the Ukrainian highlands.

Three administrative districts with some distinct features were chosen for this research in the Carpathian areas of Ukraine (see Table 1).

Table 1. General characteristics of regions in the study area of the Ukrainian Carpathians.

Name of the region	Altitude	Special characteristic
Kosiv region	350-850m above the sea level	- more arable land than other regions.
Verhovina region	600-1100m above the sea level	- colder climate in comparison to Kosiv regions; - less arable land for growing grains or gardening; - therefore, people are more dependent on livestock; - “Hutsul” type of farming and settlement: the homesteads are attached to the fields and the settlements are scattered and extend to higher altitudes.
Nadvirna region	500-900m above the sea level	- colder and wetter climate in comparison to two other regions; - famous ski resorts are situated in this region which attract a lot of tourists. Tourists give additional sources of income for this region in comparison to other study areas.

Source: Representation based on Solovyeva et al. 2011

We use two main sources of data for this article. First of all there is a socioeconomic survey conducted in the Ukrainian Carpathians with the aim to analyze the farming and grassland management system prevailing in the Ukrainian Carpathians, in particular with consideration of production itself and the influence on the environment (Solovyeva et al. 2011). With regard to the special framework of the research, we have tried to present the possibly full statistical variety of the farms/households types of the chosen regions. Altogether 33 households were interviewed. The main prerequisite for choosing households for the survey was ownership of high altitude grasslands (hay meadows or pastures). We also tried to consider different access options to machinery, income sources, different status, etc. to present possibly full picture of management types in the study regions. The questionnaire included 42 questions. The main topics covered were: size of land owned and cultivated at present and 10 years ago, the process of mowing, general details about meadow management (timing, productivity, management activities), etc. In the survey we used open and closed questions as well as qualitative and quantitative questions.

Beside economic data, botanic data on plant biodiversity of the mountain grasslands were collected with the help of a geo-botanic survey related to every questioned household. The Braun-Blanquet methodology was used for this survey (Poore, 1955). The distinct data on the following aspects was gathered for 55 sites related to the interviewed households: environmental features of the plot, land use history, height and percentage cover of vegetation, list of the plant species presented on the plot, how those species are represented.

3.3 Specification of the model

3.3.1 DEA-efficiency

Following the approach of Sipiläinen et al. (2008), positive environmental externality (in our case grassland biodiversity) is introduced as a desirable output into the modified formula of output-oriented technical efficiency. For this the output distance function is used in which efficiency is obtained by increasing the outputs with the constant inputs (Sipilainen et al., 2008, Färe et al., 1994, Mulwa, 2006):

$$(D_o(x,y))^{-1} = Max\theta_k = Max\{\theta > 0: \theta y_k \in S\}$$

s.t.

$$\theta Y_{kj} \leq \sum_{i=1}^{N} Y_{ij}\lambda_i , j = 1, \ldots M \qquad (1)$$

$$X_{kr} \geq \sum_{i=1}^{N} X_{ir}\lambda_i , r = 1, \ldots L$$

$$\lambda_i \geq 0$$

where: is an output-distance function which refers to N DMUs (Decision Making Units) $(i = 1, \dots, N)$;

$\boldsymbol{\theta}$ is the efficiency measure which estimates the maximum possible expansion of output y of farm k. In this formulation for the linear programming problem θ is a degree with which the outputs y can be expanded, while remaining producible by input vector x. This measure is reciprocal to the output-distance function and is acquiring a value between 0 and 1;

x is the set of inputs $x = (x_1, \dots, x_l)$;

y is the set of outputs $y = (y_1, \dots, y_m)$;

λ are intensity variables or weights attached to each DMU;

S is the boundary of production possibilities or the reference technology constructed from the data. The reference technology forming the frontier is represented by the set of the constraints.

So the output distance function takes an output-expanding approach to the measurement of the distance from a producer to the boundary of production possibilities (or set of reference technology) S. Efficiency is obtained by expanding the level of output while holding the level of inputs constant. θ is the efficiency measure which estimates the maximum possible expansion of output y of farm k. (Sipilainen et al., 2008, Mulwa, 2006). The constraint for the sum of lambdas being equal to 1 is reflecting the production with consideration of variable returns to scale.

For our efficiency analysis of farms performance we use the formula 1 to analyze, first of all, the regular efficiency of the farmers without consideration of the environmental output (Eff1). Secondly the same formulation of the LP problem will be used to consider both: conventional and environmental outputs (EnvEff1). Thus, we check possibility to optimize the production of both outputs (Sipilainen et al., 2008, pp. 10-11). Beside this we also test other possibilities for the output optimization:

- maximizing the traditional output given the environmental output and the set of inputs (Eff2) and
- maximizing the environmental output given the traditional output and the set of inputs (EnvEff2).

This, however, needs a special formulation of the constraints. Thus, for the two last analysis options, which can be also characterized as sub-vector efficiencies, we use formulation (2) of the LP problem (Sipilainen et al., 2008, p. 12):

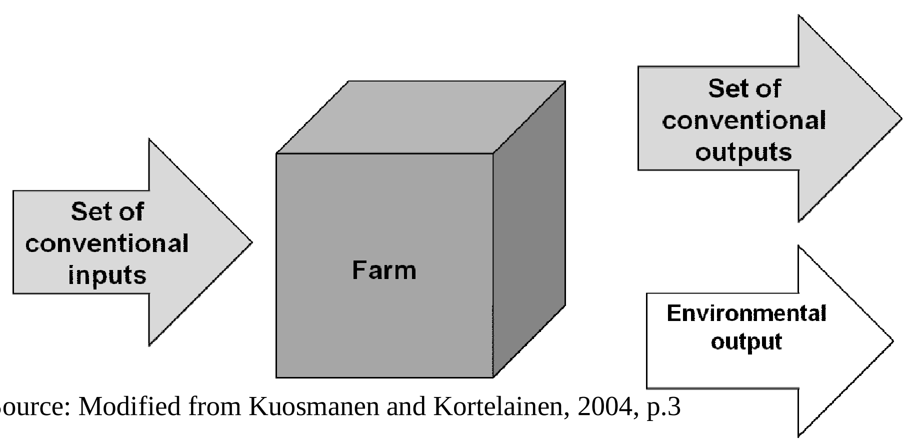
s.t.

(2)

where is representing the traditional output for the case of Eff2. For the fourth analysis option (EnvEff2) we can use the formula (2) where is referring to the environmental output.

Generally the production process in our analysis can be represented in the Figure 4 which is a modification of Figure 2.

Figure 4. The setting for the efficiency analysis.



Source: Modified from Kuosmanen and Kortelainen, 2004, p.3

In the following parts of this section we introduce more specifically the components of the model: the sets of the inputs and outputs.

3.3.2 Environmental component

Environmental component, which is incorporated into the model as an output, represents the grassland biodiversity. The influence of agricultural activities, and in particular of land abandonment, on biodiversity was a topic of many studies. Depending on what biodiversity parameters were chosen the results were quite different (MacDonald et al. 2000, Dullinger et al. 2003, Tasser & Tappeiner 2002). However most of the research showed that in case of semi-natural landscapes like mountain grasslands land abandonment can lead to biodiversity loss especially for species associated with agricultural or pastoral habitats (Fonderflick et al. 2010). The mentioned literature mentioned above uses various indicators of biodiversity for analyzing the influence of land use on the environmental factors. The observation is that the result of such investigation strongly depends on the biodiversity index chosen and parameter which is taken into consideration (MacDonald et al. 2000). Therefore, the choice of the suitable indicator for mountain grassland biodiversity was an important task.

Generally environmental indicators are not well developed for evaluation of biodiversity and landscape change. The indicators which are most often used for this purpose in case of biodiversity are: species richness (Billeter et al. 2008), richness and abundance of species or Shannon diversity index (Dullinger et al. 2003), presence of a certain set of species selected for their rarity (Fonderflick et al. 2010), etc. They are giving only a limited spectrum relevant for assessment as they are representing quantitative indicators of the grassland biodiversity but not reflecting the quality of the species and the grassland. For instance, an abandoned meadow can contain quite a high number of species but at the same time there will not be any valuable grassland species or species valuable for fodder. Moreover the additional species which are common for the forest succession will increase the species number but they would also indicate that the grassland biodiversity is under threat of disappearance.

Therefore, for this study we suggest an aggregated grassland biodiversity index that is more suitable for our study. This index combines the quantitative and qualitative evaluation and includes the following parameters which are differently weighed (see Table 2): percentage of the vegetation cover, species richness, presence of rare species, presence of species important for meadow productivity, presence of species indicating the forest succession. These indicators were weighed according to their importance for the grassland biodiversity level and they received a score based on 1 to 5 scale. The index is based on summing up of the weighed scores for each component:

$$BDI_j = \sum_{i=1}^{5} I_{ij} * w_i \qquad (3)$$

Table 2. Structure of the grassland biodiversity index (BDI).

	Indicators for evaluation (I_{ij})	**Weights (w_i)**	**Min value**	**Max value**	**Scale based scores**
1	Number of species	0,5	19	62	Scale 1 to 5
2	Number of productivity species	0,2	5	20	Scale 1 to 5
3	Number of rare species	0,15	0	5	Scale 1 to 5
4	Number of species indicating forest succession	0,1	0	6	Reverse scale with 5 for 0 species and 0 for max.
5	Vegetation cover	0,05	60%	100%	Scale 1 to 5

We assume that the index is more appropriate because it is working for a system which is humanly influenced instead of a natural system characterized by wilderness, only.

3.3.3 Conventional outputs

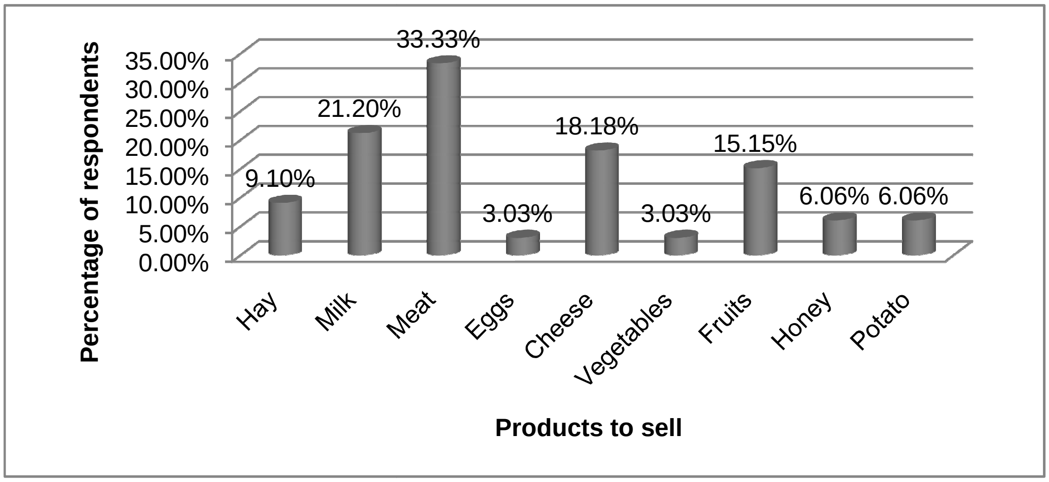
To simplify the calculation of the efficiency scores, the volume index has been used to represent the set of conventional outputs of the households. From the data collected within the survey we got the information to the most important products produced in the households. Among the most common products produced in the households are milk, meat, cheese, potato and hay. These products have been chosen for the volume index which is based on summing up the weighed amounts of output (see Table 3). Since DEA is a method for relative efficiency measurement, the units do not need to be aligned.

Table 3. Components of the output volume index.

Product	**Estimation from the questionnaire**	**Unit**	**Mean**
Milk	Information to the milk amount per cow	liters/ha per year	4370,55
Meat	Information on meat amounts sold and the meat consumed	kg/ha per year	63,92
Cheese	Information on cheese amounts sold and the cheese consumed	kg/ha per year	20,65
Potato	Output of potato per ha	kg/ha per year	5156,82
Hay	Output of hay per ha	kg/ha per year	2575,60

As mentioned above, the farmers in the region of the Ukrainian Carpathians are mostly subsistent. Only small amount of farmers sell their products (see Fig. 5) but the channels of selling are differentiate quite significantly offering quite different prices. Hence, the measurement of all the outputs in prices is complicated due to the subsistence character of the farming.

Figure 5. Selling of agricultural self-produced products.



3.3.4 Conventional inputs

Four conventional inputs are incorporated into the model. The choice of the inputs is based on the farming practices used in the region (see Table 4).

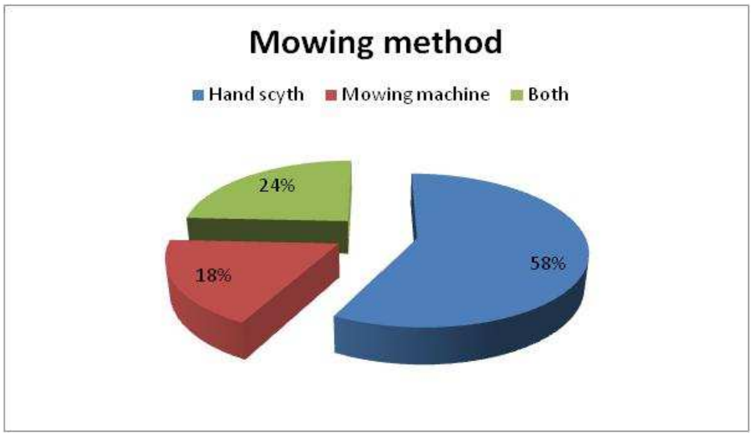
Table 4. Conventional inputs.

Input	Estimation	Unit	Mean
Labour	Time spent for work connected to grasslands	Man-hours/ha per year	946,64
Capital	Number of machines (mowing machine or truck)	Items	1,15
Fertilizers	Use of the manure or chemical fertilizers	kg/ha per year	897,86
Land	Grasslands (hay meadows and pastures)	ha	9,17 (3,75)*

*****without three largest farmers in the sample

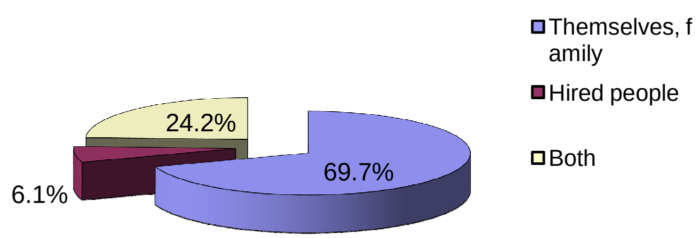
Labour appears to be the most crucial factor of production in the region. All the farming practices connected to the management of the grasslands (mowing and livestock husbandry) are very labour intensive. Altogether 57, 6% of the interviewed farmers mow using just hand scythe; 18,2% mow with the mowing machine and 24, 2% use both methods depending on the type of the meadow (see Fig. 6). Most of the work is done by the family. Very few farmers pay day labourers to mow (see Fig. 7).

Figure 6. Labour component: mowing methods used.



Source: modified from Solovyeva et al., 2011.

Figure 7. Labour component: who does the mowing.



Source: Solovyeva et al., 2011.

Capital is represented either by the mowing machine (see Fig. 6), or a truck which is used to transport the hay from the meadows (see Fig. 8) which is especially important for the cases of outer meadow (the meadow which is situated on a certain distance from the household, usually up in the mountains).

As for fertilizers, the tendency is that the fertilization is mostly used only for the inner meadow; the less accessible outer meadows are situated further and are usually left without fertilization which, according to the preliminary data, is leading to the larger amount of plant species and is positively influencing the plant biodiversity at such plots. The majority of farmers in Ukraine (74,2%) is also using solely organic fertilizers, 6,5% of farmers do not use fertilization at all (see Fig. 9). Since the majority of farmers use just organic fertilization, we consider only this type in our analysis.

Figure 8. Capital component: Usage of a truck for hay transportation.

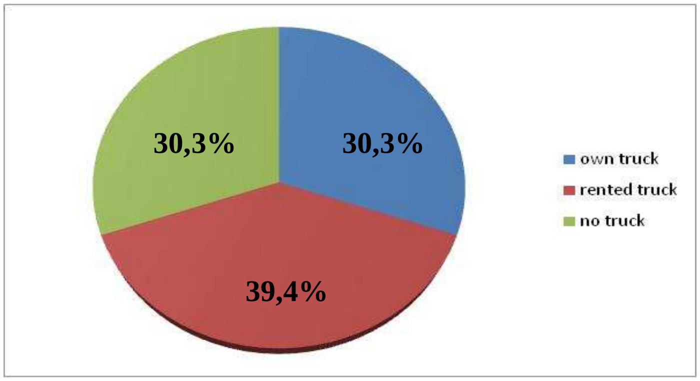
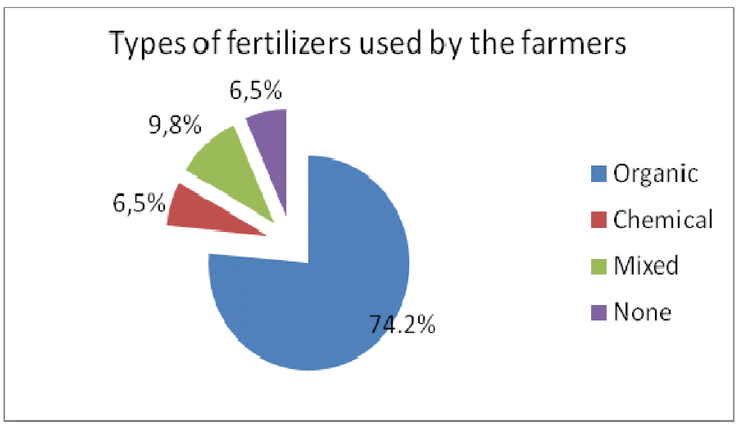


Figure 9. Fertilizers component: Types of fertilizers used by the farmers.



Source: based on Solovyeva et al., 2011.

Finally land has been also incorporated into the model as an input. This component includes the size of mountain grasslands (hay meadows and pastures) cultivated by the farmers.

4 Main results and discussion

General Algebraic Modelling Systems (GAMS) has been used to evaluate the efficiency of environmental and economic performance of the farms. The average efficiency scores for each evaluation case (see part 3.3.1) are presented in Table 5. The mean efficiency of the production in case when environmental performance is not considered (Eff1) shows the lowest value in comparison to other evaluation options (mean efficiency score=0,57). Only about one third of farmers are efficient within this type of analysis (see Table 6) and about half of them have really low efficiency scores (below 0,5). These results are partially reflecting the character of semi-subsistence type of farming which is spread in the study area. However we can see that in case when the environmental output (grassland biodiversity indicator) is considered, the mean efficiency of the farmers is significantly higher (=0,90). In case we consider the proportionate increase of both outputs (EnvEff1), the amount of efficient farmers increases up to 54% and there are no farmers with the efficiency below 0,50.

Table 5. Results of the efficiency analysis of the farming in the Ukrainian Carpathians.

Parameter	Definition	Mean	Std. Deviation
Eff1	Efficiency of production without consideration of environmental output (one output-four inputs model)	0,57	0,33
EnvEff1	Efficiency of production with consideration of environmental output: both outputs are maximized (two outputs-four inputs model)	0,90	0,15
Eff2	Efficiency of production with consideration of environmental output: conventional output is maximized	0,76	0,30
EnvEff2	Efficiency of production with consideration of environmental output: environmental output is maximized	0,87	0,18

Table 6. Distribution of the efficiency scores.

Parameter	Efficient farmers (efficiency score =1)	Farmers with efficiency score between 0,50 and 1	Farmers with efficiency score below 0,50
Eff1	30,10%	21,20%	48,50%
EnvEff1	54,50%	45,50%	0,00%
Eff2	54,50%	9,10%	36,40%
EnvEff2	54,50%	36,40%	9,10%

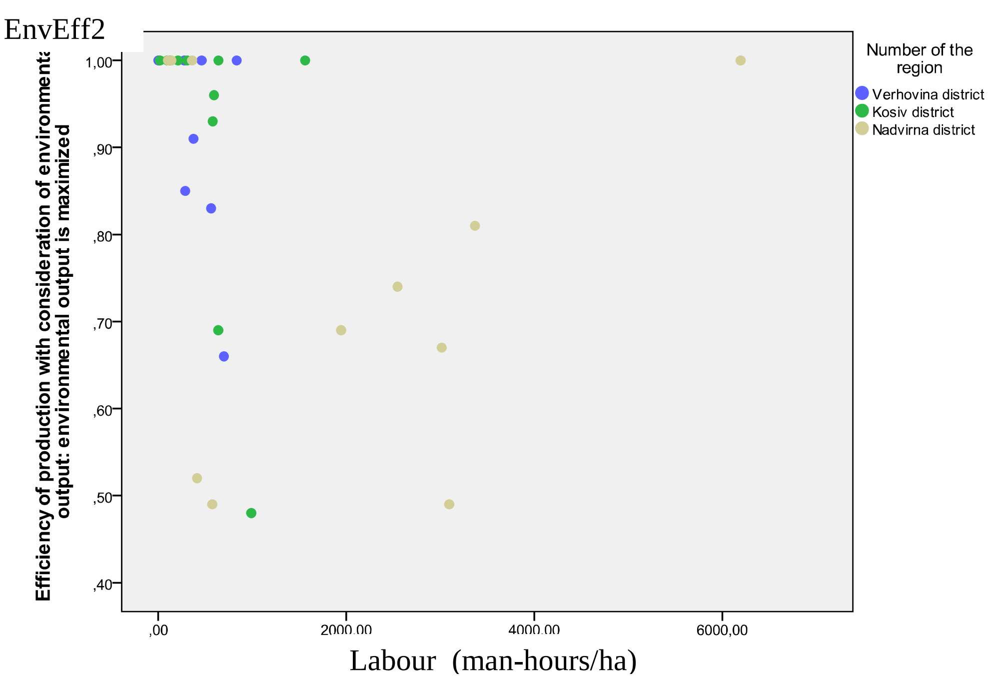
The two last options, where sub-vector efficiencies for the conventional output (Eff2) and for the environmental output (EnvEff2) are considered, are also showing the higher efficiency scores in comparison to the analysis without consideration of the environmental component (see Tables 5 and 6).

This gives us two significant implications:

- along with the standard efficiency measures, it is important to consider environmental efficiency in case the semi-subsistent type of farming is concerned;
- one can use different approaches to analysis of environmental efficiency depending on the objectives of the application of the results. Normally the outcomes of such analysis have certain policy implications, for instance, the consideration of support options for those farmers which are less efficient. So depending on the objectives of such policies (in our case those might be the increase of agricultural production keeping the provision of nature constant like in option 3 or increase of grassland biodiversity with the current level of conventional output like in option 4) different formulas for the analysis can be chosen.

As it has been already mentioned (see 3.3.4), labour appears to be the most crucial production factor for the traditional type of farming in the Ukrainian Carpathians. However, the dependency of the environmental efficiency on this factor is quite equivocal (e.g. see Fig. 10).

Figure 10. Interdependency between the environmental efficiency and labour input.



As we can see from the Figure 10, there might be differences in distribution based on the different study regions which are characterized by different climate conditions. This brings in a significant challenge connected to this kind of evaluation:

- Many of environmental characteristics are connected to site-specific natural conditions of the area; therefore it is very important to exclude the influence of this kind of site characteristics from the evaluation. This is necessary in order to assure that the difference in environmental efficiency between the farms is conditioned by different agricultural practices and not the natural characteristics which cannot be influenced by farmers. As a solution approach for the next step of our analysis it is important to consider the relative environmental efficiency of the farming in three study regions separately.

- Another big challenge of this type of evaluation has been already mentioned among the limitations of the DEA-method (see 3.1). This method has very high requirements to the data availability: the data should be especially accurate and reliable. This is a big challenge for any type of DEA-efficiency analysis but it makes it even more complicated in case the environmental parameters are considered.

5 Conclusion

The results of this research present the efficiency evaluation of the farming in the Ukrainian Carpathians. The paper further elaborates the DEA efficiency method in order to approach the analysis of environmental efficiency with consideration of positive externalities such as grassland biodiversity.

Taking into consideration the described peculiarities of traditional HNV farming with respect to the regions in Ukrainian Carpathians and the special features of the considered DEA-method, the application of the environmental and economic efficiency evaluation method can contribute to the agri-environment policy in few ways:

- It gives possibilities for farmers' performance evaluation which might be used for policy decisions, justification and design of the suitable support measures;

- It can contribute to the targeting of the policy support: in case of traditional farming this method would allow to identify the farmers which are less efficient with respect to economic and environmental performance;

- Depending on the outcomes of the efficiency analysis (and efficiency in this case is identified as environmental efficiency) the groups of farmers can be identified which need support.

This paper is a contribution to the research on the influence of traditional farming on the biodiversity and at the same time a trial to develop the environmental efficiency approach for the evaluation of economic and environmental performance of farms with consideration of positive environmental externality.

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