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Finding the optimal balance between economical and ecological demands on agriculture – research results and model calculations for a Bavarian experimental farm

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Abstract

The purpose of this paper is to analyze the interactions of the economic and ecological demands on agriculture for a farm in Germany with a whole farm modeling approach. Integration of agro-environmental indicators in the model framework enables a multiple goal optimization and the computation of trade-offs of indicators and economic returns of the farm.

The estimated opportunity costs provide valuable hints on bottlenecks of the integration of environmental claims into agriculture and help to identify reasonable incentives for environmentally sound agriculture. Furthermore conflicts between conflicting goals can be integrated to find optimal pathways of sustainable agricultural development.

Keywords: marginal abatement costs, environmentally sound agriculture, economic-ecological whole farm modeling

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1 Introduction

As agriculture provides a bunch of externalities a lot of efforts have been made to integrate public demands in agriculture. However, this challenge remains unsolved unless externalities are defined and appropriate policies designed. The question is how can agriculture be optimized to meet both the private and social needs of the farmers and the society as a whole. Theoretically, first best solutions provide the optimum where the marginal external costs[1] meet the marginal abatement costs. Opportunity costs which emerge, when a farmer considers the external costs can be interpreted as abatement costs. Furthermore transaction costs of policies have to be taken into account, i.e. if specific policies give incentives for the farmers to consider the external effects. However, this theoretical framework helps only little to find economically and ecologically optimal land use strategies. The reasons for this are manifold.

First it has to be realized that it is almost impossible to identify all the external effects of agriculture. Despite enormous research efforts in agro-ecological systems in many countries we can assess the environmental effects of specific agricultural practices only with little confidence. Stochastic influences as weather, pests and interactions with spatial patterns of the ecosystem make it difficult to predict the effect of agriculture on the environment. The impact of agriculture on the biotic environment is assumed to be more seriously but much harder to predict (Flade et al. 2001).

But even if we knew the effects of certain agricultural practices, how should we assign the appropriate value to them? Different methods of direct and indirect accounting have been proposed, but besides methodological critics (Hanley et al. 1997) these methods mostly can only evaluate a limited number of environmental effects of agriculture and hardly reflect the multifunctional character of agriculture. Last not least the appropriate design of policies to integrate the external effects remains a difficult task as most policies result in market distortions and other effects which have also to be taken into account in order to achieve optimal land use (Weersink et al., 1998).

In order to cope with these difficulties an alternative approach for determining optimal land use is to optimize the allocation of resources under the constraint of an externally

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[1] here only environmental effects are considered

determined standard. This approach has been followed for example by Yiridoe & Weersink (1998) or De Cara & Jayet (2000) in order to identify optimal abatement strategies in agriculture for nitrate and greenhouse gases, respectively. If environmental targets are set for example by legislation, these can be integrated as constraint into farm models and show opportunity costs of the realization of the targets. However, relevant standards are set only for the minority of agricultural externalities. Considerable efforts have been made by the OECD and others to coordinate agri-environmental indicators (OECD 2001). The proposed indicators by the OECD are the result of a long process of discussion between different stakeholders involved in agriculture. Therefore it can be assumed that the indicators reflect much the externalities provided by agriculture.

This paper is aimed to illustrate the implications of integrating environmental indicators into agriculture with an economic-ecological modeling approach. For this purpose the model framework MODAM has been used, which has already been applied for studies in Northeast Germany (Kächele 1999, Zander & Kächele 1999, Meyer-Aurich 2001). The calculation of explicit abatement cost curves for the indicators shall provide a basis for deriving optimal abatement strategies for the respective indicators.

2 Material and Methods

2.1 Research Network on Agroecosystems

This study is embedded in the “FAM Research Network on Agroecosystems” (Forschungsverbund Agrarökosysteme München) which is an association of research projects of the Technische Universität München and the GSF-National Resarch Center for Environment and Health located in Freising and Neuherberg, Germany. The aim of the research network is to analyze processes in agrarian ecosystems, forecast management induced systems changes and derive management strategies for a productive and environmentally sound agriculture (Auerswald et al. 2000, Tenhunen et al. 2001, Schröder et al. 2002). The research is based on investigations on the experimental farm of the research network “Klostergut Scheyern” which is located about 40 km north of Munich.

2.2 MODAM framework to analyze economic and ecological implications of different land use options

MODAM is a simulation tool which enables to model farm decisions and their economic and environmental effects (Zander & Kächele 1999). It consists of a set of relational databases and analytical functions which allow to compute the economic returns and environmental impact of land use alternatives. In the database “PLANT” plant production activities are stored with all operation sequences necessary to obtain the desired product. All activities are characterized by the applied inputs, the implements used and the time span in which the activity is normally carried out. The module “ECOL” calculates the impact of the cropping practices on the environment. From the modules “ECON” and “FARM” gross margins are calculated for each production activity for a given price scenario. A linear programming module “LP” optimizes land use in terms of economic returns or specified environmental targets. The optimizations are based on a single period LP model. One special feature of MODAM is that it considers field specific yield potentials and environmental constraints. Thus comparative advantages of specific fields can be considered with a field specific crop rotation. As a result, MODAM provides an array of land use scenarios under different frame conditions which can be used for a discussion of appropriate policies to achieve environmental objectives.

2.3 Farm model and site specific land use options

The farm model represents the integrated farm system of the experimental farm of the Research Network “Klostergut Scheyern”. The modeled farm has an acreage of 30.5 ha of cultivated land divided into 7 fields. Animal husbandry is bull fattening with a capacity of 50 bulls. For each cropping practice yield was calculated based on site specific yield potential and information about the tillage system and the preceding crop. A set of cropping practices was defined for the relevant crops of the farm model. Each cropping practice consists of a set of operation sequences in which timing, inputs, outputs and implements are defined. For each crop a site-specific array of different management practices including direct seeding and conventional practice were defined which represent the land-use options for the farmer. In order to consider soil protection two cropping strategies were implemented: Integration of catch crops with conventional tillage and integration of catch crops with reduced tillage (without plough). The latter is the realized cropping practice in the experimental farm since 1992. Besides different cropping practices two additional economically sub-optimal N-Inputs were calculated for each cropping practice to consider the choice of appropriate input rate under the constraint of environmental protection. Input-Output relationships were derived from field trials on the research site.

The calculation of gross margin is based on the applied inputs and partial depreciation of implements and machines. For the calculations available mean prices of the year 2000 and the regulations of the EU Agenda 2000 were considered.

2.4 Implementation of Indicators in MODAM to assess the ecological impact of land use options

The economic and environmental effects of all cropping practices were assessed with the MODAM framework. Therefore, indicators were derived which illustrate the impact of the land use practices on the environment. For this study site specific soil loss and global warming potential of the cropping practices were considered to indicate two major impacts of land use on the abiotic environment. Soil loss potential of the cropping practices was assessed with an adapted version of the USLE (Meyer-Aurich et al. 2001).

Coefficients for energy input and global warming potential were calculated following an adapted version of the life cycle assessment procedure (Haas et al. 2001, Wechselberger 2000). The calculations of energy inputs are based on all direct and indirect inputs of primary energy which are necessary to obtain the agricultural product. Energy for manufacturing the machines was allocated according to common depreciation rules. Global warming potential was calculated from the emission of greenhouse gases due to the production process in CO_2 equivalents (Houghton et al. 1996). Besides emissions which were directly associated with the production process of machines and inputs, N_2O emissions from the soil were calculated as 2.5% of Nitrogen input to the soil following investigations on the research site (Flessa, personal communication). The considered emission rates are about double as high as the rates suggested by Bowman (1989).

3 Abatement Costs at farm level

The model framework provides the theoretically optimal land use under the given constraints. With forced soil protection or CO_2 emission reduction opportunity costs emerge at farm level to achieve the predefined level. Figures 1 and 2 show the marginal opportunity costs at farm level for the considered indicators. The opportunity costs are considered to be the abatement costs to achieve the reduction of emissions.

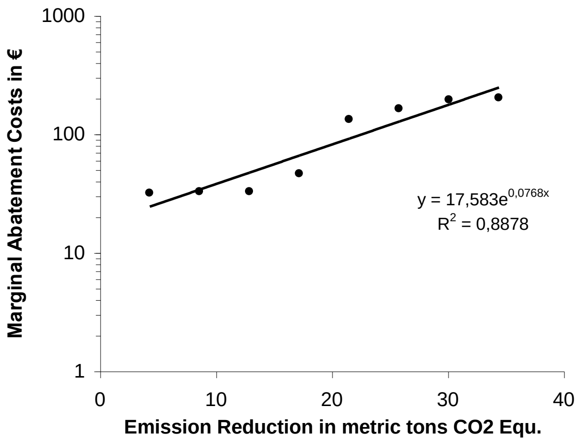

Figure 1: Marginal abatement costs of emission reduction of CO2 equivalents at farm level (each point represents a LP run with the respective forced emission reduction)

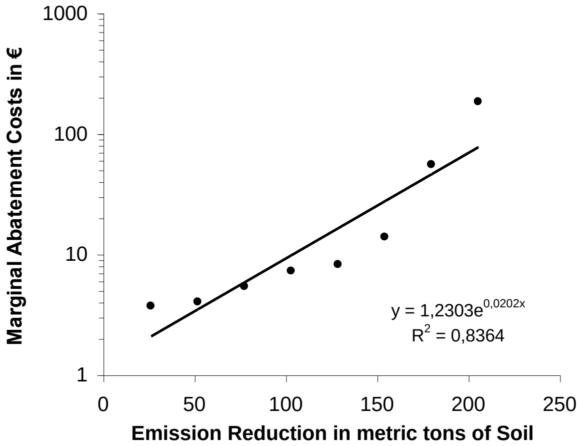

Figure 2: Marginal abatement costs of soil loss reduction at farm level

The marginal abatement costs can be fitted into exponential functions. It can be seen that depending on the indicator, abatement costs rise more or less quickly and provide information about the flexibility of the farm to integrate the specific indicators. Furthermore, optimal pollution control strategies can be discussed based on these functions. The question is, which is the optimal pollution reduction for each of the indicators. This can be derived i.e. from abatement costs in sectors other than agriculture, if specific standards are set by government. The CO_2 reduction target in Germany for example can be achieved at average abatement costs of 34 €/t CO_2 and marginal abatement costs of 101 €/t CO_2 (Stein & Strobel 1997). Hence, as long as the marginal abatement costs on farm are lower than 101 €/t CO_2, agriculture can compete with other sectors in greenhouse gas emission reduction. Therefore, the optimal emission reduction on the model farm would be about 20 t of CO_2 equivalents.

Following these calculations, this can be achieved with reduction in fertilizer and integration of set aside into the cropping sequence.

Finding the optimal emission reduction of soil is much more difficult. It has to be considered, that soil loss not only provides an external effect, but a considerable internal effect, as the farmer is dependent on the soil. However, because of time preferences of the farmer, he tends to neglect the possible future problems with an eroded soil. Also, not all of the eroded soil has to be considered as pollution. Only a specific share of the soil loss reaches watercourses and causes negative effects. Nevertheless, there is a undeniable link between soil loss and external effects of agriculture. One approach to optimal soil loss protection is to define site specific tolerable soil loss rates as proposed by Auerswald (1987). He suggests a measure as a function of site specific yield potential (maximal tolerable soil loss = “Ackerzahl”/8). The “Ackerzahl” is a well-known site characteristic of German soils.

Table 1 shows the results of model calculations under the restriction of the “tolerable soil loss” concept compared with the base scenario. It can be seen, that marginal financial losses have to be recognized if this concept is applied on that farm. For comparison, also a common policy, an agro-environmental program, has been applied to the model. With this program the farmer receives a premium of 100 €/ha for direct seeding of maize and potato in combination with a catch crop. It can be seen that the sum of the total costs for the farmer and the society are about the same with the “tolerable soil loss”-concept as with the premium. However, transaction costs for the TSL scenario have not been considered, since there is no policy known, which could assure a site specific tolerable soil loss. It should be recognized that total soil loss of the farm is even higher in the TSL-scenario than in the premium-scenario, as only on the susceptible sites soil loss is restricted.

The considered policies to reduce soil loss also influence emissions of greenhouse gases. Here the premium leads to a slight increase in GHG-emissions, while the TSL-scenario results in significantly lower GHG-emissions due to the integration of greened set aside on very susceptible fields to soil loss.

Table 1: Results from Scenario calculations

	Szenario[a]		
	Base	TSL	Premium
Total gross margin	24 407 €	24 091 €	25 598 €
Gross margin per ha	800 €	790 €	839 €
Opportunity costs [b]		317 €	-1 191 €
Transaction costs [c]			1 533 €
Sum of costs		317 €	343 €
Indicators			
Total soil loss	307	209	157
Difference from base scenario		98	150
Total GWP [d]	83 018	83 132	83 229
Difference from base scenario		114	211

[a] Scenarios: premium: (100€) for catch crops with reduced tillage, TSL: tolerable soil loss scenario
[b] costs which emerge, if the farm is forced to realize the constraints of the scenario
[c] here only transfer payments of the agro-environmental program to the farm
[d] here only from plant production system

4 Discussion and Conclusions

The presented calculations show that determining marginal abatement costs at farm level can help to approach optimal abatement strategies. However, marginal external effects of the indicators or abatement costs of other firms have to be known, to identify optimal abatement strategies. The calculations show, that the experimental farm has a comparative advantage in abating greenhouse-gases. It can probably be assumed that other farms in Germany offer similar comparative advantages and that there is a considerable potential in the agricultural sector to abate greenhouse gases. A recent study of De Cara & Jayet (2001) studied the different abatement costs in agriculture in twelve EU countries. In this study emissions of N_2O from N fertilizations were calculated with the “Bouwman-equation” (Bouwman 1989), where only half of the Nitrogen is expected to be emitted as N_2O as with the estimation followed in our study. Also, emissions due to the process of manufacturing of implements and fertilizers were not taken into account. However, the study of De Cara & Jayet (2001) also state a substantial potential of GHG abatement in the agricultural sector. They conclude that carbon sequestration with afforestation of set aside land could be a competitive measure to abate greenhouse gas emissions. Though, carbon sequestration is not without controversies as the fixation of carbon is only temporal.

Optimal abatement strategies are difficult to find, if the marginal damage costs cannot be fixed or thresholds are unknown, like it is the case with soil loss. Site specific thresholds as proposed by Auerswald (1987) can be integrated in the MODAM framework, but provide rather theoretical results, as it is hard to control site specific thresholds. Also, from the point of view of pollution abatement soil loss should rather be evaluated as a function of pollution probability than of soil quality. Hence, this threshold rather reflects the internal effect of soil loss than the external effect. An other difficulty is that the estimated soil loss only provides a proxy of the “soil pollution”. Besides uncertainties with the estimation of soil loss (Meyer-Aurich et al. 2001) also run off and pollution probabilities should be taken into account.

If more than one indicator is considered, it has to be assumed, that marginal abatement cost curves change, if restrictions are imposed to the farm. This makes the handling of the indicators more difficult. Nevertheless, the determination of abatement cost curves seems to be the only way to find optimal abatement strategies.

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