REDUCING GHG EMISSIONS BY ABANDONING AGRICULTURAL LAND USE ON ORGANIC SOILS

- A COST ASSESSMENT -

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Abstract

Roughly 6.5% of the German utilized agricultural area is located on organic soils (fens and bogs). Nevertheless, the drainage of these areas in order to allow their agricultural utilization causes roughly a third of the greenhouse gas emissions (GHG) of the German agricultural sector, being equivalent to 4% of the total German GHG emissions. Obviously, German policies trying to reduce the GHG emissions successfully must tackle this issue. The abandonment of the cultivation of organic soils would be an effective policy to reduce the GHG emissions however the question remains whether it is an efficient measure compared with the other options?

In the paper we assess the mitigation costs on the basis of the standard gross margin and tenure of the agriculturally used peatlands and with the results obtained from sector model RAUMIS. Without engineering and transaction costs the mitigation costs are in the magnitude of 10 to 45 € per to of CO_{2eq}. This makes rewetting of peatlands at least in the medium and long run a fairly efficient options for reducing GHG emissions, especially as the implications on the sector due to reallocation affects are fairly small.

Keywords: GHG-Mitigation, Landuse, peatland

1 Introduction

Undrained peatlands accumulate plant remains in waterlogged and usually acidic conditions over thousands of years. However, if these areas are drained the oxidation of the organic material starts and the peatland turn from being a net sink of Greenhouse gases (GHG) into a net emitter.

Around the world, peatlands cover roughly $3.8 * 10^8$ ha (JOOSTEN, 2009). JOOSTEN (2009) estimates that the agricultural use of peatlands induces global GHG emissions in the magnitude of 1.09 * Gtons * $CO_{2eq.}$ a^{-1}. This is equivalent to roughly 13%-17% of the non-CO_2-emmisions of global agriculture (USEPA, 2006). However, agricultural used peatlands cover only 0.8% to 1.7% of the global agricultural area. The estimate is based on the data provided by JOOSTEN (2009) and OLESZCZUK *et al.* (2008) regarding the extent of agriculturally used peatlands and the extent of the global agricultural land of $5.0 * 10^9$ ha (FAOSTAT, 2010).

In contrast to other agricultural emissions, the emissions from peatland are not necessarily correlated to the volume of production. The by far largest emitter is Indonesia, followed by Russia, and China, Mongolia, USA, Germany and Malaysia (JOOSTEN, 2009). The Top Ten emitters are accountable for more than 80% of the global GHG emissions from peatlands in 2008. Especially in South-Asia the emissions literally skyrocketed in the recent decade. Emissions from drained peatlands used for agriculture are an important source of agricultural GHG emissions primarily in Asia and Europe.

For Germany, the annual CO_2 emissions of drained peatland are in the magnitude of 16 tons ha^{-1} a^{-1} for grassland and 42 tons ha^{-1} a^{-1} for arable land (HÖPER, 2007). The emissions from peatlands are equivalent to about 40% of the non CO_2-GHG emissions of the farm sector in 2008 and correspond to roughly 4% of the total German GHG emissions (UBA, 2009). Obviously, German policies trying to reduce the GHG emissions successfully must tackle this issue. In most cases the GHG emissions from the cultivation of peatlands can only be markedly reduced if the water table is altered implying an abandonment of agriculture or at least a significant reduction of the land use intensity. The abandonment of the cultivation of peatlands would be an effective policy to reduce the GHG emissions however the question remains whether it is an efficient measure compared to other options.

Up to now the economic implications of a rewetting of agriculturally used peatlands were mainly analyzed at farm level (e.g. KANTELHARDT & HOFFMANN, 2001; SCHALLER & KANTELHARDT, 2009). To our knowledge the only regional study, that discusses this option as a mitigation strategy is conducted for Swiss agriculture (HARTMANN *et al.*, 2005). However, the authors exclude this effective option from their cost calculation as in Switzerland wetland restoration would primarily affect horticulturally used areas, making this option rather expensive.

Forage cropping and in particular dairy farming play an important role in the agricultural utilization of German peatlands (ROEDER & OSTERBURG, 2010). This fact complicates the derivation of a reliable cost estimate, as especially dairy farming is characterized by a significant share of sunk costs, as most of the capital is fixed in immobile and inalienable assets as stables and milking facilities. Therefore we use the standard gross margin (SGM), the tenure and the gross value added to obtain the short, medium and long term costs of abandoning the agricultural use of peatland. While the SGM and tenure are derived from the farm structure survey the gross value added is calculated with agricultural sector model RAUMIS.

In particular we are interested in three questions: How do the SGM and tenure respond to change in the share of peatland on the municipality level? Do the distributions of the SGM and tenure for peatland differ between the different parts of Germany? How high are the CO_2-abatement costs for the abandonment of peatlands?

The paper is structured as follows. First, we will describe the used data. Second, we briefly explain the applied method for the statistical analyses and modelling. Third, we will present the results. The paper closes with a brief discussion and outlook.

2 Material

To assess the land use on German peatlands, we disaggregate the information in the available data sources up to the municipality level. For the calculation of the area of agriculturally used peatlands we use an algorithm comparable to the one implemented in the German GHG inventory (HAENEL, 2010, p. 351). The distribution of peatlands is derived from the Geological Map of Germany at scale 1:200,000 (GUEK 200) (BGR, 2003). For each municipality we calculate the share of grassland and arable land on peatland, using the Digital Landscape Model (Basis-DLM) for Germany (BKG, 2008). The BASIS-DLM maps the distribution of different land uses at the scale of 1:2,500. We supplement this data with information on agricultural land use provided by the farm structural survey ((ASE): FDZ, 2010). This data is based on the full sample of the German farm population and is available for the years 1999, 2003 and 2007. The highest spatial resolution of the ASE is the municipality. However, one must bear in mind that the ASE does not map the farms’ activities according to the location of the plots but of the farms’ headquarters. This might especially induce some bias in Eastern Germany and

Schleswig Holstein, where the farms are comparably large, measured in ha, compared to the size of the municipalities.

2.1 Extent and distribution of agriculturally used peatland in Germany

High shares of utilized agricultural area (UAA) on peatland can especially be found in North-western part of Lower Saxony, the central part of Schleswig-Holstein, Mecklenburg-Western Pomerania, Brandenburg and the Southern part of Bavaria (Figure 1). While peatlands cover large contiguous areas in the North and East of Germany, their distribution is more locally concentrated in the South and more or less restricted to the area south of the Danube. Based on the GUEK 200 we estimate 980 000 ha UAA are located on peatland (~4.9 of Germanys UAA).

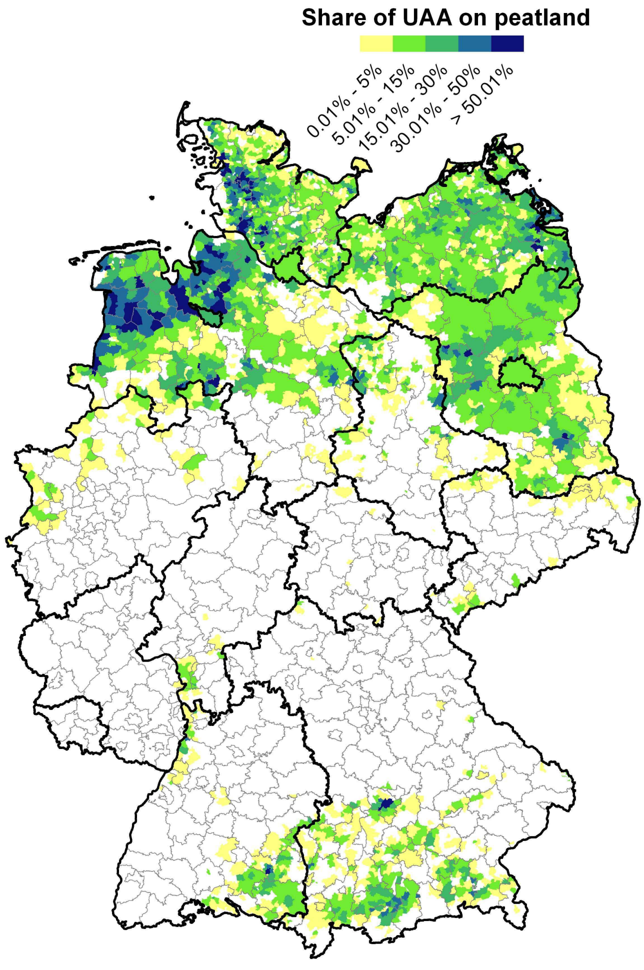

Figure 1: Distribution of the utilized agricultural area (UAA) on peatland in Germany
Source: Own presentation based GUEK 200 and BASIS-DLM

Peatlands in Germany are predominantly used by grassland or arable forage cropping (Roeder & Osterburg, 2010). This forage is primarily dedicated to feed the dairy herd which are kept at medium to high stocking levels. Only in North-East Germany low input forms of grassland management are more widespread.

3 Methods

We group the municipalities and counties according to their share of UAA on peatland into different classes. The first class aggregates the administrative units without any land on peatland. Until 25% the classes have a width 2.5% and beyond this threshold their width is doubled to 5%. For each class we calculate as dependent variable a localization Index *I* for different activities (Eq. 1) and plot it against the appropriate shares of land on peatland.

$$(1) \quad I = \frac{L_{i,j} / L_{.,j}}{L_{i,.} / L_{.,.}}$$

where $L_{i,j}$ is the level of activity i in the peatland share class j. $L_{.,j}$ is the total respective reference area (UAA) in the peatland share class, $L_{i,.}$ the total aggregated activity level, and $L_{.,.}$ is the total respective reference area (adapted from SCHMIT *et al.*, 2006).

The index I can be perceived as a specialization index. A value of one indicates that the relative level of the investigated activity in the analysed class is equal to the relative level for the entire sample. A value above one indicates that the activity is more frequent in the respective class than in the sample on average and a value between zero and one that it is less frequent.

In order to investigate deeper the opportunity costs of abandoning peatland, we analyse the cumulative density distributions for SGM and tenure. We use the SGM, the tenure and the gross value added to assess the cost of abandoning peatland. While the SGM and tenure are derived from the farm structure survey the gross value added is calculated with agricultural sector model RAUMIS. The SGM is a measure for the short term opportunity costs as it assumes that all production factors (e.g. land, labour, building, machinery) are fixed and can not be alienated, that the intensities of farming are fixed, and that the relative shares of the activities on the investigated level remain constant. This means a mixed cash cropping dairy farm will proportionally cut back its cash cropping activities and dairy herd in case it looses land. However, in reality in such a farm the extent of cash cropping will be over proportionally reduced. The tenure is more a measure of the mid-term opportunity costs as some of the farmers' fixed costs are incorporated in their willingness to pay for additional land. The gross value added is a measure of the long term opportunity costs as all fixed factors must be paid. In order to get a better picture of the intra- and interregional heterogeneity of the costs we calculated the data on farm and county level.

In order to account for the regional difference in German agriculture, we divide our sample into four study areas reflecting regions, which differ in their contribution to the area of agriculturally used peatlands and in their farm structure (Table 1). The study areas are selected on the basis of the German *Laender*. Especially the two study areas **NW** and **NE** are characterised by high shares of UAA on peatland. While only 38% of the German UAA is located in these areas, more than 83% of the agricultural used peatland can be found in these two regions.

Table 1: Definition of the study areas for the regionalized analyses

	Laender	**Share of national UAA on peatland**	**Share of national UAA**	**General farm structure**
NW	Schleswig-Holstein, Lower Saxony, (Bremen, Hamburg)	48%	22%	large family farms
NE	Mecklenburg-Western Pomerania, Brandenburg, (Berlin)	37%	16%	large commercial farms
SO	Baden-Wurttemberg, Bavaria	9%	27%	small family farms
CE	All others	7%	35%	

Source: Own calculation based on GUEK 200 and BASIS-DLM

We use POSTGRES®8.213 and POSTGIS®1.3.3. to handle the geographical data and SAS®9.1 for the statistical analysis.

For the assessment of the cost and consequences of abandonment of agricultural use of peatlands, the German agricultural sector model RAUMIS (regionalised agricultural and environmental information system for Germany) is used (WEINGARTEN, 1996; ROEDENBECK, 2004). The methodological concept of the modelling system RAUMIS is an activity based non-linear programming approach. The partial supply model covers the entire German agricultural sector and depicts agricultural production activities in consistency with the economic accounts for the sector. We differentiate 77 crop activities (including set-aside programmes and less intensive production systems) and 16 activities for animal production. From a regional point of view the model covers 326 model regions at county-level (comparable to NUTS 3). These model regions are equivalent to the smallest optimising unit for the programming approach. For each of these regions the database for several base years is stored in activity based matrices. This data constitutes the basis for simulations. The database can be divided into the sectoral economic account for the agricultural sector, regionalised statistics (activity levels, yields) and computed data (especially activity based input calculations). The model is used both for *ex-post* analysis and *ex-ante* comparative-static scenario simulations.

For the simulation of abandonment of peatland use, we implement an incremental tax of 300 to 1200 € for UAA on peatland. We perform simulations for the target year 2019, using a baseline projection of the current agricultural policy (OFFERMANN *et al.*, 2010). Full decoupling of direct payments and regional flat rate payments for both arable and grassland are considered as well as the abolishment of the milk quota.

4 Results

4.1 Response of SGM and tenure to the share of peatland

The higher share of grassland in areas with higher shares of peatland does not mean that the utilization of peatland is in economic terms less intensive compared to mineral soils. This is indicated by the positive correlation of the localization index for the SGM is with the share of UAA on peatland (Figure 2). The reason for the increasing SGMs per ha is the positive correlation between the stocking density and the share of peatland (ROEDER & OSTERBURG, 2010). The increasing stocking densities in peatland rich areas can mainly be attributed to a concentration of dairy farming in these areas. The differences between the various years are negligible.

While the SGM shows a clear response to the share of peatland, the increasing gross margins are not mirrored by a similar trend in the tenure for grassland. The tenure for arable land is not shown as the sample in particular for areas with higher shares of peatland is too small.

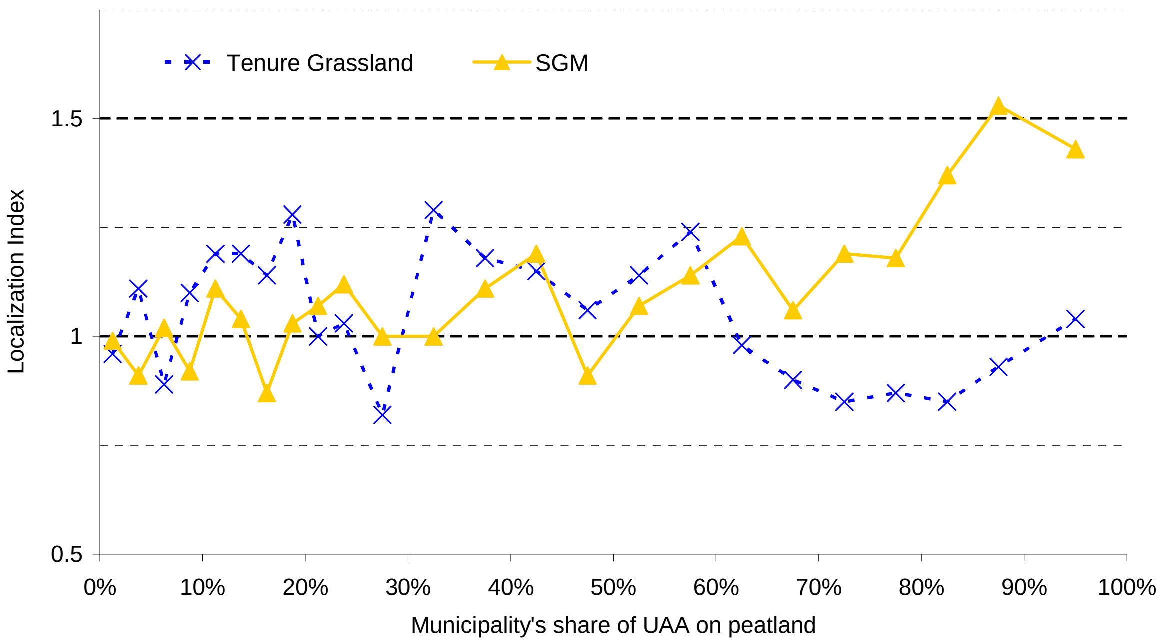

Figure 2: Localization index for the Standard gross margin (SGM) in 2007 and tenure for grassland (1999) as a function of the share of UAA on peatland

Source: Own calculation based on GUEK 200, BASIS-DLM and ASE

4.2 Distribution of SGM and tenure in the different regions

In the following section we present the results of the analysis of the cumulative density distribution (CDD) to describe the intensity gradient in the use of peatland. We present mainly results for the year 2007 as the differences between the years are generally negligible. The data for the study area **CE** are not shown as this study region summarizes *Laender* with a completely divergent farm structure in West and East Germany. Regarding the interpretation of the graphs one should keep in mind that the steeper the depicted curve is the smaller is the observed gradient.

Using SGM as indicator for the short term opportunity costs of abandoning the utilization of peatland, shows great differences between the study areas both for analysis on farm and county level (Figure 3). On farm level, the lowest median values are found in **NE** (570 € per ha) while the median reaches 1,700 € per ha in **NW**. In **NE** the differences in the productivity at farm level are comparatively small. This is indicated by the step form of the function and the narrow inter quantile range (IQR) of roughly 420 € ha. In contrast the IQR in **SO** is nearly three times as high. In **NW** the CDD of the county averages follows the distribution of the data at farm level, at least for the top-left part of the graph. This implies that here farms with a high SGM per ha are frequently located in areas where the regional average is also high. In contrast the form of the function is very steep in **SO** and **NE** implying that at county level high SGMs of single farms are levelled out by low SGM of other farms.

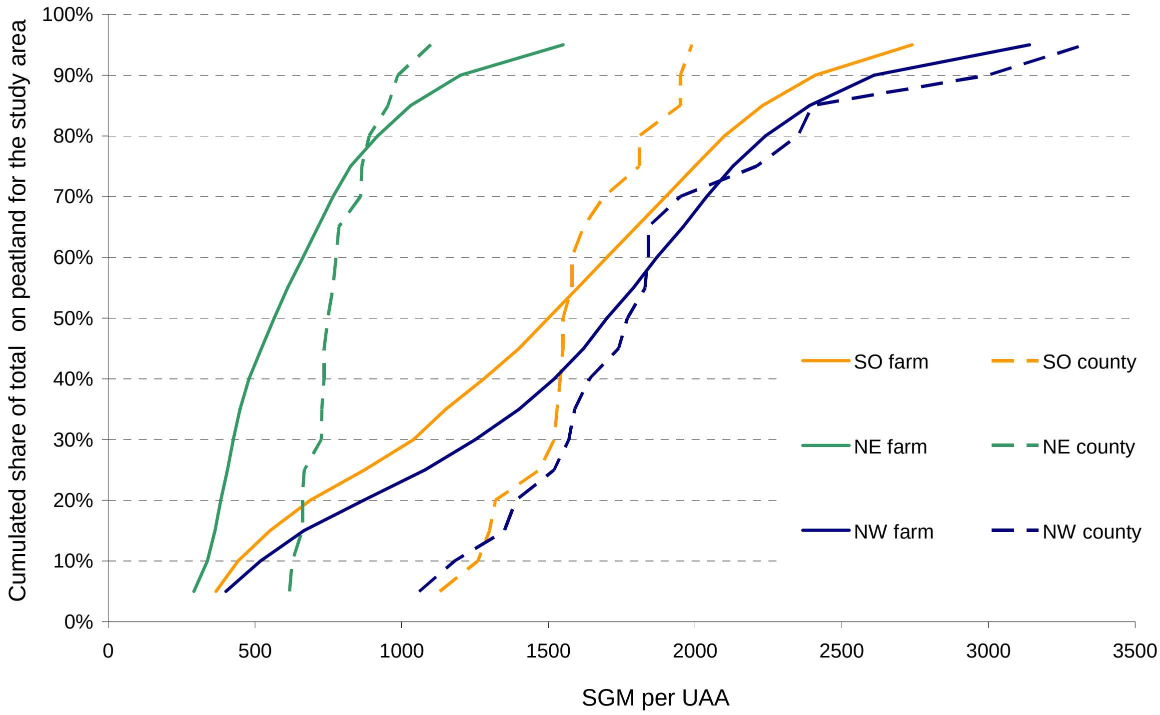

Figure 3: Cumulated density distribution of UAA on peatland as a function of the standard gross margin (SGM) (€ per UAA ha) in the four study areas in 2007 at farm and county level
Source: Own calculation based on GUEK 200, BASIS-DLM and ASE

In contrast to the SGM presented in Figure 3 the land rental payment per hectare (tenure) is an indicator for the mid term opportunity costs. Unfortunately data on tenure are only available for the full sample of German farms for 1999. Only data on the farms' average tenure could be used as the information on recent contracts is rather sporadic. We assume that the presented figures underestimate in tendency the current tenure.

With respect to the tenure the differences between the study areas are much smaller than for the SGM (Figure 4). This can be explained by the fact that dairy farming, which is of particular importance in **NW** and **SO**, is associated not only with a high SGM but also with high fixed costs and labour demands per ha. The median tenure lies between 50 € in **NE** and 165 in **NW** and **SO**. Also the tenure varies much less in the **NE** (IQR of 70 €) compared to the **SO** and **NW** (IQR of 235 €). Interestingly, in all study areas a quarter of the UAA on peatland is used by farms who did not state any tenure or a tenure of zero. Especially in **NE** and **SO** the differences in the tenure on county level are rather small (IRQ of 20 and 55 €)

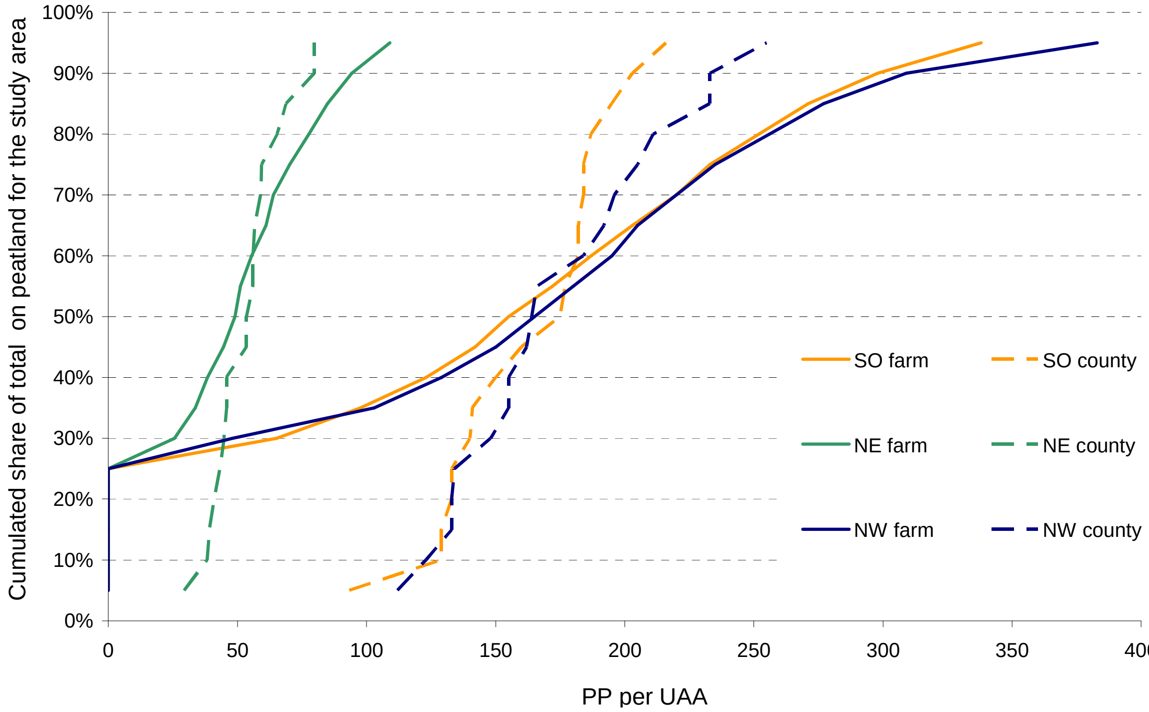

Figure 4: **Cumulated density distribution of UAA on peatland as a function of the average tenure in the four study areas in 1999 at farm and county level**

Source: Own calculation based on GUEK 200, BASIS-DLM and ASE

4.3 Results of model simulations with RAUMIS

It is assumed that restored wetlands are not eligible for direct payments related to agricultural land. The tax implemented on peatland has thus to exceed the returns on arable or grassland use, including direct payments. A tax of 300 € per hectare is mobilesing about a third part of all agricultural used peatland. Marginal land uses are reduced, such as grassland at very low stocking densities, set-aside and coarse grain (Figure 5). In case of these activities, part of the direct payments covers the production cost, so that areas are abandoned more easily. In parallel, temporary grassland is increased on remaining arable land as a substitute for lost permanent grassland. Up to a tax of 700 € per ha, the area of marginal arable crops and especially grassland is increasingly reduced, and almost 80 % of all peatland under agricultural use is abandoned. At higher tax rates less additional area is abandoned, because more competitive land uses have to be reduced. For example, green maize a comparatively competitive crop, used e.g. for subsidized biogas production, and is significantly reduced only at higher tax rates.

Impacts on agricultural output are limited compared to the reduction of 4 % of total arable land and 10 % of grassland. In case of dairy production, output drops by less than 1 %, wheat and beef are reduced by 3% to 4 %. For coarse grain and oilseeds, reductions are between 6 and 9 %. This is both due to direct loss of arable land used for these crops, and substitution effects on the remaining arable land as the share of more competitive crops increases.

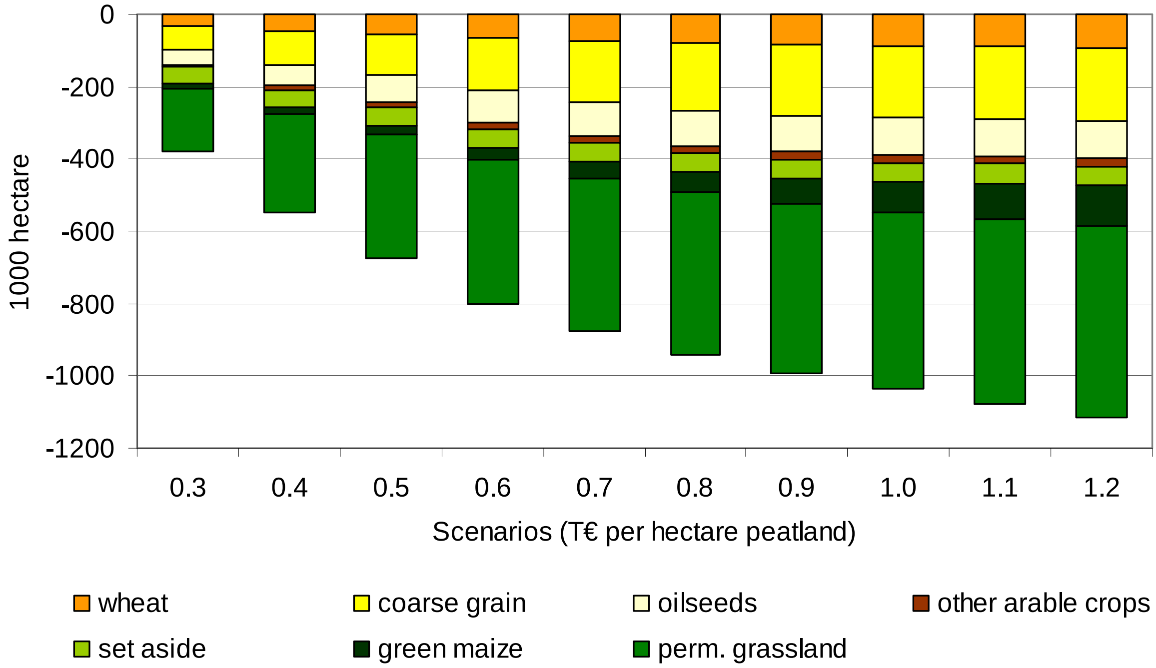

Figure 5: Area changes in 1000 hectare as a function of an incremental tax on peatland
Source: Own calculation based on RAUMIS.

Figure 6 shows the development of arable and grassland as a percentage of the total respective area in Germany, together with the development of dairy and suckler cow herds and the sectoral net value added at factor cost as indicator for farm income. Up to 600 €, the dairy herd remains stable, while the stock of other cattle such as suckler cows and heifers is reduced in the affected regions. In addition forage production on the remaining land is intensified with elevated stocking densities. Especially in regions, where stocking densities are already high, we see an additional intensification on the mineral soils.

Due to the adaptation processes, especially the maintenance of the dairy herd, total income loss is 3 % of the sectoral total (not including the stylized tax on peatland under agricultural use), although about 5 % of the agricultural land is abandoned. The sectoral labour force is reduced by only 1.5 %.

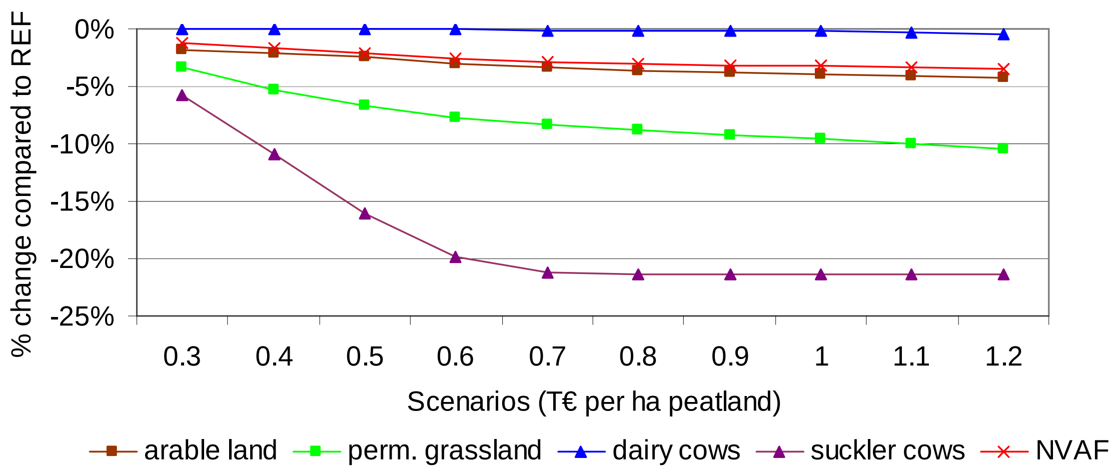

Figure 6: Adaptation path of an incremental tax on peatland (NVAF = Net Value Added at Factor cost)
Source: Own calculation based on RAUMIS.

5 Discussion and Outlook

In the following discussion we will first have a look on the mitigation cost estimates produced by the different approaches. Then we will put the results in the context of other studies on mitigation costs in agriculture. We close with a brief comment on methodological problems of the presented approach. The stated mitigation effects include only the effect of abandoning the agricultural use of peatland and the rewetting of these areas. Effects induced by reduced CH_4, e.g. due to reduced cattle stock, or N_2O emissions, caused by ceasing fertilization on the affected areas, are not considered.

The simulation results show that the consequences of abandoning agriculture on 90% of the peatland are fairly limited. This option could reduce the GHG emissions by roughly $27*10^9$ kg of $CO_{2eq.}$ per year at the expense of 280 M€ net value added. This sum is more or less equivalent to the CAP payments awarded to peatland areas. This leaves us with mitigation costs of 10 € per ton of $CO_{2eq.}$. If direct payment would be granted even for abandoned peatland the mitigation costs would be close to zero. Furthermore, the employment effects are relatively small.

The simulation results match fairly well the results derived from the analysis of tenure. If we assume that the tenure for new contracts will be magnitude of the 75% quantile, this will result in mitigation costs of 2-8 € per ton of CO_{2eq} on arable land and 3-14 € per ton of CO_{2eq} on grassland. The use of the 75% quantile is motivated by two reasons. First, the tenure in new contracts is generally higher compared to old ones. Second, as rewetting needs larger contingent areas, farmers are in a strategic advantage and it will hardly be feasible to determine precisely the differences in the opportunity costs between plots and farms. In contrast to the simulation results the empirical SGM provides an upper bound for the mitigation costs. Delimiting the mitigations costs on the SGM of the UAA on peatland overestimates the mitigation costs as adaption and reallocation of profitable activities and labour costs are not accounted for. An abandonment of 90% of the agriculturally used peatlands would imply a change of 1.2 billion € or mitigation costs of roughly 45€ per ton of CO_{2eq}.

If one compares these results with the meta-analysis of VERMONT & DECARA (2010) or the extensive assessments in MORAN *et. al* (2008) and USEPA (2006) one can conclude that rewetting peatland is for Germany at least in the medium to long run a very cost-efficient option to significantly reduce agricultural GHG-emissions. In these studies agriculture can reduce its GHG emissions by 10% to 20% for mitigation costs of up to 100 € per ton of CO_{2eq}. However, the mitigation potential for some of the most cost efficient and relevant options in these studies is currently challenged (e.g. minimum tillage) in the scientific community (BAKER *et al.* 2007) or the implementation is legally prohibited in the EU (e.g. use of ionosphores).

The results represent a first estimate of the mitigation costs. One should keep in mind that the results might be biased in one or the other direction. A sector approach, like RAUMIS, overestimates the factor mobility within a county as the resources of all farms in a county are aggregated into one “county farm”. However, the empirical analysis of the land use shows that the differences between the farms are quite substantial (see also ROEDER & OSTERBURG, 2010). Especially dairy farming and biogas production are two activities currently concentrated on peatland whose economic performance is sensitive to transportation distances. Consequently, the reallocation of forage cropping to mineral soils will induce additional costs either for the transport of the forage crops or the relocation of production facilities not covered in the model.

Furthermore, RAUMIS assumes homogenous conditions for agricultural production, this contradicts the empirical results, where we see some marked differences in the use of land on peatland compared to mineral soils (e.g. concentration of arable forage cropping). Whether the yields of the activities relocated from organic to mineral soils are comparable remains open. Consequently, the impact of this bias on the cost estimate is unknown.

Neither the simulation nor the empirical results include some additional costs as the engineering costs for rewetting the peatlands and transaction costs. Furthermore, potential effects of indirect land use change are not considered.

Estimating the mitigation costs of abandoning agricultural use on peatland is associated with some uncertainties regarding the underlying data. The various data sources delimiting peatlands in Germany differ substantially in the mapped size and distribution. This has obvious implications on the attribution of land uses to organic and mineral soils. The utilization of the different data sources for determining the peatland area and distribution will improve the confidence in the results and allows an assessment of the potential error. Furthermore, the assumption that within one municipality the land use of arable land on mineral and organic soils is identical is challenged by the empirical result that certain cultures are more frequent in municipalities with higher shares of arable land on peatland. The utilization of plot specific IACS (Integrated accounting and control system) data would allow investigating the interaction between soil type and culture on a level below the municipality.

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