Agricultural Land and Landscapes

Assessing the Resource Situation and Developing an Alternative System of Agri-Environmental Payments – Models with Applications in Sweden

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Abstract

The agricultural land provision of private and public goods is studied by interdisciplinary approaches on the supply from a resource economics perspective and on efficient policy measures from a welfare economic perspective. The socially optimal production of landscape public goods is derived theoretically by introducing the concept of quantitative hectares where measures of area and biodiversity etc. are integrated. Agri-Environmental Payments based on state Indicators (IAEPs) expressing the presence of public goods at the object level (field, landscape element) are developed and tested as an attempt to efficiently promote optimal supply in policy practice. A model of meta-criteria and criteria is developed, resulting in a coherent and complete set of seven composite indicators for Swedish conditions. Estimating the indicators in two study areas indicates large heterogeneity in the supply of public goods, and consequently that IAEPs would differ significantly across objects and accordingly from the present. The public good IAEPs turn out as giving a more efficient resource allocation, better dynamic incentives and lower transaction costs than the corresponding Swedish payments, but conflict with WTO-demands on cost-based payments and give large distributional effects.

A concept and measure of agricultural land resources is introduced, defining their size by their capacity to yield products in physical or economic terms. The physical resource measure "barley-equivalents" is developed and calculated by combining production functions with statistics from the 420 agricultural districts of Sweden. A further development is the concept of standard-hectares, making acreage comparisons possible amongst different grades of land. The economic measure of the resources is land rent, here calculated as the residual of revenues minus costs in crop production. Swedish arable resources measured by land rents are fairly heterogeneous, showing distinct regional patterns. The rent of Swedish arable land was nearly normally distributed around a mean of US$ 100 per ha (1983). The arable land resource situation is also illustrated by a new diagram that plots land rent against cumulative acreage. The model of Swedish arable resources is furthermore used to estimate the possible impacts of sub-soil compaction, urban exploitation, tropospheric ozone and other major resource influencing factors.

Keywords: agricultural land, agri-environmental payments, criteria, environmental economics, indicators, land rent curve, land resources, policy evaluation, public goods, resource economics

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Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Hasund, Knut Per (2011). Developing Environmental Policy Indicators by Criteria – Indicators on the Public Goods of the Swedish Agricultural Landscape. *Journal of Environmental Planning and Management* Vol. 54(1), 7–29.

II Hasund, Knut Per (2012). Indicator-based agri-environmental payments: A payment-by-result model for public goods with a Swedish application. Accepted March 2012 for publication in *Land Use Policy*.

III Hasund, Knut Per (1986). Jordbruksmarken i naturresursekonomiskt perspektiv. Swedish University of Agricultural Sciences, Department of Economics, Report 269. Licentiate thesis. Uppsala.

Abbreviations

AEPs	Agri-Environmental Payments
AVP	Average Value of Production
be	barley-equivalents
CAP	Common Agricultural Policy of the European Union
ha	Hectare
IAEP	Indicator-based Agri-Environmental Payments
MC	Marginal Costs
MVP	Marginal Value of Production
Mha	Million hectares
N	Nitrogen
PRTCs	Policy Related Transaction Costs
p_s^*	Social optimal price
q_s^*	Social optimal quantity
qha	Qualitative hectares
qm	Qualitative meters
qN°	Qualitative number
SEK	Swedish crowns
SLU	Swedish University of Agricultural Sciences
TB3	Gross Margin Measure 3

1 Introduction: The Research Questions

1.1 The Addressed Policy Problems

Agricultural land can be considered a resource. This resource may provide semi-ecosystem services of two kinds: private goods and non-rival or non-excludable goods, often referred to as public goods. The private goods are primarily food, energy, fibre or industrial products that have well defined property rights. The public goods provided on agricultural land are mainly biodiversity, cultural heritage and other social landscape amenities such as scenery and recreational access. There are also non-environmental public goods involved, in particular food security (in terms of future supply capacity). This character of providing a spectrum of services is often referred to as multiple production; see e.g. Nilsson et al. (2008).

An aim in this work has been to address policy relevant problems related to agricultural land and its services. Social efficiency is the normative criterion that is adopted in the thesis to determine what is considered as a policy problem, and what is not. This means that any land use or land management that gives a lower net of total benefits minus total costs than what would be possible by changing resource mix, technology or output mix would be a relevant problem, to consider for possible policy measures. In this welfare economic perspective, a principal problem in how to manage agricultural land resources concerns the positive external effects of production that are environmental public goods. The two articles I and II address the policy problem of how to develop agri-environmental payments (AEPs) to these environmental services, that is, policy measures that are efficient and comply with established fairness and feasibility criteria. The environmental problems in question are briefly described in chapter 1.2 below.

Multiple production involves technically linked output relations, although not necessarily in fixed proportions. A point of this study is that policy measures may give producers incentives to a socially more optimal output mix, besides a more optimal output quantity of the environmental public goods. As presented in the articles, welfare economic analysis shows that an AEP related to the value of the positive public good theoretically have the properties of an efficient policy measure. The challenge of this study is how this can be done in practice.

Paper III, the licentiate thesis, concerns the policy issue if the arable land resources will suffice for future demands, or if there is a risk that the welfare of future generations may be reduced by factors that could be met by appropriate measures. Hence, the licentiate thesis III deals with possible problems related to arable land resources' capacity to provide commodities. There is a scientific controversy whether private markets are able or not to efficiently handle very long term effects even for private goods (see e.g. Harrison, 2010, or Zhuang *et al.*, 2007) or to handle complex uncertainty problems (e.g. Kahneman and Tversky, 1973, or Tversky and Kahneman, 1973). The thesis does not deal with these issues, but rather study their possible origin. A resource economic concept and a linked measurement methodology are developed that enables assessments of the resource situation and analysis of resource influencing factors. Less controversial is to state that food security is a matter of intergenerational distribution. In a welfare economic policy perspective, food security of arable land resources is a public good in terms of non-use, bequest values.

All three contributions to the thesis (I, II, III) are highly interdisciplinary approaches. The thesis is based mainly on applied research.

1.2 Swedish Agricultural Land, Landscapes and their Environmental Qualities

1.2.1 Agricultural land and landscape elements

In quantitative terms, arable land in Sweden has declined from 3.5 Mha in 1950 (SBA, 2005b) to 2.65 Mha in 2007 (SS, 2010). The decline has been largest in the north and the forest regions (*ibid.*). Traditional meadows[1] have plummeted from 2 Mha to 9400 hectares during the 20th century (SBA, 2005b, 2009). In addition, the area of semi-natural pastures[1] has declined

[1] Traditional meadows and semi-natural pastures are permanent grasslands used for hay-making and grazing, respectively. that never have been exposed to measures such as soil cultivation, fertilizing or pesticide spraying.

drastically, but is now stabilised around 230,000 ha (SBA, 2005a, 2009). There are in total 490,000 ha of permanent grasslands[2] (SS 2010).

Stonewalls, ponds and other field elements have been removed in large numbers until a ban was imposed in 1985. In other cases, they have disappeared functionally as the land was abandoned or afforested. Surveys by Ihse (1995) indicate that at least 50% of the former field elements in Sweden have been removed since 1947.

1.2.2 Environmental qualities of the agricultural landscape

A wide spectrum of environmental qualities and services provided in the agricultural landscape are assigned environmental values. Those that are public goods (see 2.1) are here divided into the three main categories biodiversity, cultural heritage, and socio-cultural qualities, where the latter includes scenery, identity (national, regional, local), access for recreation, etc.

The modernization of food production has caused drastic changes of Swedish agricultural landscapes over the last decades. The maintained area and its environmental qualities have been reduced by changes in technology and mixture of input factors. This process is likely to continue. The use of fertilizers and pesticides have reduced the biodiversity of pastureland and field edges. Decreased management of field elements, permanent forest edges and pastureland with lower grazing pressure and less clearing of shrubs and brushwood have negative ecological, cultural heritage, and socio-cultural landscape effects (SBA et al., 2002; Jonasson and Kumm, 2006; SBA, 2006). Similar patterns of agricultural landscape deterioration have taken place in most industrialized countries (EEA, 1995; OECD, 1999).

Concerning biodiversity, there have been significant reductions of habitats and population sizes. About half of all red-listed species in Sweden belong to the agricultural landscape, which comprises 1700 threatened species (SSIC 2005). The decline is caused by the loss of traditional meadows, semi-natural pastures, and field elements, as well as qualitative deterioration. Traditional meadows and many of the semi-natural pastures are the most species rich terrestrial habitats in Scandinavia (Svensson, 1988; Kull and Sobel, 1991).

The cultural heritage of the agricultural landscape is linked to land use patterns and structures showing earlier systems of cultivation, and to cultural relics such as wooden fences, cultivation cairns and coppiced trees. These qualities have been impaired by the large scale abandonment of arable and

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[2] The official Swedish land use category "permanent pastureland" refers to land that is used for grazing and not suitable for plowing. Accordingly, grazed permanent leys on arable land are not included.

pasture land, the removal of field elements in arable fields, and the changed management methods (Ihse, 1995).

1.3 Outline of the Thesis

The thesis continues with a brief exposition of the theoretical foundation of the two AEP-articles, where the optimal price for landscape public goods is derived from the introduced concept of qualitative hectares. Using the theoretical conclusion on conditions for efficient policy measures, the approach of indicator based AEP is then developed in section 2.3 as an attempt to apply such "public good-differentiated" payment principles in practice.

Chapter 3 summarizes the papers, starting with article I where an indicator system is developed by a multi-criteria model. The developed IAEPs are assessed with respect to efficiency, fairness and implementation feasibility criteria in article II. The other aspect of agricultural production, the arable land as a resource for providing private goods, is treated in the licentiate theses III, section 3.3. It starts by analyzing the resource features, followed in 3.3.4 by the development of physical and economic resource measures based on these concepts, and estimates of the Swedish resource situation. A tentative analysis on factors influencing the future resource situation by applying the resource model is presented with the example of sub-soil compaction in section 3.3.5.

Chapter 4 concludes the thesis by a discussion on its assumptions, methods and results.

2 Theoretical Background: Landscape Public Goods and Policy Measures in a Welfare Economic Perspective

2.1 Social Efficiency and Environmental Qualities

Agriculture produces biodiversity, cultural heritage, and other socio-cultural qualities. If agriculture ceased, much of these environmental goods and services would disappear. Traditional agriculture provided more of such environmental services by technical complementarity in joint production with food. Changing technology and changing relative prices have, however, reduced the supply drastically over the last decades (see Romstad *et al.* (2000), Vatn *et al.* (2002), Wossink and Swinton (2007)), which explains the trends described in chapter 1.2.2 above.

A welfare economic partial explanation to the environmental problem is that these services are positive externalities of agriculture. Accordingly, farmers are not paid for these environmental services by any private market, which implies that there are neither economic incentives, nor any external financing for the production.

The externality problem is caused by two characters of these products: they are non-excludable and non-rival in consumption, or with a popular term, they are public goods. Furthermore, these public goods are included of considerable proportions in the utility functions of many persons. Taken together, this implies that private markets, based solely on property rights and contracts, will not provide socially efficient land use or environmental quality of the land at present conditions.

Non-excludability implies that it is not possible to prevent anyone from consuming the good. This applies independent of property rights and payments: a person's consumption cannot be restricted by legal rights or if (s)he does not contribute to the environmental service. Consequently, there are free-riding incentives that lead to socially sub-optimal production of non-excludable environmental services (Randall, 1972). Many of the environmental qualities in the agricultural landscape are non-excludable, not the least non-use values of biodiversity and cultural heritage or use values in terms of scenery and local identity.

Also non-rivalry leads to less than optimal provision of biodiversity, pastureland or other landscape goods. The reason is that the market underestimates their social value by considering only the values assigned by the buyer(s), but neglecting the values that are assigned to these services by all other persons that are additive because their consumption is not reduced by rivalry. (Randall, 2002; Samuelson, 1954)

The transaction costs to supply landscape public goods above the by-product equilibrium (q^*_m in *Figure 1* below) at private markets are in most cases prohibitively high, even for co-operative solutions; see Coase (1960), Dahlman (1979), Vatn *et al.* (2002). The high costs are caused not merely by the non-excludability character but also by the heterogeneity of the good and of the large number of persons affected (Vatn *et al.* 2002). There are many thousands of arable fields, pastures, and field elements in Sweden, all different. Object size, local climate, management history, hydrology, surrounding landscape, frequency of visitors, and innumerable other site conditions vary widely. There are furthermore different values involved in varying degrees between the objects, where biological, cultural heritage, and socio-cultural values are just broad categories; see OECD (1999). Also the consumers of landscape services are quite heterogeneous. Our consumption patterns, preferences and incomes differ, which further obstructs voluntary arrangements and increases the transaction costs.

Besides increasing the transaction costs, another consequence of the heterogeneity is that the marginal costs and the marginal social benefits of producing the landscape public goods vary widely from site to site. That is a fundamental motive for the approach of this study.

Social efficiency is the crucial criterion in most economic policy analysis and in this study, and it is determined by the marginal social costs and benefits. Efficiency implies that the optimal amount of agricultural land, landscape elements and environmental qualities of respective kinds are produced at lowest possible cost (in a given situation of available technology, etc.; see Varian (1992) and Johansson (1993). The socially efficient amount of environmental services is marked as q^*s in *Figure 1* below, just at the quantity where marginal social costs equal marginal social benefits. The horizontal axis in the diagram illustrates the quantity of environmental services provided by Swedish permanent grasslands. They are measured in qualitative hectares, qha, which express the objects' area multiplied by their respective indicator estimates on presence of environmental public goods per hectare. This is a new concept, making it possible to analyse the heterogeneous conditions of the landscape where benefits and costs are not proportionate across objects.

The farmers' marginal production costs, $MC_{p,p}$ in *Figure 1* are their additional costs of increasing the area or the environmental quality of agricultural land minus the increased incomes from producing more market commodities (Romstad et al., 2000). The social marginal costs include also

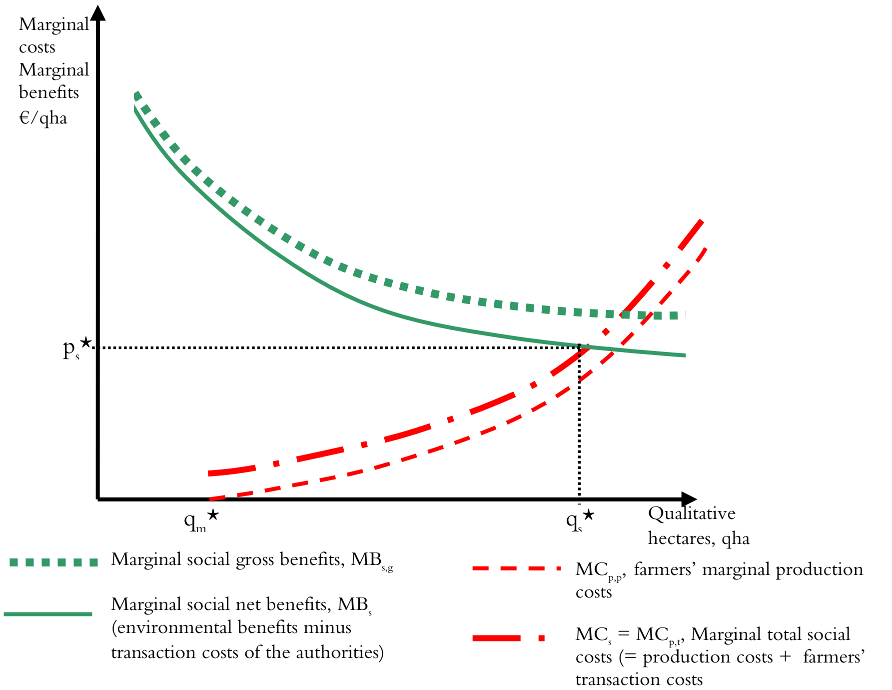

Figure 1. Principal sketch indicating the social optimum (q_s★) and optimal price (p_s★) of public goods in the agricultural landscape

possible transaction costs of farmers connected with the increase. The marginal social benefits, MB_s, are society's willingness to pay for an incremental provision of these public goods, minus the transaction costs of the authorities to support the supply.

A situation without any policy measures to support the production of environmental services would provide such public goods only as by-products, marked by $q^{\star}_{m}$ in the figure and as stated earlier. To increase the provision of environmental services above this amount implies net costs, the $MC_{p.p}$. Increasing the provision above q_s★ is not socially efficient, as costs would rise more than benefits.

2.2 Policy Measures: Right Instrument for Right Problem

The landscape public goods are positive externalities of agriculture, since they would disappear if there were no active management. Consequently, negative policy instruments such as prescriptions or restrictions on land management would be little effective. Farmers cannot be forced to maintain privately unprofitable land or use unprofitable management methods. Besides being inefficient, they would violate the common conception of justice (Hodge, 1991) and the Producer Compensation Principle, PCP[3].

Thence, an efficient provision of these public goods would require some form of public financing (OECD, 2001). Neither uniform payments coupled to management regulations, nor cross compliance demands would be efficient, however, because of the heterogeneous conditions. Some pastures or elements would be offered payments below their social values, whereas other would be overpaid. Targeted agri-environmental payments would generally be more appropriate (Falconer et al. 2001). Theoretically, payments differentiated per hectare by presence of public goods would have the necessary properties to provide efficient incentives and an efficient resource allocation (Lankoski and Ollikainen, 2003; Rollett et al., 2008). An efficiency prerequisite is that such a uniform payment per unit of public good is settled at a rate equal to the marginal social costs and equal to the marginal are benefits (see e.g. Edwards and Fraser, 2001), as expressed by Equation 1:

$$p_s\star = MC_s(q\star) = MB_{s,n}(q\star), \qquad \textbf{Equation 1}$$

where:

- $p\star_s$ is the social optimal price in € (EUR, SEK, USD, etc.) per unit of public goods, measured by qualitative hectares,
- $MC_s\star$ is marginal social total costs, and
- $MB_s\star$ is marginal social net benefits[4]

The optimal price, $p_s\star$ of equation 1 is also derived in *Figure 1* on page 15.

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[3] This principle is a fairness criterion, inverse to the Polluter Pays Principle, PPP, and stating that providers of positive environmental effects should be remunerated (Vail *et al.*, 1994).

[4] The baseline or reference point for the marginal benefits and costs (opportunity costs of the land) is abandonment, an agriculture-off situation.

2.3 Approach on Indicator Based Agri-environmental Payments

The two papers (I, II) summarized in chapters 3.3.3 and 3.3.4 below are based on a study that addresses the problems of social inefficiency related to the environmental public goods of the Swedish agricultural landscape, as described in chapters 1.2.2 and 2.1 above. The study is an attempt to develop policy measures to attain a socially efficient production of these public goods, but that besides efficiency also satisfy criteria of fairness or implementation feasibility.

A result of the welfare economic analysis is that a uniform payment equal to the price P_s^* of *Figure 1* per unit of landscape public good have the properties of a potentially socially efficient policy measure. The approach of the study is to test whether this theoretical conclusion can be made operational in practice. Since public goods are not measurable *per se*, the key of this approach is to develop state indicators that express the presence of public goods and to apply agri-environmental payments based on these indicators.

Accordingly, this model involves value-differentiated payments that are higher proportionately to the value of the environmental public goods. The indicators are estimated and the IAEPs are at the object[4].level, in order to get an efficient incentive structure and resource allocation. The approach is a response to the request for tangible and targeted estimates of the environmental services and directed policy instruments, since these services are public gods that neither can be measured directly, nor be handled efficiently by private markets (Hodge, 1991; OECD, 2007; Rollett et al., 2008; Wossink et al., 1999; Zalidis et al., 2004). The developed IAEP-model may then be classified as a large scale, multiple-objective and "maintenance + enhancement" approach; see Schwartz et al. (2008).

The IAEP-approach is an attempt to develop a systematic, consistent and complete model including all steps from identifying the policy problem to policy implementation. Main steps of the model are:

1. Establishing the conditions
   a. Identifying or settling the policy objectives
   b. Theoretical analysis (market inefficiencies, policy implications)
   c. Identifying and limiting the set of environmental services
2. Developing indicators
   a. Development of criteria based system to assess candidate indicators
   b. Choice of indicator criteria
   c. Generation of candidate indicators
   d. Assessing candidate indicators according to criteria
   e. Selection of indicators

3. Designing the IAEP-system
   a. Developing/identifying the policy measure alternatives to assess
   b. Designing and choosing operative assessment criteria
   c. Developing an system of weighting the criteria assessments
   d. Estimations, calculations or qualitative judgments of effects relative criteria, scoring
   e. Comparative analysis, overall evaluation
   f. Choice of IAEPs
4. Implementing the IAEPs
   a. Establishing a payment tariff per indicator unit
   b. Estimating indicator values for each object
   c. Informing farmers about their IAEPs, specified per object. Options for corrections
   d. Disbursing the IAEPs to the farmer
   e. Monitoring of the effects, analysis, revision of the system

Article I presented in chapter 3.1 is focused on the development of feasible indicators, or step 2 and 4b of this sequence, and in particular on step 2b and 2d. Article II is focused on the later step 3 of the process, the assessment of the IAEPs relative other policy measures, in particular step 3c and 3d, although there are also sections on 1b and 4a.

In short, step 1 identifies the environmental services that are appropriate for AEPs. This study aims to cover all environmental public goods in the agricultural landscape that are positive externalities, except possible climate effects. In step 2, indicators are developed by the systematic use of criteria, and in step 3, an IAEP-system is developed based on these indicators.

In practice, the idea is that a public good indicator value is estimated annually for each object. These indicator estimates are in the next step multiplied by the optimal price per unit of produced public goods or some other politically established tariff to settle the objects' respective IAEPs. By separating the measurement of the presence of public goods (in e.g. physical or biological terms) from the valuation of the public goods (in monetary terms), the values become more transparent and more flexible, easier to adjust. Hence, this approach deviates from suggested or existing auctioning or contracting payment systems by their nature of value differentiated payments *ex post*.

3 Summary of the Articles and the Licentiate Thesis

3.1 Developing Environmental Policy Indicators by Criteria – Indicators on the Public Goods of the Swedish Agricultural Landscape

This article describes the model of developing indicators for IAEPs, exemplified briefly by two of the indicators and with an empirical application in two study areas. Three steps in this process are in focus: developing indicator criteria by the use of meta-criteria, developing indicators by the use of these criteria, and monitoring to get estimates of the indicators.

So, to find out the actual amount of public goods provided at each landscape object, indicators are developed and later estimated. In the process of developing as good indicators as possible for this purpose, four meta-criteria are applied to develop a set of indicator ranking criteria. The use of meta-criteria and the systematic use of criteria by a multi-criteria analysis method have not been used in this context before.

The multi-criteria analysis of alternative, candidate indicators and of indicator sets combines a disjunctive, non-compensatory method with a linear additive method; see Janssen and Munda (1999) and Dodgeson *et al.* (2000). Eight composite criteria are used to assess the indicator candidates: policy relevance, quantitative responsiveness and reliability, temporal responsiveness, comparability, data validity and precision, monitoring costs, scientific quality, and informative or pedagogic quality. To assess systems of indicator combinations, five criteria are applied: covering, non-overlapping, number of indicators, flexibility, and unbiasedness. Each criterion is assigned a range of outcome scores and a weight related to its importance in the multi-criteria analysis. The ranking and selection of indicators involved multiplying the candidates' scores with the weights of the respective criteria before aggregating into a total assessment score. An expert panel with representatives of relevant disciplines was consulted throughout the process.

The analyses showed that state indicators measured at the object level are superior for IAEP-systems. By using quantitative measures of physical phenomena, policy arbitrariness can be reduced and more abstract qualities be reflected, such as biodiversity or scenery. The choice of state indicators is in line with the conclusion of the welfare economic analysis that the payments should be related to the amount of provided public goods. It turned out that the object level is optimal when balancing monitoring costs against the need to direct the payments for providing an efficient incentive structure and resource allocation. A set of seven indicators is ranked best in the assessment process:

- Arable field indicator
- Permanent grassland indicator
- Linear elements indicator
- Point field elements indicator
- Forest edge indicator
- Bio-rich trees indicator
- Historic relic indicator

All seven are composite indicators, formed by their respective sets of indicator variables. There are defined criteria determining what is required to attain the factor scores of the variables. An object's indicator estimate is calculated by an algorithm that aggregates the attained scores. The indicators are measured in qualitative hectares, meters or numbers, qha, qm or qN°. Hence, these novel measures are intended to express the amount of public goods of fields, pastures and landscape elements.

Having developed and tested the indicators, all landscape objects in two study areas are monitored to get their respective indicator estimates. The estimation was carried out by using existing GIS-data, aerial-photo surveying and field surveys. The results of the survey evoke a fairly wide and finely-graded spectrum of indicator estimates across the objects. This is supposed to give a similar distribution of directed payments.

A conclusion of the application and evaluation is that the indicators appear capable of reflecting the differences in environmental quality between objects with fairly good precision, at least with respect to biodiversity. The presence of cultural heritage and other socio-cultural qualities is judged to not be reflected by the same precision by the indicators.

3.2 Indicator-based agri-environmental payments: A payment-by-result model for public goods with a Swedish application

For the purpose of investigating the policy instrument properties of the developed IAEP-system and testing whether it would be an improvement also in practical policy implementation, this article assesses the IAEPs against the present Swedish AEP-measures for permanent grasslands and field elements.

The assessments are carried out *by multi-criteria* analysis, where a disjunctive, non-compensatory method is combined with a simplified multi-attribute method; see Dodgeson et al. (2000), Janssen and Munda (1999), and Keeney and Raiffa (1993). In this method, the policy measure alternatives are evaluated with respect to efficiency, fairness, and implementation feasibility. Each of these three criteria has a set of sub-criteria. The assessment criteria are selected and designed based on literature surveys. The respective scores of the alternative policy measures of these sub-criteria are weighted together by standard procedures of clustering trees (ibid.). By this method, AEP-design alternatives get outranked if they do not comply with the non-compensatory criteria, that is, with the Producer Compensation Principle or the Legal equality criterion. Other alternatives are ranked according to their scores in the multi-attribute assessments. The assessed IAEP-alternatives differ with respect to how their indicators are designed.

The finally chosen IAEP-system is based on the seven public good indicators in the design described in chapter 2.3 above. With the aim of demonstrating the outcome on the object, farm, and study area levels and compare the IAEPs with the present payments, a tentative but "low-level" tariff of 1000 SEK/qha/y for permanent grassland, 1 SEK/qm for linear elements, and 100 SEK/qN° for point elements were employed in this study. The tariff should correspond to the optimal price per unit of public goods derived in chapter 2.1 and illustrated in *Figure 1*. The tariffs are based on the best available valuation studies on the Swedish population's willingness to pay for these landscape goods (Drake 1992, Hasund 1998).

The alternative IAEP-designs differ with respect to how well they perform in terms of Environmental effects, Management measures, Production costs, Transaction costs, Informative properties, and Control properties. Comparing the most optimal IAEP-system against the current Swedish payment programmes indicates that there is a significant potential for better environmental effect, a more efficient resource allocation, better dynamic incentives and lower transaction cost. The system appears to be practically implementable with satisfactory acceptance, control, and flexibility properties. The IAEPs do not, however, comply with tailoring and with present WTO- and corresponding CAP-demands that AEPs have to be cost-based.

Concerning the assessments of the respective criteria, efficiency is analysed in terms of social efficiency by the Kaldor-Hicks efficiency criterion (see e.g. Johansson (1993) or Varian (1992)). The present, cost-based Swedish AEPs are little differentiated or targeted to provide environmental public goods, but have still managed to preserve the pastureland area and have positive effects on the environmental quality on many sites (SBA, 2006, 2008; SBA et al. 2002;; MA, 2003; Andersson et al., 2008). An optimally designed IAEP system can, on the contrary, improve the environmental targeting and involve lower costs, since farmers are free to choose technology and adapt to varying farm conditions (Blandford, 2001; Rollett et al., 2008; Schwartz et al., 2008). Multiplying the indicator estimates of the permanent grasslands in Selaö case study area with the tariff 1000 SEK/qha/y, show that the IAEPs would give a significantly wider range and another relative distribution of payments across pastures. The total payments to the grasslands would also be significantly larger, which indicates that the present payments may be too low for providing social efficiency. If calibrating the payment tariff to make the total IAEPs equal to the present payments to Selaö grasslands, the result is still that a large share of the objects are substantially over- or underpaid relative IAEPs differentiated by the presence of public goods.

Concerning policy related transaction costs (PRTCs); they are expected to be significantly lower for the farmers in an IAEP-system since there are no contracting procedures, although their costs of acquiring information probably will be larger. The PRTCs of the authorities are also assessed as significantly lower. Their major costs arise from estimating the indicators. However, much of the data can be obtained from existing GIS-databases or from air-photo surveying at a quite low cost. The field surveying costs vary between 1 – 10 EUR/object, exclusive of travel costs.

Policy acceptance and confidence assessed by interviews are promising, as nearly all farmers expressed preferences for the IAEP-system giving full scope to choose technology and management level. There are hardly any officials who do not accept the IAEP-system; still, almost half of them preferred the present system.

An important difference between the present AEPs and the IAEPs is that the latter provides economic incentives for developing new management measures to enhance environmental quality.

3.3 Arable Land Resource Economics [Jordbruksmarken i Naturresursekonomiskt Perspektiv]

3.3.1 Land Resource Economics in a Policy Perspective

The licentiate thesis is an attempt to combine an economic resource concept – where the size of the resource is determined by supply and demand – with a natural science approach of assessing how a set of factors may influence the resource situation. The approach is thence rather interdisciplinary. A key feature of the economic resource concept is that land becomes a resource only to the extent that its use may give a positive net welfare benefit. This deviates from standard resource assessments, and entails a more dynamic view of the resource. Another crucial quality of the developed land resource model is to assess the resource by its potential to provide a flow of products, the land's use-capacity. Applying this resource approach makes it possible, at least in principle, to assess the impacts of all the factors that may act on the resource stock supply in policy relevant measures.

3.3.2 Introduction

Contrasting the two articles that deal with the environmental, public goods of agricultural land, the licentiate thesis deals with the other major multi-functional product: arable land as a resource for providing material eco-system services in terms of food, bio-energy or other private goods.

This investigation examines the arable land resources from a national supply, food security and natural resource perspective. The ambition is to develop a foundation for being able to deal with questions of the following nature: Will the arable resources be adequate in a situation where imports are not possible? What future privations will result from urban expansion on high yielding land? What is the potential for producing raw materials for the chemical/technical industry or for energy purposes? What risks do resource damaging cultivation techniques and exogenous pollution constitute to the land resources? A more theoretical question concerns how much of the production should be ascribed to the land resource. This can be seen as assessing the land's semi-ecosystem services.

The calculations of the arable land resources are carried out for serving resource management and economizing issues, also including substitution possibilities between land, energy, rock phosphate etc. They may also be relevant to old and recent concerns whether land resources would suffice to meet increasing demands for food, bio-energy and other products.

The thesis has three main parts. The first gives a conceptual basis. It aims to elucidate crucial concepts and to develop a fruitful approach to handle arable land as a resource. Land characteristics that are important are described in a resource policy and in an agricultural perspective. The second part develops methods for measuring arable land resources. It also surveys Swedish arable land resources, in quantitative and qualitative measures, and with respect to regional distribution. Until now, there has been no empirical data on Swedish arable land considering differences in land quality. The third part is an attempt to assess the twelve factors that are considered most important with respect to probability and potential impact on the supply of arable and resources in Sweden.

3.3.3 Resource features

A production resource with a renewable flow

In characterizing arable land as a resource, this paper claims that it is less fruitful to treat it as a pure natural resource, but rather as a production resource, with a natural resource component and an anthropogenic capital component. The natural resource component consists of the innate conditions: soil material, climate, topography and acreage of land. The capital component results from investments in land reclamation, drainage, fencing, soil improvements, etc, that increase the productive capacity of the land. Over time, cultivation and other human activities will influence the resource base as well. The capital and natural resource components jointly determine land's productive capacity, and cannot be separated.

Arable land can be classified as a fund-resource. Terminology refers to funds giving a perpetual return to be used, versus "inventory-resources" whose stock decreases when exploited. Accordingly, the resource has a stock capable of giving conditionally renewable flows of products. The flows consist of agricultural products in the form of raw materials for food, textiles, energy, etc. Utilizing this flow in principle does not affect the stock. The stock may, nevertheless, be intentionally or unintentionally increased or decreased by the cropping system, land investments, or exogenous factors such as urban exploitation, heavy metal deposits, etc. These processes are more or less reversible, but mostly at a cost. There is a time-scale of easily to hardly influenced (sustainable) resource variables, with plant accessible Nitrogen at one end and the soil's particle size distribution towards the other end. Consequently, a crucial feature of the resource is that, although it is a fund resource giving a renewable flow, its physical base is not fixed but can be increased or decreased.

From the applied perspective, a major conclusion of the conceptual analysis is that the resource size may be determined by the lands capacity to yield products.

Determinants of the resource

Resources exist only in relation to a certain society. To exist, the resource has to be demanded by society, and there must be sufficient knowledge to exploit it. The material base is certainly a prerequisite, but if these additional conditions are not met, substances in nature are not resources, but mere phenomena. The term "resources" will be used in this study for land that gives a positive return (that is, $\sum PS + \sum CS > 0$, the sum of society´s producer and consumer surpluses is positive) to society when exploited. Other land may be called potential resources, whose land use-capacity may increase in the future so that it can provide a surplus of returns above cost of utilization if, for example, technology or prices change.

According to neoclassical economic theory, the size of the arable land resource stock is determined by demand and supply. Since land is a production input, demand for arable land is a derived demand. It originates from the demand for agricultural products, and from the substitution possibilities regarding inputs as well as consumption. Input substitution refers to the farmers' inclination to use land relative to other inputs in the cultivation. It is determined by price and the marginal productivity of land in relation to other inputs, such as fertilizers. Consumption substitution depends on price and quality of agricultural products compared to substitutes like fish or artificial fibre.

Technology, size of population, consumer preferences and incomes are essential in determining how much land that will be considered viable.

The physical supply

Arable land resources have a quantitative dimension (hectares), as well as a qualitative dimension (fertility). Fertility depends on a combination of edafic, climatic and topographic factors. If the resource concept is to also reflect the qualitative dimension, it has to include all the factors that influence the land's production capacity. Consequently, the size of the arable land resource stock may be described by a set of site variables, such as clay fraction at various soil depths, humus content, cation exchange capacity, or efficient soil depth, but also seasonal distribution of precipitation, length of growing season, etc. The number of more or less important site variables, and possible combinations of them, is, in this huge complex of fertility factors, almost limitless.

The economic supply

The economic supply of arable land depends on the physical supply (the material base), institutional factors, the available technology, etc. Unlike the land's physical use-capacity, its economic use-capacity depends not only on fertility, but also on distance to markets, and on aspects of field layout such as size, shape and density.

As noted above, the physical supply consists of a natural resource component and a capital component. Draining, terracing, or building greenhouses would increase the supply when demand or new technique makes these investments profitable. If land markets were perfect, land with the highest use-capacity would be cultivated first. Each increment of land supplied would incur higher costs of development, as well as higher cultivation costs per unit of production.

The possibilities to substitute other inputs for land are restricted by the law of diminishing marginal returns. We note however, that at a certain technology, agricultural production may be enhanced in two ways: by intensification (i.e. larger inputs of labour and other resources per unit of land), or by expanding the arable land stock. Increasing arable land resources can be done by bringing new land into production or by investments that increase the productive capacity of existing fields.

According to the theory of marginal productivity, economic rent is the difference between revenues and costs of the production, i.e. $q_i^*(AVP-AC)$. The rent, in this case "land rent", is treated as an economic surplus, a residual that is credited a factor of production. On land of lower use-capacity, the average cost (AC) is relatively higher when MVP = MC and the optimal level of production is lower, both circumstances implying a smaller land rent. (Barlowe, 1978)

The differences in fertility imply that arable land is not a homogenous resource. This fact influences how the resource should be treated in economic theory. One way is to standardize the fields and pastures, that is, convert them into comparable units (cf. table 1 below). Another way is to treat the resource as a number of distinct, interchangeable factor inputs, with different attributes, but among which substitution is possible.

3.3.4 Measuring Swedish arable land resources

On basis of the developed land resource perspective, this study has estimated the Swedish arable land resources in economic and physical terms. Average land use-capacity and its variance, as well as the distribution of different grades of land are estimated in aggregate and by region.

Measuring the flow

Traditionally, agricultural land resources have been quantified by simple measures of the acreage of tilled land plus pastureland. To capture the qualitative dimension, an approach has been to classify land into a range of use-capacity categories. This method, however, does not allow for cardinal comparisons. It is not possible, for instance, to say how many hectares of class-4 land that are equivalent to 10 hectares of class-1 land. A third approach has been to supplement the acreage measures with data on site variables. However, this method is costly and also subject to several interpretational ambiguities. For instance, optimal soil texture under a certain set of climatic and topographic conditions, may not be so under another. An alternative to stock measurements is to measure resource assets by their flows: their capability to generate products in economic or physical terms. Such a method has been developed in this study by several variants, and applied to the agricultural land of Sweden.

The method: Barley equivalents as a physical measure

If the aim is merely to investigate the production capacity of fields, and to see how it is distributed throughout the country, physical measurements would be the most relevant. However, classifying land on the basis of its yield capacity in kilograms of protein or kilojoules of energy, is impaired by several shortcomings. Therefore, in this study, the land's capacity to yield barley was chosen as the variable on which to base the classification. Barley is a proper reference crop in the sense that it is 1) cultivated all over the country, and 2) representative (if barley yields are low, land's use-capacity is generally low and vice versa).

The field classification is based on the barley "standard yields" for the 420 "yield survey districts" of Sweden. These districts are demarcated by to be as homogenous as possible concerning the crop farming conditions: soils, topography, and climate. For crop insurance purposes, standard yields are calculated annually for each crop and district on the basis of several decades of empirical investigations. The standard yield is an estimate of the yield that can be expected if the weather and other conditions that influence the crops are quite normal. (SS 1983) However, different cultivation techniques do influence the standard yields. To achieve a more pure measure of the land's use-capacity, the standard yields were calibrated in this study to theoretical yields at 0 versus 90 kg nitrogen fertilizer per hectare, using regional fertilizer statistics and fertilizer-yield functions.

Results of the physical investigation

Swedish tilled land resources are approximately normally distributed around a median of 3,500 kg barley-equivalents per hectare (kg be/ha), at a fertilization level of 90 kg N/ha. The survey districts range from 2,100 to 5,100 kg be/ha. At 0 kg N/ha the theoretical median yield is 2,100 kg be/ha.

The relative difference between the highest and the lowest yielding survey districts is considerably bigger at 0 kg N compared to 90 kg N per hectare. The standard deviations are 27% and 16% of the respective median. Natural disparities in fertility may thus partly be leveled out by modern farming technique.

Figure 2 gives a picture of the Swedish physical resource situation, when the 420 survey districts have been aggregated into eight production areas. These areas are still "homogenous" concerning crop farming conditions, but much less so than the yield survey districts.

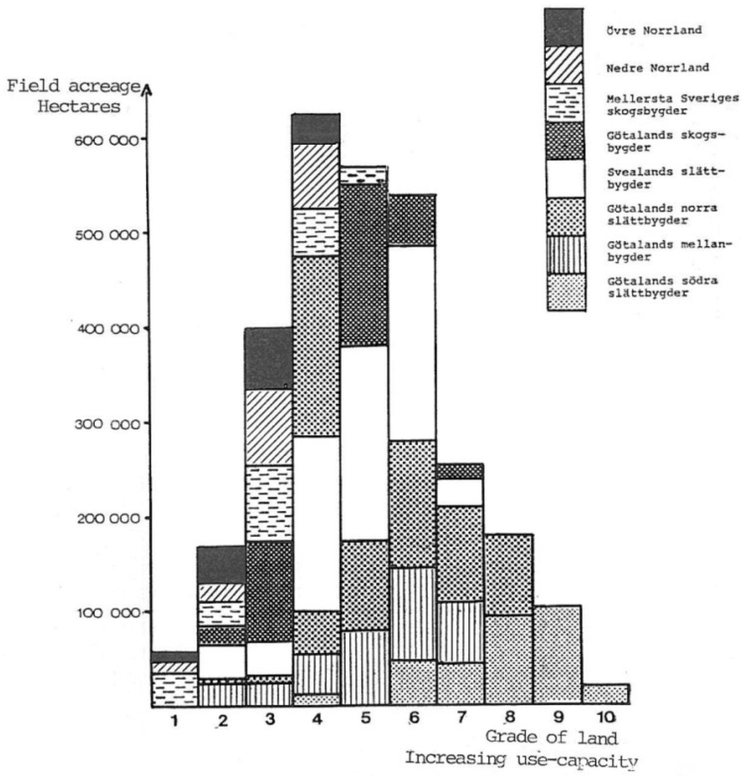

Figure 2. The acreage of arable land in the eight Swedish production areas, distributed into 10 grades according to barley yielding capacity at 90 kg N/ha. 1983. Grade 1 has the lowest yield, less than 2,350 kg barley-equivalents per hectare. The grade width is 300 kg be/ha.

A new concept called ”field index” is developed. The concept may be used for comparing arable land resources across the country, to express the size of arable land resources and their regional distribution. It is measured by “standard-hectares”. The standard-hectare for a survey district is calculated on the basis of its theoretical yield in comparison with acreage-weighted national average theoretical yields. For example, 10,000 hectares in Kristianstad county corresponds to 11,300 standard-hectares, or average Swedish hectares. The differences are larger between field indices of yield survey districts (compared to county field indices), between field indices based on theoretical yields at fertilization level of 0 kg N/ha (vs. 90 kg N/ha), or field indices based on economic yields (vs. physical yields).

The ”arable resource values” can be expressed as the region’s capacity to generate a flow of barley-equivalents at fertilization level 90 kg N/ha, i.e. theoretical yield multiplied by field area. Such figures have been calculated for all yield survey districts, counties and production areas.

Method: Calculating revenues minus costs

Arable land resources can also be measured by the capacity to generate a flow in economic terms. Land rent is such a measure, adopted in the thesis.

In southern Sweden, revenues per hectare are substantially higher than in the north, but the cultivation is likewise encumbered with higher costs of pesticides, fertilizers, irrigation, etc. To obtain a measure of the value of production for fields in different regions, land rent is chosen as the basis for the classification. As a residual of revenues minus costs, it reflects the various land use-capacities, differences that exist in soils, climate and topography.

Land rent has been calculated in this study as the difference between revenues and incremental costs for the 16 main crops for each of the 420 "homogenous" yield survey districts in Sweden. The calculations take into account the standard yields and acreage of each crop in the respective districts. A standard yield value is then obtained by multiplying yields by average annual prices. Crop insurance statistics from the National Agricultural Marketing Board and from Statistics Sweden are used. Data on costs are obtained from the regionalized gross margin calculi that are published annually by Agriwise, SLU. These (TB3) include all incremental costs that arise due to cultivation of a certain crop, such as seed, fertilizers, transports, drying, machines and labor.

Besides a simpler measuring and classification base-method, the land resource in economic terms is measured by four other variants of calculating the land rent:

- Land class revision with respect to field lay-out
- Adjustments of variable costs with respect to differences in yields within the production areas.
- Exclusion of potatoes for processing and sugar-beet areas
- Exclusion of labour costs

The base-variant is used as reference for comparisons and further presentations of results.

Results: A regional pattern

Swedish arable resources measured by land rents are fairly heterogeneous. In 1983, the rent on the total resources of arable land was approximately normally distributed around a mean of 600 SEK/ha. The maximum was 2,700 SEK/ha. Distinct regional patterns exist. In general, land rents decrease from the south to the north, and from the plains to the woodland regions. This was expected, the investigation provided figures of the differences.

One reason land resources are more heterogeneous when measured in land rents than in physical terms is that profitable crops cannot be cultivated in some of the areas. Low grades of land may have reasonably good yields of energy or protein, but are hardly suited for crops such as wheat or sugar-beets. Another reason is that costs do not fall as much as revenues do, moving from a high to a lower yielding field.

The land rent curve

A new diagrammatic method is developed to illustrate the arable land resource situation. It plots land rent measured in SEK/ha, against cumulative acreage (Figure 3). According to Ricardo (1817) and to later theories of marginal productivity, successively lower yielding grades of land are brought into cultivation as demand rises. Inversely, the curve indicates how much land is threatened by abandonment if the profitability of the agricultural sector measured in land rents declines.

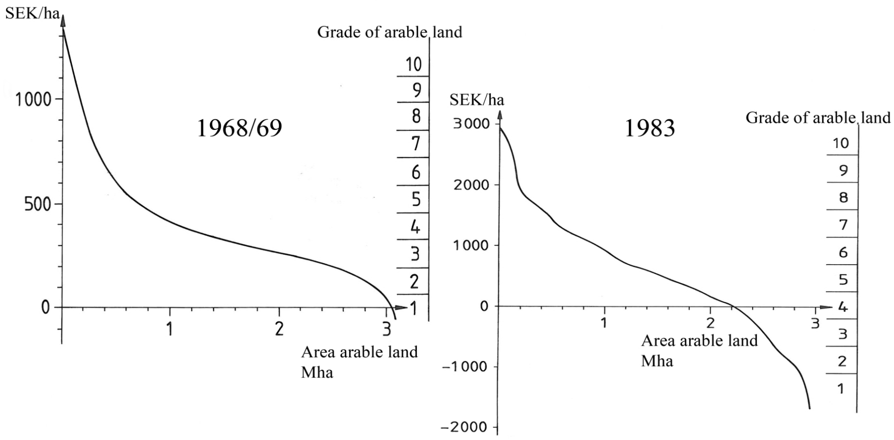

Figure 3.The Swedish arable land rent curves of the years 1968/69 and 1983. Value of money for respective year.

Three segments are distinguishable in Figure 3. In the first segment, 0 – 0.5 Mha, land rents decline steeply from the highest yielding areas. In the middle, 0.5 – 2.3 Mha, the differences in rents are not that pronounced, and in the third segment 2.3 – 3.0 Mha there is again a sharp decline. The cause of the curve's steep slope at the lowest grades is most probably that the main share of land with this character has already been withdrawn from agriculture owing to low profitability.

Inter-temporal comparisons

The arable land resource stock is not immutable. Comparing the arable land situations of 1968/69 and 1983, indicate changes in total land use-capacity as well as regional distribution. In general, land rents decreased. The plains in the south and middle of the country were relatively more valuable in 1983, having a smaller difference in land rents compared to superior land of Plain districts in southern Götaland, and an improved position compared to the northern production areas.

The welfare contribution of arable resources

Given the condition that the cost of all farm labour should be accounted at farm-worker salaries and that other inputs should be paid their market prices, it can be concluded that the area between the land rent curve and the field acreage axis corresponds to the concept "producer surplus". It is accordingly a minimum estimate of the land's contribution to national welfare. In 1983 the total net contribution was 1,700 MSEK (c. 300 MUSD).

3.3.5 Scarcity or surplus? – factors changing the resource base

The model of Swedish arable land is used for analyzing possible effects on the national and regional resource situation in the future. Only supply influencing factors (driving forces) are treated. The licentiate thesis analyses the twelve factors that are considered as most important in Sweden; soil acidification, soil poisoning, photochemical oxidants, reduced humus content of soils, losses of organic soils, subsoil compaction, wind erosion, water erosion, urban expansion, other land exploitation, climatic change, and land reclamation. Here, a brief presentation is given for subsoil compaction, followed by an overall assessment.

Applying the developed resource concept that the resource size is determined by the land's capacity to yield a flow of products, any factor that influences the yields will change the resource stock correspondingly. Consequently, the resource size may be altered not only by areal changes but as well if any of the edafic, climatic or topographic fertility components (factors) are influenced. The factors can be exogenous as well as endogenous to agriculture.

Sub-soil compaction – example of an analyzed factor

The mechanization of agriculture has brought about soil compaction by vehicles and machinery. The volume of coarse soil pores decreases, which primarily results in reduced permeability for air, water and roots, and secondarily to more costly cultivation or reduced yields.

The damages increase with vehicle weight, amount of driving, soil moisture and clay content. Pressure decreases with soil depth, but much less gradually under a heavily loaded wheel. In the subsoil, it is the total load, i.e. the axle weight, which determines the compaction. The critical limit for damages in the subsoil (>40 cm soil depth) is 6 tons axle weight. Risks differ across regions and farming systems.

Subsoil compaction, contrary to top soil compaction, results in irreversible damage that accumulates over time. Ground frost or other processes have little or no rehabilitating effect. The possibility of loosening it by sub-soilers is also in most cases discouraging: it is expensive, difficult and does not give lasting results.

Method: Calculating the influence of subsoil compaction

The effects on the resource have been calculated for two possible scenarios using the developed resource model of physical and economic flow measures. One scenario extrapolates the present trends of subsoil compaction. In the other scenario, the influence of subsoil compaction on the resource situation is calculated on the assumption that all arable land sooner or later will be exposed to loading by heavy vehicles.

The influence of subsoil compaction on arable land resources in physical terms is derived from the yield capacity in each of the 420 yield districts, multiplied by a reduction factor, R<1. The reduction factor is specific to each district, and determined by:

1. Clay content of the dominant soil types in the district: the yield reducing effect varies by 2 – 9% over the existing soil types (Håkansson, 1984)
2. The probability of subsoil compaction: In the first scenario, the risk depends on the crop pattern: the lowest risk, 0.3, for grains and oil-plants, the highest, 1.0, for sugar-beets. Since the second scenario assumes that all land will be exposed, compaction probability is 1.0.

When calculating the resource measured in economic terms, i.e. land rent, it is presumed that the reduction of revenues due to subsoil compaction is proportional to the losses in yield, while costs are not influenced. Revenues are accordingly multiplied by the districts' respective reduction factors.

Results: Subsoil compaction reduces the land resources

In the scenario of partial land compaction, the land rents of the Swedish arable resources will on an average decrease from 570 SEK/ha to 490 SEK/ha. Owing to the reduced yields, no land will be graded in the highest class 10. The largest losses are expected in the plains of the Southern and Central parts of the country.

The resource measured by its physical flow will not decrease as much as its economic flow. At the fertilization level 90 kg/ha, the national average barley yielding capacity will decrease from 3,560 kg to 3,490 kg barley equivalents per hectare. It implies that the national arable resources will decrease by about 2 %. Expressed differently: subsoil compaction may bring about reductions of the yield capacity as large as if 56,000 standard hectares were irreversibly destroyed. If, instead, it is assumed that all land sooner or later will be exposed to some vehicle with an axle load more than 6 tons, the arable resources will probably decrease by 5 %, corresponding to 140,000 standard hectares.

A comprehensive view of resource impacts

The twelve factors are assessed in the thesis with respect to their effects on the land's physical use-capacity and its economic use-capacity (land rents), which are discussed in terms of food security, producer and consumer surplus. There are four main ways in which the arable land's value as a resource may be influenced, positively or negatively:

1. the area of arable land (erosion, urban expansion, etc.).
2. the hectare yields (ozone, soil compaction, erosion, etc.)
3. the costs of cultivation (soil acidification, wind erosion, etc.)
4. the quality of agricultural products (soil poisoning, ozone, etc.).

The factors differ in importance by direction (positive, negative or either), magnitude (the potential to change), and probability. It is evident that the uncertainty about future changes is large. Besides the large potential of yield increasing technology, the negative influences dominate the picture, although reduced top-soil compaction and climatic change may increase the land supply qualitatively. However, all factors can be influenced by measures. The possibility of counteracting the threats and compensating for resource degradation or increased demands by land reclamation and land improvements also appear to be quite large.

Historically, tilling of organogenic soils, wind erosion, urban expansion etc, seriously damaged or destroyed substantial arable areas in the country. On the other hand, the resource has increased by reclamation, pedogenesis, fertilizing, drainage, etc.

Air pollutants like ozone seem to be the biggest threat to future arable resources. Soil compaction and losses of organogenic soils through cultivation also may seriously impair the yield capability, but these damages are possibly easier to avoid. Most likely, urban expansion and similar land exploitation will entail substantial irreversible losses of land from cultivation. The impacts are to some extent additive, and in some cases synergistic. Taken together, the tendencies involve risks of rather large encroachments, damages that might correspond to more than half a million standard hectares.

The tentative investigation indicates that it is in general the highest yielding land that runs the risk of being most negatively affected. This has an equalizing impact that probably makes the nation's arable land resources somewhat less heterogeneous, at least in their physical capacity.

4 Discussion

A first issue to discuss is whether the assumptions of the studies are realistic, theoretically sound and fruitful. In short, the approaches are based on standard assumptions of neoclassical micro economy. A crucial assumption of the developed economic measures in the licentiate thesis III is that the crop mix in each district is optimal, subject to the land's conditions for cultivation, prices, technology, crop sequence restrictions, etc. This is certainly not 100% realistic, and should be kept in mind when interpreting the results. They may, however, give a good approximation of magnitudes and indicate regional differences, considering that all models are simplifications.

The efficiency of the IAEP-system developed and assessed in the articles I and II depends on the core assumption that farmers are rational profit maximizers. Nor this assumption is perfectly realistic. This deficiency does, however, not prevent such systems for being theoretically more efficient than uniform or management cost based payments, and to operate towards efficient land use in practice.

A second issue concerns the weak and strong qualities of the used methods. The social efficiency of the IAEPs hinges on the availability of relevant and valid estimates on the values of the environmental services provided by agriculture. Such measures are yet little available. Another decisive issue is the design of the indicators: to what extent they can be objective measures of public goods via the presence of physical features in the landscape. The indicator outcome of the study is partly tentative, that could be refined and developed.

The developed physical and economic measures in the licentiate thesis are capable of providing commensurable estimates of the land resources at national and regional levels. The methods do, however give a slightly oversimplified picture since the land resources within the districts are not perfectly homogeneous. Although based on available knowledge on possible effects, the models' usefulness for prognosis is partly limited, as they are not dynamic.

A final issue discussed here is the usefulness and policy implications of the results. The IAEP-system has the potential of giving a socially efficient land use. The study gives evidence that it is feasible to develop state indicators expressing the environmental qualities of agricultural sites and elements also in practice on the large scale. Payments linked to estimates of such indicators may be significantly more efficient, giving higher environmental qualities, and comply better with several other feasibility criteria. A major challenge lies in the design of the indicators, to balance precision against transaction costs. Before actually becoming implemented, serious obstacles in WTO-rules and transformation resistance from present systems have to be overcome.

What concerns the licentiate thesis III, physical measures on land resources probably have greatest interest from a future supply and food security perspective to calculate arable land's supply capability. Situations where this may become interesting include resource scarcity scenarios of import restrictions, or increased demand for food and bio-energy, possibly combined with environmental restrictions on the use of chemical inputs. The developed land resource concept and calculations aim at contributing to the question on how to apply the precautionary principle when it comes to basic human needs in very long term perspectives of thousands of years. Land rent is a single, cardinal and monetary measure applicable everywhere. It is suitable for comparisons of land across regions. The land rent figures give a fairly good picture of economic conditions for cultivating the land, but are less appropriate for calculating the food producing capacity. The values obtained show the competitive powers of land in different soil or climatic conditions, and may identify which areas are threatened by abandonment. The study shows that the method is able to reveal significant changes in the resource situation even over a relatively short time.

The three papers together indicate that the resources of agricultural land and its provision of private and public goods are not safeguarded at optimal levels, and that there is a scope for policy measures if the aim is to maximize social welfare over time.

References

Adams, R.M., Glyer, J.D., Johnson, S.L. and McCarl, B.A. (1989). A reassessment of the economic effects of ozone on U.S. agriculture, JAPCA, Vol. 39 No. 7, 960–968.

Andersson, R., Kaspersson, E., Wissman, J. (2008). Slutvärdering av miljö- och landsbygdsprogrammet 2000 – 2006 – vad fick vi för pengarna? SLU, Dnr SLU ua 12-3269/07, Uppsala.

Barlowe, R. (1978). Land resource economics. Englewood Cliffs, New Jersey: Prentice-Hall.

Blandford, D. (2001). Are Disciplines Required on Domestic Support? The Estey Centre Journal of International Law and Trade Policy, 2:1, 35-59.

Coase, R. H. (1960). The Problem of Social Cost. *The Journal of Law and Economics*, III, 1–44.

Dahlman, C. J. (1979). The Problem of Externality. *The Journal of Law and Economics*, 22, 141–162.

Dodgeson, J., Spackman, M., Pearman, A., Philips, L. (2000). Multi-criteria analysis manual, Department for Communities and Local Governments, UK, London.

Drake, L. (1992). The non–market values of the Swedish agricultural landscape. *European Review of Agricultural Economics*, 19, 351–364.

Edwards, G., Fraser, I. (2001). Reconsidering agri-environmental policy permitted by the Uruguay round agreement. *Ecological Economics*, 37:2, 313-326.

EEA, European Environment Agency, 1995. Europe's environment – the Dobris Assessment, Copenhagen.

Falconer, K., Dupraz, P., Whitby, M. (2001). An Investigation of Policy Administrative Costs Using Panel Data for the English Environmentally Sensitive Areas. *Journal of Agricultural Economics*, 52 (1), 83–103.

Harrison, M. (2010). Valuing the Future: the social discount rate in cost-benefit analysis. Productivity Commission. Australian Government.

Hasund, K. P. (1986). Jordbruksmarken i naturresursekonomiskt perspektiv, Uppsala: SLU, Department of Economics, Report 269.

Hasund, K. P. (1998), Valuable Landscapes and Reliable Estimates. In: Dabbert, S., Dubgaard, A., Slangen, L., Whitby, M. (eds.), The Economics of Landscape and Wildlife Conservation, Wallingford, New York: CAB International, 65–83.

Hodge, I. (1991). The Provision of Public Goods in the Countryside: How Should it be Arranged? In: Hanley, N. (ed.), Farming and the Countryside: An Economic Analysis of External Costs and Benefits. CAB International, Wallingford, 179–196.

Håkansson, I. (1984). Jordpackning, Statens lantbruksinformation. Forskning och praktik 1984:4.

Håkansson, I. (1985). Swedish experiments on subsoil compaction by vehicles with high axle load, Soil use and management. 1985:4. SLU (1983)

Ihse, M. (1995). Swedish agricultural landscapes – patterns and changes during the last 50 years, studied by aerial photos. *Landscape and Urban Planning*, 31 (1-3), 21-37.

Janssen, R., Munda, G. (1999). Multi–criteria methods for quantitative, qualitative and fuzzy evaluation problems. In: van der Bergh, J. (ed.), Handbook of Environmental and Resource Economics. Edgar Elgar Publishing, Cheltenham, 837–852.

Johansson, P.–O. (1993), Cost–Benefit Analysis of Environmental Change. Cambridge University Press, Cambridge.

Jonasson, L., Kumm, K.–I. (2006). Betesmarkerna efter 2003 års jordbruksreform – hot och möjligheter. Jordbruksverket, 2006:3. Jönköping.

Kahneman, D., Tversky, A. (1973). On the psychology of prediction. *Psychological Review* 80: 237–251.

Keeney, R.L., Raiffa, H. (1993). Decisions with multiple objectives. Preferences and value tradeoffs. Cambridge University Press, Cambridge.

Kull, K. and Zobel, M. (1991). High species richness in an Estonian wooded meadow. *Journal of Vegetation Science*, 2, 715-718.

Lankoski, J., Ollikainen, M. (2003). Agri–environmental externalities: a framework for designing targeted policies. *European Review of Agricultural Economics*, 30 (1), 51–75.

MA, Ministry of Agriculture [Jordbruksdepartementet] (2003). Ett levande kulturlandskap. SOU 2003:105. Stockholm

Nilsson, F. O. L., Hasund, K. P., Gren, I.-M., Surry, Y. (2008). Multifunctional Agriculture – What does the Economic Literature Tell Us?. *International Review of Environmental and Resource Economics*. Vol. 2. Issue 4, pp 281–319.

OECD, Organization for Economic Co-operation and Development (1999). Handbook of incentive measures for biodiversity: design and implementation, Paris.

OECD, Organization for Economic Co-operation and Development (2001). Improving the Environmental Performance of Agriculture: Policy Options and Market Approaches, Paris.

OECD, Organization for Economic Co-operation and Development (2007). Effective Targeting of Agricultural Policies, Paris.

Områdeskalkyler - jordbruk (1983). Uppsala: SLU, Research Information Centre.

Randall, A. (1972). Market Solutions to Externality Problems: Theory and Practice. *American Journal of Agricultural Economics*, 54 (2), 175–183.

Randall, A. (2002). Valuing the outputs of multifunctional agriculture. *European Review of Agricultural Economics*, vol. 29, no. 3, pp. 289–307.

Ricardo, D. (1817). The principles of political economy and taxation. London.

Rollett, A., Haines-Young, R., Potschin, M., Kumar, P. (2008). Delivering environmental services through agri-environment programmes: a scoping study. Land Use Policy Group, Report. Peterborough, Nottingham

Romstad, E., Vatn, A., Rørstad, P. C., and Søyland, V. (2000). *Multifunctional Agriculture – Implications for Policy Design*, Department of Economics and Social Sciences, Agricultural University of Norway, 21. Ås.

SBA, Swedish Board of Agriculture [Jordbruksverket] (2005a). Ängs- och betesmarksinventeringen 2002 – 2004. 2005:1, Jönköping.

SBA, Swedish Board of Agriculture [Jordbruksverket] (2005b). *Svenskt jordbruk i siffror 1800 – 2004*. Statistikrapport 2005:6. Jönköping.

SBA, Swedish Board of Agriculture [Jordbruksverket] (2006). Kulturhistoriska bidrag och särdrag – uppföljning och utvärdering av miljöersättningen till natur– och kulturmiljöer. 2006:10, Jönköping.

SBA, Swedish Board of Agriculture [Jordbruksverket] (2008). Årsrapport 2007. Landsbygdsprogram för Sverige år 2007–2013. CCI 2007SE06RPO001, Jönköping.

SBA. Swedish Board of Agriculture [Jordbruksverket] (2009). Statistical Yearbook of Swedish Agriculture 2008, Jönköping

SBA *et al*., Swedish Board of Agriculture, Swedish Environmental Protection Agency, Swedish National Heritage Board (2002). Miljöeffekter av EU:s jordbrukspolitik. 2002:2, Jönköping.

SS, Statistics Sweden (1983). Statistiska meddelanden J 1983:7.2. Stockholm.

SS, Statistics Sweden (2010). Jordbruksstatistisk årsbok 2010 med data om livsmedel. Stockholm

SSIC, Swedish Species Information Centre [ArtDatabanken] (2005). Rödlistade växter i Sverige 2005, Swedish Red Data Book of Plants 2005, Uppsala.

Samuelson, P. A. (1954). The Pure Theory of Public Expenditure. *Rev. Econ. Stat*., 36, 387-389.

Schwartz, G., Moxey, A., McCracken, D., Huband, S., Cummins, R. (2008). An analysis of the potential effectiveness of a Payment-by-Results approach to the delivery of environmental public goods and services supplies by Agri-Environmental Schemes, Land Use Policy Group. Available from: http://www.lupg.org.uk/pdf/LUPG_Payment_by_Results_Feb09.pdf [2009-02-25]

Svensson, R. (1988). Floravård i jordbrukslandskapet. Sven Bot Tidskr, 82, 458–465.

Tversky, A.; Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science* **185** (4157): 1124–1131.

Varian, H. R. (1992). Microeconomic Analysis, 3rd. edn. W. W. Norton & Company, New York, London.

Vatn, A., Kvakkestad, V. and Rørstad, P. K. (2002). *Policies for Multifunctional Agriculture. The Trade-off between Transaction Costs and Precision*, Department of Economics and Social Sciences, Agricultural University of Norway, 23. Ås.

Wossink, A., van Wenum, J., Jurgens, C. and de Snoo, G. (1999). Co-ordinating economic, behavioural and spatial aspects of wildlife preservation in agriculture. *European Review of Agricultural Economics*, 26 (4), 443-460.

Zalidis, G. C., Tsiafouli, M. A., Takavakoglou, V., Bilas, G., Misopolinos, N. (2004). Selecting agro–environmental indicators to facilitate monitoring and assessment of EU Agri-Environmental measures effectiveness. *Journal of Environmental Management*, 70 (4), 315–321.

Zhuang, J., Liang, Z:, Lin, T. and Guzman, F. de (2007). Theory and practice in the choice of social discount rate: a survey. Asian Development Bank. Economics and Research Department. ERD Working Paper Series 94. Manila. Available from: . http://www.adb.org/Documents/ERD/Working_Papers/WP094.pdf [2010-03-01]

Appendices

The thesis is based on the two articles and the licentiate thesis listed below: (They are referred to by their roman numbering.)

I. Hasund, Knut Per (2011). Developing Environmental Policy Indicators by Criteria – Indicators on the Public Goods of the Swedish Agricultural Landscape. *Journal of Environmental Planning and Management* Vol. 54(1), 7–29

II. Hasund, Knut Per (2012). Indicator-based agri-environmental payments: A payment-by-result model for public goods with a Swedish application. Accepted March 2012 for publication in *Land Use Policy*.

III. Hasund, Knut Per (1986). Jordbruksmarken i naturresursekonomiskt perspektiv. Swedish University of Agricultural Sciences, Department of Economics, Report 269. Licentiate thesis. Uppsala.