FACEPA

Farm Accountancy Cost Estimation and Policy Analysis of European Agriculture

FACEPA

Methodology for including environmental outputs in cost and profit functions

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Executive Summary

At present there are around 450 thousand hectares of grazing land in Sweden. These grazing lands provide a number of services that are valued by society. Examples are open landscape, cultural heritage and biodiversity. In this paper, focus is on biodiversity. The pastures are important habitats for both flora and fauna, and no less than 40 percent of Sweden's red listed species are represented. The preservation of the grazing lands does, of course, require grazing animals. However, extensive grazing is costly, e.g. since animals are to be attended to every day, they shall be moved between pastures in order to keep the correct grazing pressure, etc. To support agricultural production using grazing the Swedish government provides environmental support. The objective of work package 7 is to analyse the relation between biodiversity and the farmers' production decisions. Deliverable 1 contains a methodological approach as how to include measures of biodiversity in the cost and profit functions.

Preservation of grazing land and preservation of biodiversity are important environmental objectives in Sweden. To evaluate the policies an extensive data base containing biodiversity in pastures was constructed during 2002-2004. The data base contains both flora and fauna, together with other variables such as water, large trees or cultural values from e.g. old buildings. The data is however not directly usable for economic analysis and a discussion on how to make indicators on biodiversity from the biological data is provided. The data is not possible to directly match with FADN, but this is done in a matching procedure including the Swedish register for agricultural support, the Swedish farm register, and FADN.

Having biological data matched with FADN it is possible to include an index of biodiversity in the cost function. However, the provision of biodiversity is not only dependent on grazing but on nature qualities outside the control of the farmer. All types of nature cannot form habitat for all species. Not taking this into account will give biased results as some pastures contain many types of nature and should thus be able to provide more biodiversity without increasing costs. Two approaches to model this in the cost function are discussed. The first is to adjust the biodiversity measure to differences in natural conditions. In this approach the observed biodiversity is related to which species the different nature types support. The second approach models differences between pastures by directly including the area of different nature types as quasi-fixed inputs in the cost function.

In addition to the cost function approach, we discuss how to assess farmers' valuation of grazing land through modelling the profit function of farmers. The reason for being interesting in the valuation of grazing land is that it may be seen as a quasi-fixed netput, and hence the payments for this land are not necessarily equal to the benefits from it. In order to evaluate how farmers' evaluate land that is important for the biodiversity in Sweden, we have to compare the payments with the opportunity costs of grazing land. If the payments for grazing land are higher than the opportunity costs, then the policy has created a "buffer" that makes the area of grazing land less sensitive to changes in economic conditions.

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Abbreviations and Acronyms

EU	European Union
FACEPA	Farm Accountancy Cost Estimation and Policy Analysis of European Agriculture
FADN	Farm Accountancy Data Network
TUVA	Swedish database containing biological and cultural values in meadows and pastures

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Introduction

Meadows and semi-natural *grazing lands* are important for the conservation of biological diversity and preservation of cultural heritage values in Sweden and across the EU generally. A defining characteristic of these lands is that they have never been tilled, nor spread with agro-chemicals. Recognition of their value to society underlies Sweden's national environmental goal: *A Varied Agricultural Landscape* which states, "by 2010 all meadow and semi-natural grazing land shall be preserved and managed in such a way so as to preserve its value". In practice, preservation requires that this land continues to be grazed on a regular basis. Today, as over the eons, this task is performed by ruminants, principally sheep and cattle, which are part of an agricultural enterprise.

At present there are around 450 thousand hectares (ha) of grazing land in Sweden, compared to 1.3 million ha in 1923 (SJV 2003:2). However, since Sweden joined the EU in 1995 the profitability of maintaining grazing land has increased and the downward spiral of land abandonment has abated. This development has two principal explanations. First, livestock subsidies (or *headage-payments*) provided by the EU's Common Agricultural Policy (CAP) have been conditioned on the producer having a minimum area of *forage* for grazing livestock. Since grazing land is eligible forage area, headage-payments have provided an indirect subsidy for farmers to use and hence conserve grazing land. Secondly, a system of environmental payments for maintaining grazing land has been developed.

Since 2005 the EU support scheme has been decoupled, meaning that agricultural payments are no longer related to the volume of production. Thus, headage-payments are no longer available, but farmers receive payments based on their area of agricultural land. For grazing land, the decoupled payment can be combined with the environmental payments resulting in a payment scheme with three levels of subsidies per hectare. The first level is the decoupled payment, the second level is environmental payments for providing grazing land, and the third level is an additional payment for providing grazing land with premium values. The intention with the agri-environmental payments is to compensate for “costs for obligations exceeding the cross-compliance”. This is done at a higher value the more environmental output that is produced. Thus, the cost of providing environmental services is at heart of the support scheme.

The objectives of deliverable 1 are; (1) to present the concept of biodiversity and put it in a Swedish context, and (2) to provide a methodology for how to estimate the relation between costs and environmental outputs at farm level. The estimation requires detailed information on output and cost structures as well as environmental data at farm level. Data on farm netputs stem from the Swedish FADN database while environmental data is available from the TUVA database, which is built with the purpose of evaluating Swedish environmental policies. The data is, however, not collected in a way that is directly suitable for economic analysis, and how to include the environmental objectives in the analysis will to a large extent be dependent on the structure of the data. The first part of the paper will therefore contain a presentation of the data structure and how this relates to Swedish environmental objectives. The discussion includes how to construct indices from environmental indicators primarily serving for biological use. Also, a discussion on how the matching between biological data and the FADN database is presented. In the second part of the paper, a discussion on how these data will be included in the cost and profit functions will be discussed.

Environmental output indicators

In this project environmental outputs are defined as the farmers' provision of biodiversity. Other environmental outputs such as the provision of open landscapes valued for their beauty, etc., are not taken into account, although such values of course are important as well.

Below the concept of biodiversity is discussed. The aim is not to present a full discussion or definition of the concept, but to introduce some of the problems existing in the definition as related to biodiversity in the empirical application. This section is followed by a discussion on how to operationalise biodiversity in the project.

The concept of biodiversity and Swedish environmental policies

The concept of biodiversity is complex in itself and it has proven difficult to establish a unique and generally accepted definition. Molander (2008) discusses three different hierarchies, the *genetic*, the *taxonomic*, and the *ecological*, from which biodiversity can be defined. In the genetic hierarchy the concept of preserving genes is important, where the genetic variation can be analyzed using e.g. modern DNA technique. The commonly used concept of species is defined in the taxonomic hierarchy, while e.g. an ecosystem is from the ecological hierarchy. Concepts from the three hierarchies are all important in the discussion on biodiversity, a fact that shows some of the complexity in a stringent definition. In this application the approach is to follow how the concept is used in Swedish environmental policies.

The existence of different *biotopes* is important for nature conservation. A biotope is a geographically defined area in which a species live. Properties of the biotope, e.g. chemical or physical, determine which species belongs to it. A pasture is a biotope, but different properties cause the flora and fauna to differ between different pastures. Thus, different pastures constitute different biotopes. The focus in Swedish environmental policies on the kind of biotopes pastures provide should be viewed in the light of Sweden being by far covered with forest, which constitutes a different set of biotopes. With this starting point the pastures add to the biodiversity by providing biotopes for other kinds of organisms than forests are able to do. Patches of open land scattered across forest regions is often viewed as a diverse landscape. This does, however, not necessarily imply that the biodiversity from a species perspective is maximized. While many species can take advantage of the zones between pastures and the forest, other will need larger areas of open landscape (Molander, 2008).

While a pasture is a specific biotope, the variations in species might still differ between pasture areas. Some pastures are viewed as more valuable in Swedish conservation policies (Rural development program for Sweden 2007-2013). Measuring the variety of species within the pastures is, however, not straight forward. New species will by definition add to the variety, but as pointed out by Molander some species might e.g. destabilize the balance between existing species and thus be negative in the long run. This is the case for some species present in Swedish pastures as will be discussed in detail below.

Another topic in the definition of biodiversity is to what extent regional patterns should be taken into consideration. Should e.g. a nationally rare species be preserved if it is common in other EU countries? Thus, even if viewing policies from a strictly national horizon, the international dimension is always present since species are spread across national boarders. This line of reasoning is also present within Sweden where a parallell question is if species should be preserved on a regional basis.

Swedish environmental policy has 16 specified objectives, of which one is *a rich diversity of plant and animal life*. The long term objective includes e.g. that habitats should exist in sufficient numbers to maintain long-term viable species populations and that biodiversity is primarily maintained by a combination of conservation of species and their habitats (www.miljomal.nu/english, where also a further discussion is provided). An important interim target is that by 2015 the proportion of species classified as threatened will have fallen by at least 30 % compared to 2000.

Also the environmental objective of *A Varied Agricultural Landscape* has objectives directly related to biodiversity. Examples are

- Agricultural land is cultivated in such a way as to minimize adverse environmental impacts and favour biological diversity
- The agricultural landscape is open and varied, with plenty of small habitats and water environments
- Endangered species and habitat types, and also cultural environments, are protected and preserved

In addition to this an interim targets is that "by 2010 all meadow and semi-natural grazing land shall be preserved and managed in such a way so as to preserve its value" (www.miljomal.nu/english).

As is obvious from the objectives presented above, both the concepts of species and of habitats (biotopes) are important. In Sweden, despite an increasing focus on habitats and of course eco-systems, Molander (2008) concludes that the concept of species still has a very strong position in the discussions on practical nature policies (p141).

Swedish semi-natural pastures and the TUVA database

Data on biodiversity from the TUVA database will be used in the project. TUVA contains a number of biological variables in a sample of Swedish semi-natural pastures. Below, we present a short introduction to semi-natural pastures and more thorough description of the TUVA database.

Swedish semi natural pastures

Semi-natural pastures are grasslands that have not been exposed to yield-improving measures (e.g. fertilizing) and that have been grazed and kept clear from bushes over the years. This process has lead to a nitrogen scarce environment with a continuous stress on the flora due to regular grazing. This favors many smaller species since grazing primarily stresses the larger plants that are more exposed to the animals. Also, e.g. small patches of bare soil created when the cattle step on the ground are important for species reproducing by seeds since the patches are ideal growing grounds for new plants. Some species reproducing this way only live for one year, and an annual reproduction is necessary for the species to survive. This is why continuous grazing over the years is stressed as important. Semi-natural pastures are important habitats for many red-listed species in Sweden. In order to conserve this biodiversity, a continuous management through grazing is necessary – otherwise the pastures will lose a number of species dependent on the grazing animals and in the long run the pastures will turn to forest (Nilsson, 2009; Ekstam and Forshed, 1997).

The TUVA database

The purpose with the TUVA inventory is to provide data for evaluations of e.g. policies within the Swedish rural development program for 2007-2013, fulfillment of national goals concerning the environmental objective of *A Varied Agricultural Landscape*, etc.

The inventory consists of Swedish agricultural land used for semi-natural grazing that contains substantial environmental or cultural values. Data was collected during 2002 to 2004 for over 300 000 ha of land. 270 000 ha of semi-natural grazing land were classified as valuable, whilst the remaining 31 000 ha were not included in the further analysis. In total a full inventory was preformed for more than 48 000 different parcels of land.

The sample is not randomly chosen from Swedish semi-natural grazing lands. The pastures are chosen from pastures being studied earlier, pastures having applied for environmental support, as well as not formerly known pastures that have been identified during the data collection process. Thus, the TUVA database is biased towards pastures with high environmental (or cultural) values.

In the inventory data is collected for e.g. flora, fauna, existence of large trees, wetlands, and cultural qualities (Swedish Board of Agriculture, 2005b). Inventory data is stored in the database as presented in table 1.

Table 1. *Examples of TUVA data*

Data category	Description
Flora	Herbs, grass, fungi, moss
Fauna	Birds, butterflies, other animals
Trees	Large trees, dead/dying trees, etc.
Water	Wetlands, marshes, springs, etc.
Cultural qualities	Buildings, old fences, etc.

Not all of the data has been collected systematically and a further discussion on this is provided below when discussing the possibilities for using TUVA data for measuring biodiversity. Here, a short description of the occurrence of the variables in fig 1 is presented. Concerning the *flora*, so called vascular plants is in focus in the data base. In total about 420 000 registrations of vascular plants has been done in the field studies. The most common is "gulmåra" (Galium Verum) which is present in more than 20 000 pastures. Species from the *fauna* has been reported from 6 500 pastures. Reporting fauna is voluntary and most species reported are birds and butterflies. Data on *trees* has been collected systematically because many trees have both environmental and cultural values. More than 50 000 trees affected by humans for collecting e.g. winter fodder for the animals, and 22 000 trees with a diameter of more than 1 meter have been registered. Concerning the occurrence of *water,* some kind of wetland has been registered in 21 000 pastures. The most common are fresh water beaches, smaller fresh water accumulations, and creeks. In addition to environmental indicators, a number of *cultural* variables have been collected. In the pastures almost 20 000 buildings are present, predominantly barns. Other cultural qualities has been found in approximately 20 000 pastures (Swedish Board of Agriculture, 2005a).

As discussed in previous sections, biodiversity is dependent not only on grazing but on the type of nature the pasture is located in. Some plants grow on damp soil and others want a dryer environment. To cover the types of nature present in the pastures, all land is divided into categories based on Natura2000 types of nature. Of the 48 527 pastures in the TUVA database 15 712 have only one type of nature, while 31 968 have more than one (847 pastures did not have type of nature defined). In figure 1 a GIS-representation of a pasture shows how the same pasture might contain more than one type of nature and how these are situated in relation to each other.

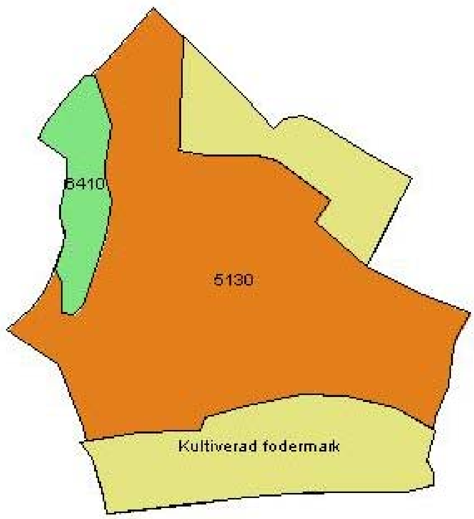

Figure 1. A pasture having more than one Natura2000-type of nature

The area labeled 5130 is a type of moorland covered with junipers, while the area 6410 is a damp meadow. The area "kultiverad fodermark" is land that to some extent has been exposed to yield-increasing measures, e.g. fertilizing (Swedish Board of Agriculture, 2005a). In total 161 000 hectares of land have been identified as some kind of Natura2000 type of habitat, while 77 000 hectares have not (Swedish Board of Agriculture, 2005a).

Using TUVA data for estimating biodiversity

Using all these variables as environmental outputs would not be appropriate for a number of reasons. The first is that some of the collected variables are more associated with cultural than environmental qualities. Although cultural qualities are valuable, such variables are not used in the environmental analysis. Further, a number of the biological variables are not systematically sampled but rather put in the database due to special interest of the person collecting the data. This is e.g. the case with fauna-variables. Also, it has been possible to register plants of special interest, but this was not mandatory in the data collection. Variables that have not been systematically collected are not used in the analysis.

The focus of the data collection has been on a set of vascular plants. These vascular plants were chosen by biological experts as indicators of the environmental quality of the pastures. The indicator plants were not chosen to give a full representation of the amount of plant species in the pastures, but as indicators of biotopes suitable for a rich biodiversity. Thus, they are common enough to be found and recognized by the persons collecting the data. In total 69 vascular plants were systematically collected. 60 of these are indicators of high quality, while the remaining are indicators of low quality. An example of the latter is the stinging nettle (*Urtica dioica*) which is favored by fertilizers. Fertilizers (and stinging nettles) are disadvantageous for species dependent on continuously grazed lands.

The potential biodiversity provided by *trees* is indicated with the number of large trees present in the pasture. A large tree is at minimum 1 m in diameter at its thinnest part from chest-height and downwards.

The potential biodiversity provided by *water* is indicated by the total number of different waters present in the pasture. Information on waters in the pasture is given for creeks, ponds, marshes, bogs, fresh water beaches, marine beaches, ground water affected land, and three types of temporarily flooded lands.

Measuring Biodiversity in Swedish Pastures

Nilsson (2009) has calculated the biodiversity output of Swedish farmers. His basic indicator is a combination of area and biodiversity indicators. The indicator for biodiversity is constructed from four sub-indicators

1. *Type of land*. If a pasture is semi-natural it gets the value four, otherwise one (Nilsson also has cultivated land in his application).

2. *Maintenance*. If the general height of the grass sward is less than two decimeters and the organic litter is less than 5 cm the indicator gets a value of three. All pastures in Nilsson fulfill this property.
3. *Vascular plants*. Count of the number of populations of indicator species. The indicator value is 0 for 0 populations, 0.5 for 1-3 populations, 1 for 4-6 populations, and 2 for above 6 populations.
4. *Bush diversity*. The indicator value is 0.25 if there are at least six different species of bushes, otherwise 0.

The four indicators are added, thus creating a biodiversity index between 0 and 9.25. The biodiversity indicator is multiplied with the area provided by the farmer to get the total amount of biodiversity output.

The index presented above weighs together a number of different characteristics. No natural weighting mechanism such as prices is available. In our application, the main approach will be to focus on one of the indicators, vascular plants, and then complement with other indicators. These will be used separately. There are a number of reasons for focusing on vascular plants in our application. The pastures in the TUVA database are chosen as to be well maintained semi-natural grazing land. Thus the first indicator will not vary across observations and is thus not used. This is most probably the case for the second indicator as well (as it is in Nilsson) although no information is available. Nilsson's indicator "bush diversity" is one of many alternatives describing biodiversity more generally as is shown below.

Vascular plants are considered to be a useful indicator of the maintenance of the grazing land and thus the habitat of many endangered species. A decrease in threatened species is an important objective as discussed above, and about 40 percent of Swedish red-listed species are present in pastures and meadows (Rural development program for Sweden 2007-2013). Although this refers to all kind of species, focus in the data collection aiming at evaluating the objectives has been on plants.

A natural starting point for describing biodiversity is a simple count of species of plants present in the pasture. However, this approach does not tell the entire story since a number of species are actually not associated with well-managed pastures, but the other way around. Thus only species that we want to be present in the pastures will be used for measuring biodiversity. This is of course a value judgment, but as is shown above when discussing the TUVA data, the species in the data collection are chosen to represent more/less well managed pastures. Denoting the representation of a wanted species in pasture *p* by *R* (i.e. R is a dummy variable taking the value 1 if the species is represented and 0 otherwise), a first indicator of biodiversity (I_1) would be

$$I_1^p = \sum_j^J R_j \qquad\qquad p = 1...P$$

Where *j* is the species, *J* is the total number of species, and *p* represents pastures.

The number of wanted species will be our base indicator for biodiversity, but the indicator will be complemented by other specifications. E.g. can I_1 be viewed as a special case of a *biological benefit function* as specified by e.g. Arponen et al (2005), Moilanen (2007), and van Teeffelen et al (2008). In a biological benefit function the benefits received from a species might be weighted. An indicator, I_2, for the biological benefits received from a pasture might then be expressed as

$$I_2^p = \sum_j w_j R_j \qquad\qquad p = 1...P$$

where w_j is a species specific weight depending on how valuable the species is to society. Again, this is a value judgment. Assigning different values to w will always imply a specification of how valuable the species are compared to each other. Arponen et al (2005) use the red-listing and regional rarity as a base for determining w where rarer species get a higher weight.

A complement to counting plants is looking at the possibility of the pasture to supply a habitat for other species. A possible indicator for this is the presence of *large trees*. A large tree might be an important habitat for many insects, lavas etc. Thus, this kind of indicator will focus on the habitat-dimension of biodiversity rather than directly approaching the variety of species. A number of other possible indicator are available, e.g. bushes and the presence of creeks, ponds, beaches, etc. Small waters are important habitats for many species that benefit from the absence of a fish population. Without the predation from fish, an ecosystem that is different from fish-inhabited waters will develop. The importance of waters is also stressed in the environmental objective of a varied agricultural landscape.

The importance of being close to other pastures

The biodiversity in a pasture is, of course, not independent of the surrounding environment. E.g. an isolated patch of open land in a forest-dominated landscape has relatively smaller recover ability when exposed to disturbances than pastures located in clusters. With other pastures around, seeds are spread between the different parcels of land, and if a species is extinct from a pasture – e.g. because of low grazing pressure during a period – it might return when the conditions are favorable again. Such re-colonization is more difficult in isolated spots (Larkeson-Nowostawski (2009). For further reading, see Krebs 2001).

Matching environmental data to FADN

The TUVA database is not possible to directly match with economic data since it has no indicator for who owns the land. Rather, the data is organized using GIS coordinates for the areas. This gives information about the location of the fields. However, this is still not directly useful for matching to FADN since the FADN data does not contain geographical information about the location of grazing land. The key to the matching problem is found in the data base used by the Swedish Board for Agriculture for administrating EU agricultural support. When applying for EU support the farmer registers the geographical location of the areas – information that is stored in the “block database”. The block data has been matched to the TUVA database for 2003. The farmer applying for support is registered in the Swedish farm register, which in turn is possible to link to the FADN data . The procedure is shown in figure 2

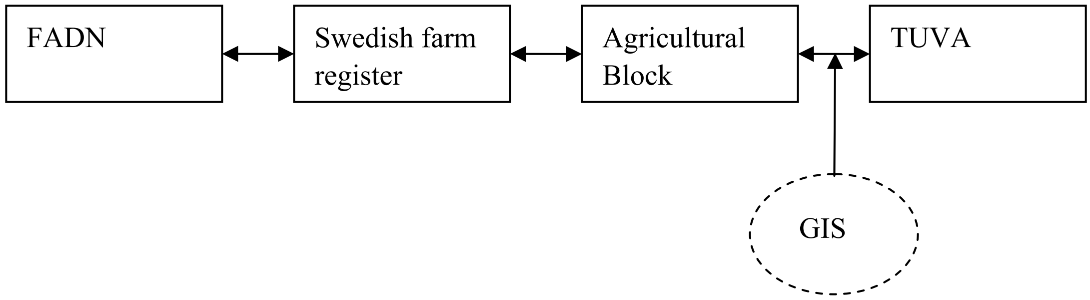

Figure 2. Matching FADN and TUVA

The major problem arising in the matching is between the TUVA database and the agricultural blocks. This matching was done using GIS-coordinates and it has thus been possible to determine which agricultural block that overlaps which TUVA object. The agricultural block does, however, not necessarily coincide fully with the TUVA object. Also, the TUVA object might consist of more than one agricultural block (and more than one farmer), and no information is available on how large share of the TUVA object is overlapped by which agricultural block. The structure is presented graphically in figure 3

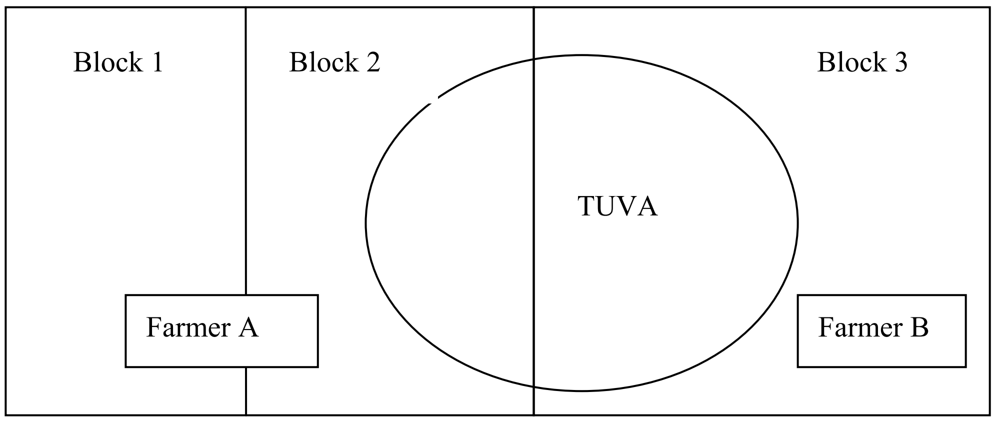

Figure 3. Geographical insteraction between farms, agricultural blocks and TUVA areas

Environmental outputs in farmers' decision making

A point of departure for analyzing farmers supply of environmental services is that the revenue exceeds cost of supplying these services and/or that the environmental services are produced jointly with marketable outputs (see e.g. Wossink and Swinton, 2007, for a discussion). This study assumes that there is a joint production, which implies that one may study whether market outputs and environmental services are complements or substitutes. In Swedish semi-natural pastures, revenues stem primarily from the agri-environmental supports and from the pastures providing feed-stuff to the cattle in the beef-production. When choosing to produce milk and beef using grazing as an input the farmer will jointly produce habitats for many plants and animals that are dependent on pastures for their survival. This has no market value to the farmer, but additional environmental support might be available if providing a rich biodiversity. The costs of providing grazing land contain both direct costs and alternative costs for labour and land. The direct costs involve e.g. fencing, clearing bushes, and transportation of animals between pastures in order to keep the grazing pressure within the limits for gaining support from the agri-environmental scheme. Transportation and looking after the animals on a daily basis is labour intensive and the farmer's time has a value in other uses within the farm as well. Grazing land could be used for other purposes as well, forest being the most realistic alternative.

The environmental services in this study will be measured indirectly through the hectares of valuable grazing land and directly through a biodiversity index. It is assumed that these services are fixed in the short term. That is, the valuable grazing land with its biodiversity may not turn to forest or arable land in no time, which partly depends on that a conservation contract runs for five years. In order to evaluate the effects of environmental services on farmers' production decision, we use two different approaches: The profit function and the cost function. The profit function is more general since it includes both the farmers' input and output decisions, and hence one may assess farmers' valuation of environmental services through the shadow price equation of land with environmental services or a more direct measure of, for example, biodiversity (see Peerlings and Polman, 2004). This is of interest since the environmental services are fixed in the short term, which implies that the shadow price reflects the marginal cost of producing these services. In the cost function approach the effects of environmental outputs on production costs are modeled by directly relating the costs of production to differences in environmental services.

Both the profit and cost functions will be estimated using econometric techniques. As far as we are aware nobody has previously studied the decision to maintain grazing land and biodiversity with farm level econometric models. A reason for this could be that the CAP system of livestock subsidies is particularly complicated to model econometrically (Colman and Vavra, 2002). Another is that grazing land conservation has previously been studied primarily from a consumer perspective rather than the producer's (e.g., Carlsen, 2001).

We have chosen an econometric rather than a programming approach because of uncertainty surrounding farmers' valuation of grazing land as an input to meat and milk production. Specifically, little is known about the productive capacity of semi-natural grazing land, which can vary considerably from farm to farm and region to region. For this reason we hope to utilize the information revealed by farmers' *actual* production decisions over time—which we have detailed knowledge of—to estimate their implied valuation of grazing land. An econometric approach provides the tools to do this and thus reveal information that is otherwise privy to farmers. The problem of farmers hiding information relevant to designing agro-environmental policy instruments is a general frustration for financially constrained policymakers (e.g., Hart and Latacz-Lohmann 2005).

Previous research

Studies of the supply side of environmental benefit production from agriculture are fairly new. In their pioneering studies, Peerlings and Polman (2004) use a similar approach to this paper to investigate the joint production of milk and landscape services, and Bonnieux *et al.* (1998) analyze farmers' decisions to produce or not produce environmental services, also using a microeconomic approach. As such this paper represents an extension of the research published in these studies.

Moschini (1988) has developed a theoretical framework for analyzing the resource allocation effects of supply-restricting policies. We adopt his framework to model the restricted supply of grazing land and other outputs under the CAP. His model however does not allow estimation of farmers' valuation of grazing land. Boots *et al.* (1997) solve a similar problem by valuing milk production quota using the *virtual pricing* approach (Neary and Roberts, 1980; Lee and Pitt, 1986). We also use virtual pricing to value grazing land.

A number of studies have modeled farmer's decision using the cost function. Alvarez et al (2006) estimate the shadow price for milk quotas in Spain using a cost frontier with land as a quasi fixed input. They find the quota value decreasing over time as a consequence of increasing marginal costs and decreasing milk prices, although the effect is partly compensated by increasing efficiency.

Morrison-Paul et al (2002) use a combined Generalized Leontief – Quadratic functional form to estimate a cost function for analyzing the pesticide use in U.S. Agriculture with regional dummy variables included to analyze regional patterns. The shadow value of pesticides is calculated in order to reveal the costs of environmental regulations decreasing the allowable usage. Morrison-Paul (2001) uses a similar functional form to analyze the cost structure in the U.S. beef industry. In the application three fixed control variables (capital, materials, and cattle) were used.

Regarding Swedish semi-natural pastures, Kumm (2004) shows that the additional costs of grazing on pastures scattered accross the Swedish forest dominated landscape is not covered by the present environmental allowances. If recreating larger pasture mosaics by incorporating adjacent forest and arable land the cost of production would decrease.

A study of particular interest for estimating the cost of producing environmental outputs in Sweden is Nilsson (2009) who develops a methodology for estimating costs of biodiversity production. Focus in the study is the additional cost of producing biodiversity when animals are already kept at the farm. Costs for providing pastures are not available at farm level but calculated from assumptions of costs per area and perimeter of the field. The biodiversity output is calculated as a combination of area and a number of characteristics as has been discussed above. The empirical application estimates the cost of agricultural production of biodiversity in the Selarö island in lake Mälaren and in the municipality of Vetlanda. Nilsson puts forward that using farm level costs and more production areas would be the next step in order to estimate a cost function that will be useful in policy work. Doing this is one of the contributions of our paper.

Theoretical model of farmers' valuation of conserving grazing land

A useful economic tool for predicting farmers' market behavior is the profit function, which gives the firm's maximum profit as a function of prices. Before formulating the profit function note that **q** is used to denote a vector of $i = 1,..,I$ variable netput quantities with associated price vector **p** and *x* the area of grazing land that is supported by a payment (i.e., price) *s* per ha grazing land (In Appendix A we show how headage and environmental payments can be expressed as a single price per ha grazing land). Under the restricted profit function, which is used for considering short-run decisons, farmers are assumed to choose levels of **q** and *x* that maximize profits subject to a vector of $k = 1,..,K$ quasi-fixed inputs **z.**

Given this background the restricted profit function is formulated as

$$\Pi\left(\mathbf{p}, s, \mathbf{z}\right) = \max_{\mathbf{q},x} \left\{\mathbf{p}'\mathbf{q} + sx; F\left(\mathbf{q}, x, \mathbf{z}\right) = 0\right\}. \tag{1}$$

The profit function Π is the maximum attainable profit from choosing netputs **q** and grazing land area *x* given prices **p**, payment *s*, quasi-fixed netputs **z** and the existence of the transformation function *F*. The assumed properties of the profit function are standard: nondecreasing in output prices and fixed inputs, non-increasing in input prices, linear homogeneous and convex in prices, concave in quasi-fixed quantities, continuous and twice differentiable.

The area of grazing land, as stated earlier, is in practice fixed in the short-run. First, previously abandoned grazing land is an irreversible effect from an environmental perspective in the short-run and, secondly, farmers receive environmental payments to "conserve" the remaining area of grazing land under five-year conservation contracts. We therefore assume that the area of grazing land is quasi-fixed such that $x = \overline{x}$.

Further, an important element of the CAP, are output constraints in the form of production quotas. For any particular farm the netput vector can be partitioned into constrained outputs, e.g., milk, q^0 , and unconstrained netputs, $\mathbf{q}^1 = (q^1_{,..,} q^I)$. Similarly the price vector can be partitioned into p^0 and $\mathbf{p}^1$ .Thus, in the short–run, the farmer chooses levels of unconstrained netputs to maximize profits given quota constrained milk output q^0 and contracted grazing-land area $\overline{x}$. Following from Helming *et al.* (1993) the output constrained profit function relevant to farming under the CAP can be expressed as

$$\Pi^c\left(p^0, \mathbf{p}^1, s, \mathbf{z}\right) = \max_{q^0,x} \left\{p^{0'}q^0 + s\overline{x} + G\left(\mathbf{p}^1, s, q^0, \overline{x}, \mathbf{z}\right)\right\} \tag{2}$$

where Π^c is determined by the total revenues from milk output and grazing-land conservation plus the net returns from unconstrained outputs over variable input costs.

The partitioned profit function *G* is defined as

$$G\left(\mathbf{p}^1, s, q^0, \overline{x}, \mathbf{z}\right) = \max_{\mathbf{q}^1} \left\{\mathbf{p}^{1'}\mathbf{q}^1\right\} \tag{3}$$

where G is the maximum attainable profit from unconstrained production given prices $\mathbf{p}^1$, payment s, milk quota q^0, grazing land area $\bar{x}$, and quazi-fixed inputs $\mathbf{z}$.

The maximum attainable profit under CAP constraints is

$$\pi\left(\mathbf{p},s,q^0,\bar{x},\mathbf{z}\right)=p^{0'}q^0+s\bar{x}+G\left(\mathbf{p}^1,s,q^0,\bar{x},\mathbf{z}\right) \quad (4)$$

where π is the profit from exogenously given milk output and the area of managed grazing-land, plus the maximal profit from production of unrestricted outputs.

Hotelling's lemma implies that the netput demand and supply functions implied by the farmers' profit maximizing decisions given the output constraints are:

$$q_i^*\left(\mathbf{p},s,q^0,\bar{x},\mathbf{z}\right)=\frac{\partial G\left(\mathbf{p}^1,s,q^0,\bar{x},\mathbf{z}\right)}{\partial p^i} \qquad i=1,..,I \quad (5)$$

where q_i^* is the optimal quantity of the i^{th} netput. Since the area of grazing land is limited, there exists a virtual price μ that would induce the farmer to freely choose the area $\bar{x}$ (Fulginiti and Perrin, 1993). Hence, also by Hotelling's lemma

$$\mu\left(\mathbf{p},s,q^0,\bar{x},\mathbf{z}\right)=s+\frac{\partial G\left(\mathbf{p}^1,s,q^0,\bar{x},\mathbf{z}\right)}{\partial\bar{x}}, \quad (6)$$

where the virtual price or value of grazing land to the farmer is influenced by the size of the payment s for conserving grazing land minus the opportunity cost of managing grazing land $\left(\partial G/\partial\bar{x}\le 0\right)$ which is determined by netput prices $\mathbf{p}$, the size of the milk quota q^0, the given area of grazing land $\bar{x}$ and the level of quasi fixed inputs $\mathbf{z}$.

Similarly, the virtual price of milk quota, θ, is defined as

$$\theta\left(\mathbf{p},s,q^0,\bar{x},\mathbf{z}\right)=p^0+\frac{\partial G\left(\mathbf{p}^1,s,q^0,\bar{x},\mathbf{z}\right)}{\partial q^0}, \quad (7)$$

where $\partial G/\partial q_0\le 0$ is the marginal cost (or shadow price) of producing an additional unit of milk.

With recourse to the envelope theorem we can also recover the shadow prices of the quasi-fixed inputs from the optimized profit function. These are

$$\lambda^k\left(\mathbf{p},s,q^0,\bar{x},\mathbf{z}\right)=\frac{\partial G\left(\mathbf{p}^1,s,q^0,\bar{x},\mathbf{z}\right)}{\partial z^k} \quad \text{for } k=1,..,K. \quad (8)$$

In order to make the discussion slightly less abstract, one could specify the model so that (the exact specification will be done in later workpackages) the netput vector **q** contains $i = 1,..,7$ netputs where; q^1 is the value of total commodity output, q^2 is the area of arable crop output (excluding forage area),[1] q^3 is the area of grass silage output, q^4 is the area of arable forage output, q^5 is total livestock input in terms of animal units, q^6 is purchased feed costs and q^7 is all other variable costs of production. For the purposes of our study, three general classes of land-use were identified; i) arable crops, $q^2 + q^3$, ii) arable forage, q^4, and iii) grazing-land, *x*, where the total area of forage is $x + q^4$. Note that arable land can be used as forage area to collect headage-payments or to produce silage or arable crops, whereas grazing land has no alternative agricultural use. Abandoned land is assumed to regenerate to forest in the long-run, a relatively low value land use. Forest however cannot be converted to agricultural land (in the short-run at least), hence the total area of agricultural land is physically constrained in the short-run.

The economic interpretation of the solution to the farmers' land allocation problem is illustrated in Figure 4. Panel (a) illustrates the allocation of arable land between arable crops, q_2 and forage, q_4. The area of silage is not shown to keep the diagram in two dimensions, but is allocated according to identical principles. The marginal profit (or derived demand functions), $\partial G / \partial p^i$ for $i = \{2, 4\}$, are decreasing and follow from Equation (5). Given the limited area of arable land, denoted $\overline{L}$, the marginal profit from the competing land uses, q_4 and q_2 (and of course q_3 which is not shown), must be equal on the margin to ensure profits are maximized, and the size of this marginal profit is equal to the shadow price of arable land, $\lambda_{\overline{L}}$, which follows from Equation (8). If marginal profits are not equalized for competing land-uses then the farmer could increase profits be reallocating land. Panel (b) illustrates the farmers' marginal valuation of grazing land. Since this area is fixed in the short-run a positive profit or *rent* will exist on the margin, the size of which is equal to the virtual price of grazing land, μ. With recourse to Equation (6) farmers receive an explicit payment *s* for managing grazing land but are also faced with implicit or opportunity costs of devoting resources to management, which are represented by the increasing marginal cost function $\partial G / \partial \overline{x}$.

The difference between the payment *s* and marginal opportunity costs is the farmer's implicit valuation of grazing land. If this valuation is positive then a marginal reduction in commodity prices or livestock subsidies will not impact the area of grazing land. Rather, a reduction will be absorbed or "buffered" by lower rent to grazing land. Further, the higher the rent on the margin, the less sensitive the area of grazing land will be to changes in economic conditions and the greater the buffering effect.

As in Peerlings and Polman (2004) one may take an additional step and derive a supply function of biodiversity based on the first-order condition in Equation (6).

[1] The price of crop area is equal to the CAP area payment for eligible crops.

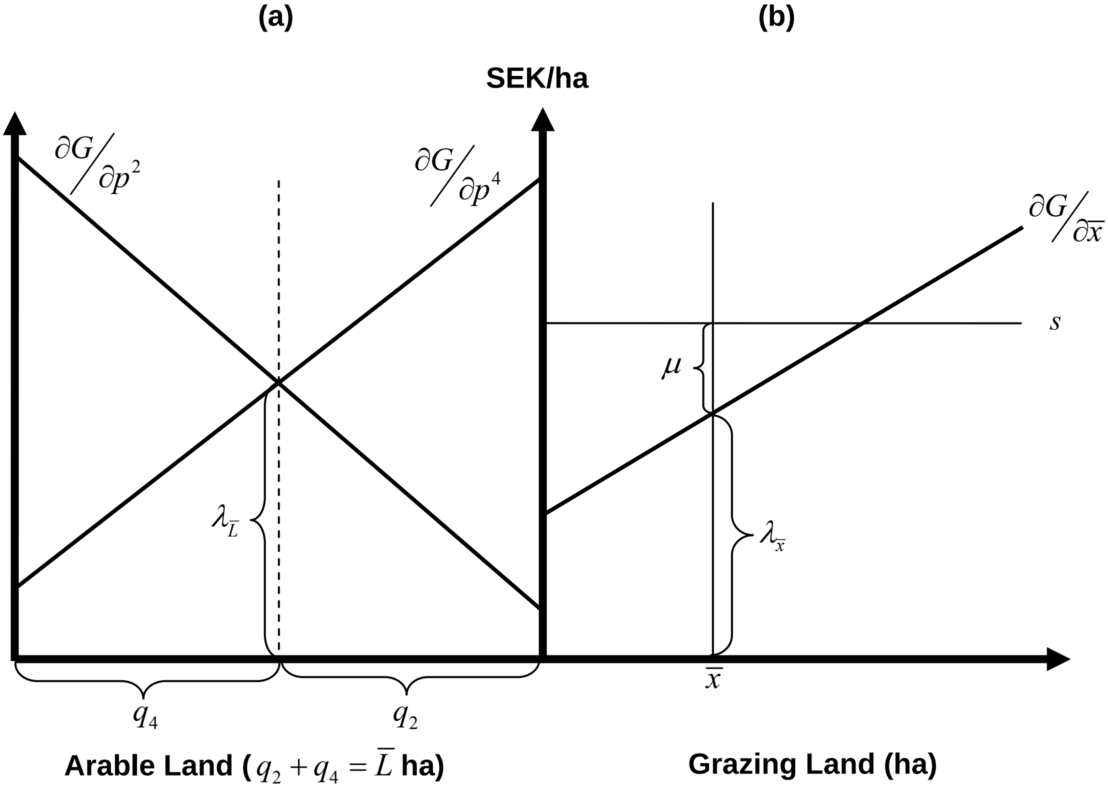

Figure 4. Solution to the farmers' land allocation decision

The policy implication of a rent on the margin is that, the higher the rent the less sensitive land-use will be to reductions in subsidies (i.e., headage-payments). As long as the rent is positive, the farmer will have no incentive to reduce the area of grazing land: if he did then profits would decline. The size of the rent is therefore an important variable for policymakers concerned about the conservation of grazing land. As was shown previously the size of this rent is affected by a number of exogenous variables, and not simply the payment to grazing land, *s*, the others being; variable netput prices and the levels of quasi-fixed netputs.

The system of equations defined by Equations (4) and (5) can be used to estimate all the parameters of the profit function given the exogenous variables $(\mathbf{p}, s, q^0, \overline{x}, \mathbf{z})$. Once these parameters are known, Equations (6) to (8) can be used to calculate the virtual prices of grazing land and milk quota, and the shadow prices of the quazi-fixed inputs. Price elasticities for variable netputs can be derived by suitable transformations of the estimated netput functions (details of which can be supplied by the authors on request). In the next section we present and estimate the empirical model, from which we derive farmers' valuation of grazing land and milk quota, shadow prices of quasi-fixed inputs, and relevant price and quantity elasticities (which reflect the slopes of the curves shown in Figure 4 in reality) .

The cost of producing environmental outputs

When we use the cost function perspective, we could choose from two different approaches in order to investigate the effect of environmental services or biodiversity on the firms' cost structure. Our study will consider both of them. In both approaches, a variable cost function is used since capital and land are quasi-fixed inputs. In the first approach, we model biodiversity as a quality index. That is, although the quality of farms' market outputs may be measured in terms of their biodiversity, it may be (1) problematic to value this quality at the market and (2) difficult to change biodiversity in the short run (e.g. due to contracts). Still, biodiversity may be costly and it may restrict the optimization of farms' production process. Hence biodiversity may act as a cost-shifter between otherwise identical farmers, and such an approach has been used in *inter alia* by Mocan (1995) as well as Shimizutani and Suzuki (2005) in order to measure quality-adjusted cost functions in child care and elderly care. Variables representing quality as both biodiversity in itself and as habitats (nature types) are available from the TUVA database, and are further discussed below.

Second, an alternative approach is to model biodiversity as an additional attribute of the farm output that farmers consider when they optimize their businesses. In this case quality (or biodiversity) becomes endogenous. That is, an increased biodiversity might – if large enough – entitle the farmer to additional environmental support or even higher prices if this attribute may be communicated to and is appreciated by consumers. This approach has been used *inter alia* by Blank and Eggink (2001) and Gertler and Waldman (1992) in order to quality adjust cost functions. If we use this approach, then the short run cost function is defined as

$$C(w, y, z) = \min_{x \geq 0}\{wx : x \in L(y, z)\}$$

Where x is a vector of variable inputs, y is the output vector and z represents the quasi-fixed inputs. [1] $L(y,z)$ is the input requirement set, i.e. the amount of x necessary to produce y given the amount of the fixed inputs z available in the production process. y is a vector containing all outputs, but for our purposes it is illustrative to divide the output vector into conventional production y^c and, environmental outputs y^e. This will give the cost function

$$C(w, y^c, y^e, z) = \min_{x \geq 0}\{wx : x \in L(y^c, y^e, z)\}$$

The environmental output, y^e, can be determined by the farmer by different methods of production. The production of y^e does, however, also depend on nature qualities that are not under control of the farmer. That is, the quality or the biodiversity level is determined partly endogenously and partly exogenously.

As *inputs* in the productions are, of course, used inputs used for milk and beef production (x, z). The provision of biodiversity from the pastures is dependent on nature qualities that are not possible for the farmer to change, at least not in the short run (e.g. the presence of marine shores, different geographical locations, etc.). The nature types interacting with the farming activities in order to provide habitats for plants and animals are an important aspect of the quasi-fixed inputs in the production of biodiversity. In the project we will consider a number of different ways to include this in the cost function. We do not present a single empirical specification, but possible ways to continue. Which models will be chosen depend on the data and further empirical work.

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[1] E.g. Alvarez et al (2006) model agricultural land as quasi fixed, while Mocan (1995) use physical space as a quasi fixed input for estimating costs in American child-care centers.

The *first* way to include differences in the nature type is to adjust the biodiversity measure to take nature type into account. Each type of nature is expected to be able to support a specific number of species – i.e. it has a maximum possible provision of biodiversity. This maximum is of course not only dependent on the nature type, but also on e.g. how far north the pasture is located. Many pastures have more than one type of nature, and the more types the higher biodiversity could be expected to be present. By relating the observed biodiversity to the maximum, given by the natural conditions found in the pasture, an index will be constructed. This index is then included in the cost function as an environmental output. One way of doing this is a technical approach following biological expertise judgments on possible biodiversity. This approach is dependent on biological information about which species different nature types support.

The *second* way is to include differences in the access to nature types directly in the cost function. In this approach, the hectares of different nature types are included as quasi fixed inputs. A 10 ha pasture may, for example, containing 5 ha of nature type "A" and 5 ha of nature type "B" will be divided into two quasi-fixed inputs of 5 ha each. Referring to figure 1 (the map of a TUVA object), each of the areas "kultiverad fodermark", "6410", and "5130" will be modeled as separate inputs. In aggregate the different nature types will sum up to the total area of pasture. Even if the traditional production of milk and beef is not dependent on nature types, the distinction between different kinds of pastures (nature types) is important for the production of biodiversity. An alternative is to include nature type-dummies in the cost function. This approach is similar to Morrison-Paul et al (2002) (or the first approach discussed above) using regional dummies. Data contains several different types of nature, and it is an empirical question if all these are to be used separately, or if some of them could be aggregated.

As environmental *output* (y^e) when modeling environmental services as an output will be area adjusted for biodiversity quality. Adjusting the area for biodiversity will be done by multiplying the area of grazing land with a biodiversity index describing the biological variety within the pasture. An example illustrating the procedure is an area of 10 hectares providing 10 species. Using the number of species as index, this would correspond to 10*10 = 100 units of output. This approach is similar to that of Nilsson (2009). Estimates of biodiversity that will be used have been discussed above. A property of this output specification is that the same amount of output could be produced using a large area with low biodiversity or a smaller area with high biodiversity.

The biodiversity adjusted area has the advantage of taking both the biodiversity in itself and the area providing it into account. Although the concept of biodiversity is often discussed in a species-dimension (see e.g. Molander, 2008) and not directly related to areas, the area is of course a necessity since it functions as habitat for the species. Also, areas are important in practical nature conservation policies.[1] Only using a biodiversity index as output indicator would imply that two pastures having the same biodiversity, but different sizes would be modeled as having the same output. This is partly true, if only looking at the variation of species. This would imply that smaller pastures are more efficient providers of biodiversity since less input is necessary to provide the same output. A single biodiversity measure does neither take into account that smaller areas might be more vulnerable to disturbances, and thus face a larger risk for losing biodiversity in the long run.

A further implication of the approach outlined above is that nature type – i.e. the habitat – is modeled as an input. This follows from the discussion on biodiversity as the final output. Of course, habitat is an important target for environmental policies and could be modeled as output as well (or as an exogenous factor restricting the farmers'

[1] See e.g. the Swedish environmental objectives in "A Rich Diversity of Plant and Animal Life" where one objective is that "Habitats exist in sufficient numbers to maintain long-term viable species populations.

optimization possibilities as in the first approach). An attractive feature of this is that the habitat could contain biodiversity that is not represented in the available data.

Functional form in the empirical model

A number of studies have estimated econometric profit- or cost functions using agricultural data. E.g. Boots et al (1996), Helming et al (1993), and Peerlings and Polman (2004) estimate a normalized quadratic specification of the profit function. Csajbok et al (2005) use the same specification with FADN data for a number of Dutch farms. Morrison Paul et al (2002) estimate a cost function specified as a generalized Leontief, while Morrison Paul (2001) estimate one specified as a combination of Generalized Leontief and Quadratic. These are examples of functional forms used for estimating the functions, but others such as the Translog function used by e.g. Gertler and Waldman (1992) are available as well. Although a flexible form will be used, the specific choice of will be a matter for the empirical application.

Conclusions

The presence of semi-natural grazing lands is important for Sweden's environmental objectives concerning both *a varied agricultural landscape* and *a rich diversity of plant an animal life*. At present there are around 450 thousand hectares of grazing land in Sweden. To evaluate the policies an extensive data base (TUVA) containing biodiversity in pastures was constructed during 2002-2004. The data base contains both flora and fauna, together with other indicators such as water, large trees or cultural values from e.g. old buildings etc. The objective of work package 7 is to discuss the relation between biodiversity and the cost of production. Economic data is provided in the FADN data base and in the Swedish farm register. The conclusion from the analysis is that biological data is possible to match to data bases containing economic information, and that it is possible to use the biological variables as indicators of biodiversity in an economic model. Methodologies for doing this concerns e.g. which species should be included in the biodiversity output, how to aggregate observations on individual species, and how to include this and other important biological indicators in the cost and profit functions.

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