REDUCING GHG EMISSIONS BY ABANDONING AGRICULTURAL LAND USE ON ORGANIC SOILS

NORBERT RÖDER and **BERNHARD OSTERBURG**
Institute of Rural Studies
of the Johann Heinrich von Thünen-Institute (vTI),
Federal Research Institute for Rural Areas, Forestry and Fisheries
Bundesallee 50, D-38116 Braunschweig, Germany
norbert.roeder@vti.bund.de

Contributed paper at the
IATRC Public Trade Policy Research and Analysis Symposium
'Climate Change in World Agriculture: Mitigation, Adaptation, Trade and Food Security'
Universität Hohenheim, Stuttgart, Germany, June 27-29, 2010

Abstract

6.5% of the German UAA 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 compare the land use on mineral and organic soils using the data of the farm structure survey. We assess the mitigation costs on the basis of the standard gross margin of the agriculturally used peatlands and with the 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 are fairly small due to reallocation affects.

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. Table 1 shows that emissions from drained peatlands used for agriculture are an important source of agricultural GHG emissions primarily in Asia and Europe.

Table 1: Annual $CO_{2eq.}$ Emissions from agriculturally used peatlands

	Emissions in 10^9 kg $CO_{2eq.}$ a^{-1}			
	1990	2008	1990	2008
Africa	47	56		
Uganda			16	20
America	63	64		
Brazil			12	12
USA			33	33
Asia	326	698		
China			42	68
Indonesia			200	500
Malaysia			14	48
Mongolia			30	45
Australasia	15	30		
Papua New Guinea			4	20
Europe	253	238		
Belarus			27	27
Finland			12	8
Germany			33	30
Iceland			18	18
Poland			20	18
Russia (European part)			85	88
Rest of the World			160	154
Total	**704**	**1086**	**704**	**1086**

Source: Own presentation based on JOOSTEN (2009)

At national level the relevance of emissions from peatlands (based on JOOSTEN 2009) in relation to emission of agricultural non CO_2-GHG (based on USEPA, 2006) varies greatly. While in Indonesia the emission from peatlands exceed the non CO_2 emissions by a factor of 3.6, they account only for an equivalent of 7% of these emissions in the USA.

In Germany the emissions from peatlands is equivalent to about 40% of the non CO_2-GHG emissions of the farm sector in 2008. These emissions 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 discuss 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.

We base our assessments of the costs of rewetting Germanys agriculturally used peatlands on a two step procedure. In the first step, we provide detailed information on the current agricultural use. In particular we will compare the utilization of peatlands with the one of mineral soils. Based on this data we can estimate the distribution of opportunity costs at farm level. In the second step we will use the agricultural sector model RAUMIS for assessing the impacts of abandoning the agricultural production on peatlands on commodity output and net value added, and to analyse interferences with area-related direct payments of the EU Common Agricultural Policy.

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.

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 the same algorithm as the German GHG inventory

(HAENEL, 2010, p. 351). The distribution of peatlands is derived from the Soil Map of Germany at scale 1:1,000,000 (BUEK 1000) (BGR, 2010). 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.

In order to allow a comparability of the data throughout the years, we grouped the municipalities that exchanged land during redivisions of local governments into joint mapping units. This leaves us with 10,060 base units for the analyses. For the analyses at the county level we merged the 85 urban counties to adjacent rural ones, resulting in 317 units.

UAA on peatland covers 12 800 km² (~6.5 of German UAA) and is highly spatially concentrated. High shares of UAA on peatland can especially 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, there distribution is more patchy in the South.

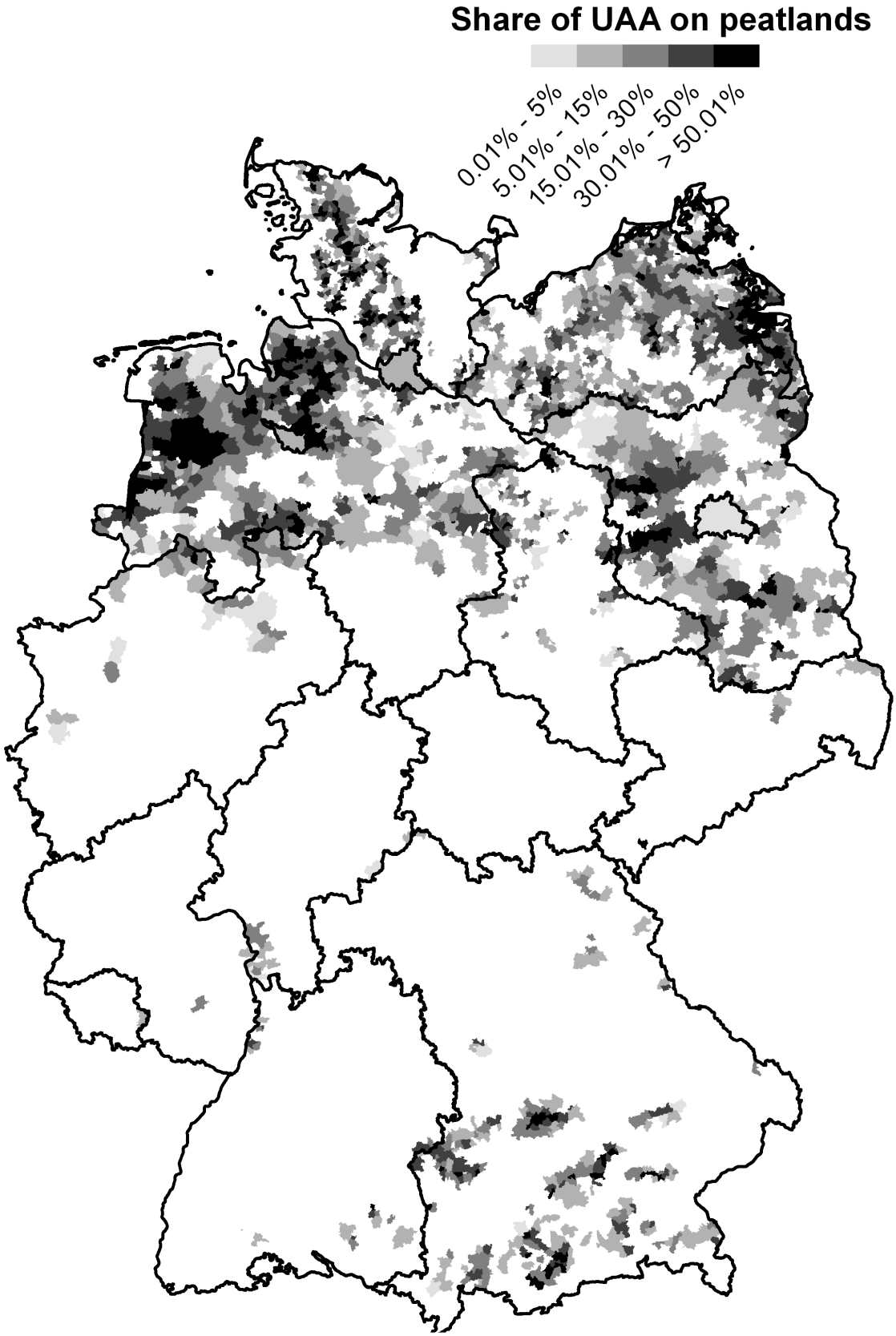

Figure 1: Distribution of UAA on peatland in Germany
Source: Own presentation based on BUEK 1000 and BASIS-DLM

Methods

The aim of the statistical analysis is to distance whether the land use changes in response to a changing share of agricultural land on peatland. We define the share of grassland (p_{GL}), arable land (p_{AL}) or UAA (p_{UAA}) on peatland as (Eq. 1):

$$(1)\quad p_{GL} = \frac{A_{GL,P}}{A_{GL,T}}; \quad p_{AL} = \frac{A_{AL,P}}{A_{AL,T}}; \quad p_{UAA} = \frac{A_{GL,P} + A_{AL,P}}{A_{GL,T} + A_{AL,T}},$$

where $A_{GL,P}$ and $A_{AL,P}$ are the respective areas of grassland (*GL*) and arable land (*AL*) on peatland, while $A_{GL,T}$ and $A_{AL,T}$ indicate the respective total areas in a given administrative unit. These shares are calculated for Germany in total and each of the *m* municipalities and *c* counties.

We group the municipalities and counties according to their share of *GL*, *AL* or agriculturally used land (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. 2) and plot it against the appropriate shares of land on peatland.

$$(2)\quad I = \frac{L_{i,j} / L_{.,j}}{L_{i,.} / L_{.,.}}$$

where $L_{i,j}$ is the level of activity *i* in the peatland share class *j*. $L_{.,j}$ is the total respective reference area (GL, AL or 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 the first experiment, we calculate $L_{i,j}$ in four different ways in order to assess the impact of a changing resolution regarding the distribution of peatlands on the results. From experiment one to four the resolution becomes coarser. In the first experiment we use all the available information (Eq.3):

$$(3)\quad \begin{aligned} L1_{i,j} &= \sum_{m \in j} \sum_{f \in m} \left(p_{AL,m} * A_{AL,f} * \lambda_{AL} + p_{GL,m} * A_{GL,f} * \lambda_{GL} \right) * s_{i,f}; \\ s_{i,f} &= \frac{L_{i,f}}{A_{AL,f} * \lambda_{AL} + A_{GL,f} * \lambda_{GL}} \end{aligned}$$

where $A_{AL,f}$ and $A_{GL,f}$ are the arable land and grassland of farm f located in municipality m. $L_{i,f}$ is the activity level at the farm and λ_{AL} and λ_{GL} are binary variables indicating whether arable land, grassland or both are the appropriate reference for the respective activity.

In the second experiment we assume that information on the distribution of UAA on peatland at municipality level is not available separately for arable land and grassland but only for UAA as a whole. Consequently Eq. 3 simplifies to Eq. 4:

$$(4)\quad L2_{i,j} = \sum_{m \in j} \sum_{f \in m} p_{UAA,m} * \left(A_{AL,f} * \lambda_{AL} + A_{GL,f} * \lambda_{GL} \right) * s_{i,f}$$

In the third experiment (Eq. 5) we assume that only information on the county in which a given farm is located is available, while differentiated information regarding the shares of grassland and arable land are provided:

$$(5)\quad L3_{i,j} = \sum_{c \in j} \sum_{f \in c} \left(p_{Aal,c} * A_{al,f} * \lambda_{al} + p_{gl,c} * A_{gl,f} * \lambda_{gl} \right) * p_{i,f}$$

In the forth experiment (Eq. 6) we use only county level information on the location of the farm and analogous to Eq. 4 only the aggregated share for UAA on peatland is known:

$$(6)\quad L4_{i,j} = \sum_{c \in j} \sum_{f \in c} p_{UAA,c} * \left(A_{AL,f} * \lambda_{AL} + A_{GL,f} * \lambda_{GL} \right) * s_{i,f}$$

In order to investigate deeper the land use gradient on peatlands, we analyse the cumulative density distribution for a set of selected indicators. These indicators include

standard gross margin, stocking (all livestock, grazing livestock, dairy cattle) and tenure for arable land and grassland. We calculated the density plots in six different ways. These variants differ in the way the activity data is aggregated (farm, municipality or county level) and whether the share of peatland is calculated based on differentiated values for arable land and peatland or on one intermediate one.

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 2). 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 2: 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)	35%	16%	large commercial farms
SO	Baden-Wurttemberg, Bavaria	10%	27%	small family farms
CE	All others	7%	35%	

Source: Own calculation based on BUEK 1000 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, an incremental tax of 300 to 1200 € has been implemented on UAA on peatland. We perfom 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.

Results

Only in roughly a fifth (2,274 of 10,060) of the German municipalities at least some UAA is located on peatland (Table 3). 4.4% of the German arable land (p_{AL}) and 10.9% of the grassland (p_{GL}) are located on peatlands. Only in roughly 500 municipalities (Q75) more than 28% of the municipalities' arable land is located on peatland. While the number of municipalities with grassland on peatland just slightly exceeds the number of municipalities with arable land $p_{GL,m}$ is roughly twice as high as $p_{AL,m}$. However, the correlation between the two shares is fairly low, taken the low resolution of the soil data. If the shares are calculated at county level instead, the peatland area is much more diluted than at the municipality level. In addition the correlation between $p_{AL,c}$ and $p_{GL,c}$ is markedly higher than between $p_{AL,m}$ and $p_{GL,m}$.

Table 3: Descriptive statistics on the share of grassland (*GL*) and arable land (*AL*) on peatlands for different administrative levels (municipality (*m*), county (*c*))

	All observations			Non zero observations only				
	No.	Avg.	St. Dev.	No.	Q25	Q50	Q75	Pearson's r
$p_{AL,m}$	10,060	4.4%	11.4%	2,074	4.6%	13.1%	28.2%	
$p_{GL,m}$	10,060	10.9%	22.1%	2,241	9.8%	28.5%	53.5%	
$p_{AL,m}$, $p_{GL,m}$				2,274				0.65
$p_{AL,c}$	317	4.4%	6.5%	154	0.9%	3.6%	10.2%	
$p_{GL,c}$	317	10.9%	15.8%	160	2.0%	8.9%	22.1%	
$pl_{a,c}$, $p_{GL,c}$				160				0.78

Source: Own calculation based on BUEK 1000 and BASIS-DLM

The cumulative density plot shows that when data are aggregated at the county level only, especially the extent of areas with high shares of peatland is greatly underestimated (Figure 2). An economic analyses based on county averages only, would therefore underestimate the economic consequences as farms are generally fairly immobile and the more concerned a farm is by a (political) measures the fewer and the more costly are generally the adaption options (eg. KANTELHARDT & HOFFMANN, 2001).

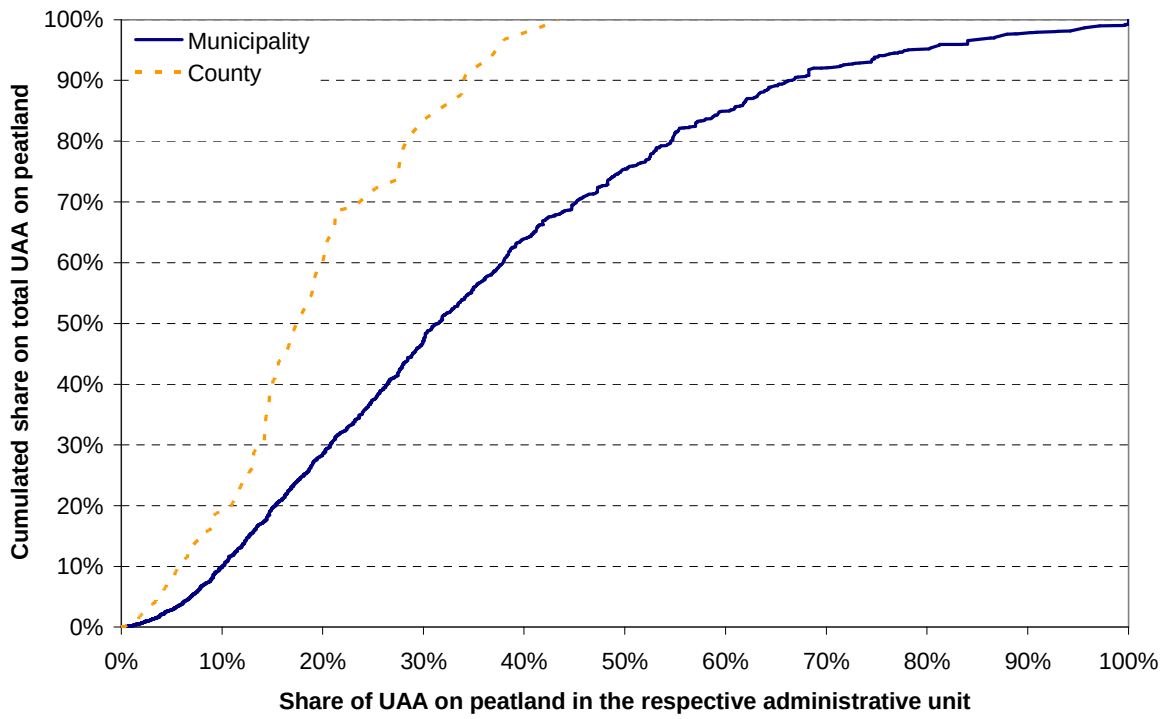

Figure 2: Cumulative density distribution of the UAA on peatland as a function of the share of UAA on peatland

Source: Own calculation based on BUEK 1000 and BASIS-DLM

Based on Eq. 3 we present in the following paragraph some descriptive information on the agricultural utilization of peatlands in the four study areas (Table 4). In 2007 on

average half of the UAA on peatland is used as arable land (AL), this share is only higher in **CE** were peatland areas are generally more scattered. The study area **NW** differs in several aspects from the remaining. First, the share of arable forage cropping (AFC) (mainly maize) on the arable land is on the expense of cash cropping (CC) twice as high as in the other areas. Second, in **NW** rose the share of AL on UAA by 7% between 1999 and 2007, while it remained the constant in all areas. In all areas, the area of AFC increased from 111,000 ha in 2003 to 156,000 ha in 2007, while the area of CC declined by 27,000 ha in the same period. This expansion is likely due to cultivation of maize for biogas as the number of grazing livestock units (GLU) dropped in the same period by 7%.

Table 4: Agricultural utilization of the peatlands in the four study areas in 2007

	AL on UAA[1)]	GL on UAA	MFA on UAA	AFC on AF	CC on AL
NW	49%	51%	70%	40%	60%
SO	48%	52%	63%	23%	77%
NE	53%	47%	56%	18%	82%
CE	58%	42%	54%	20%	80%
Germany	**51%**	**49%**	**64%**	**29%**	**71%**

Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE
1) AL: Arable land; GL: grassland; MFA: main forage area; AFC: arable forage crops; CC: cash crops

Localization indizes

The results for the localization indices are presented for the year 2007 only as the difference between the three investigated years are generally negligible. We will focus on five indicators describing the type and intensity of land use: share of grassland, standard gross margin per ha, stocking density of livestock, stocking density of low input grazing livestock, and the share of maize.

The proportion of grassland (GL) on the UAA increases as the share of UAA on peatland gets higher (Figure 3). Even in areas with very high shares of peatlands (i.e. greater than ~60% at municipality and ~30% at county level) the share of grassland on UAA is only 1.5 to 2 times as high as on the national average. This implies that even in municipalities where the share of UAA on peatland exceeds 60%, still 40% to 60% of the UAA is used as arable land. As the localization index on the county level reaches similar levels but at much smaller shares of peatland, one can conclude that in regions with higher shares of

peatland also the likelihood that mineral soils are used as grassland is strongly elevated compared to the national average.

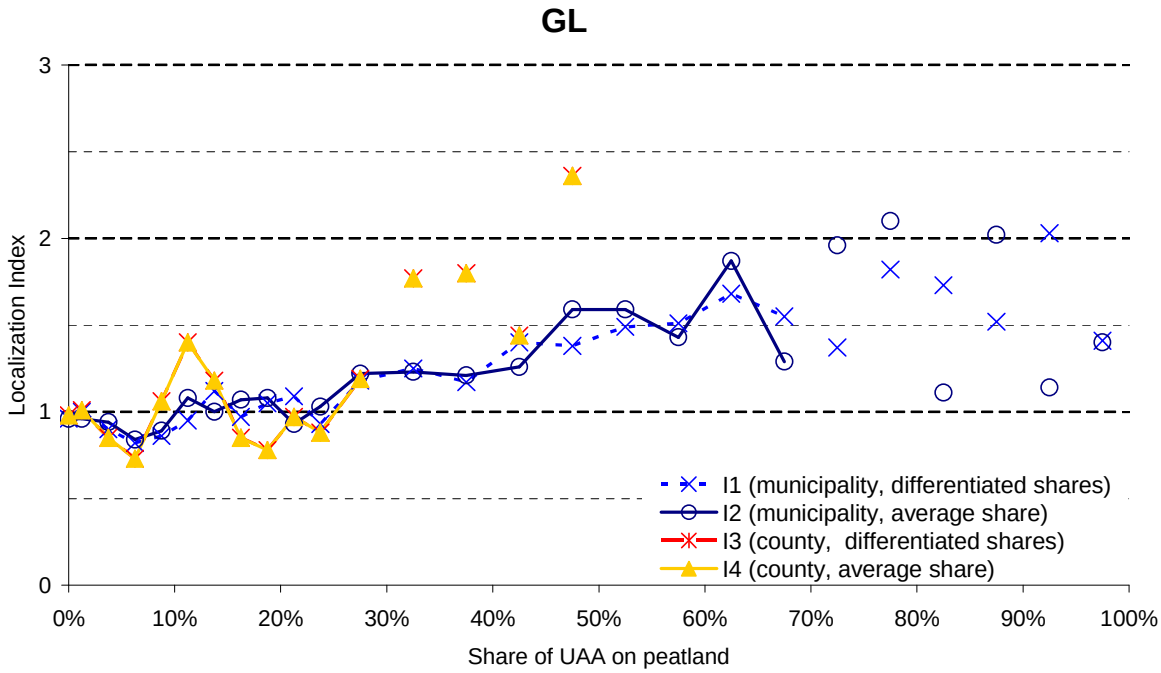

Figure 3: Localization index for grassland as a function of the share of UAA on peatland for different types of spatial data aggregation
Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

The higher share of grassland in areas with higher shares of peatland does not mean that the utilization of peatlands is in economic terms less intensive compared to mineral soils. Irrespective of the chosen data aggregation the localization index for the standard gross margin (SGM) fluctuates over a wide range of shares of UAA on peatland around 1 (Figure 4). This means that generally the average SGM per ha is not influenced by the presence of peatland. In regions with very high shares of peatlands the SGM per ha is even higher compared to regions without any peatlands. However, the respective localization indices are based on comparatively few observations.

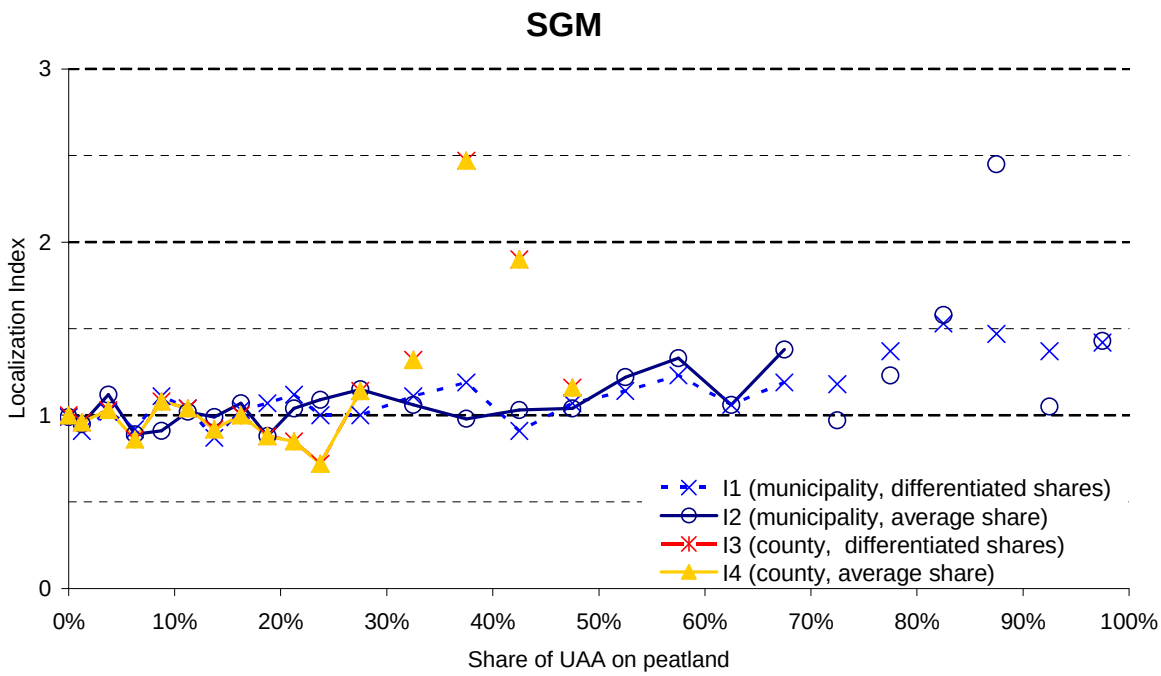

Figure 4: Localization index for the Standard gross margin (SGM) as a function of the share of UAA on peatland for different types of spatial data aggregation
Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

The reason for the constant or even increasing SGMs per ha is the positive correlation between the stocking density and the share of peatland (Figure 5). The increasing stocking densities in peatland rich areas can mainly be attributed to a concentration of dairy farming in these areas (not shown).

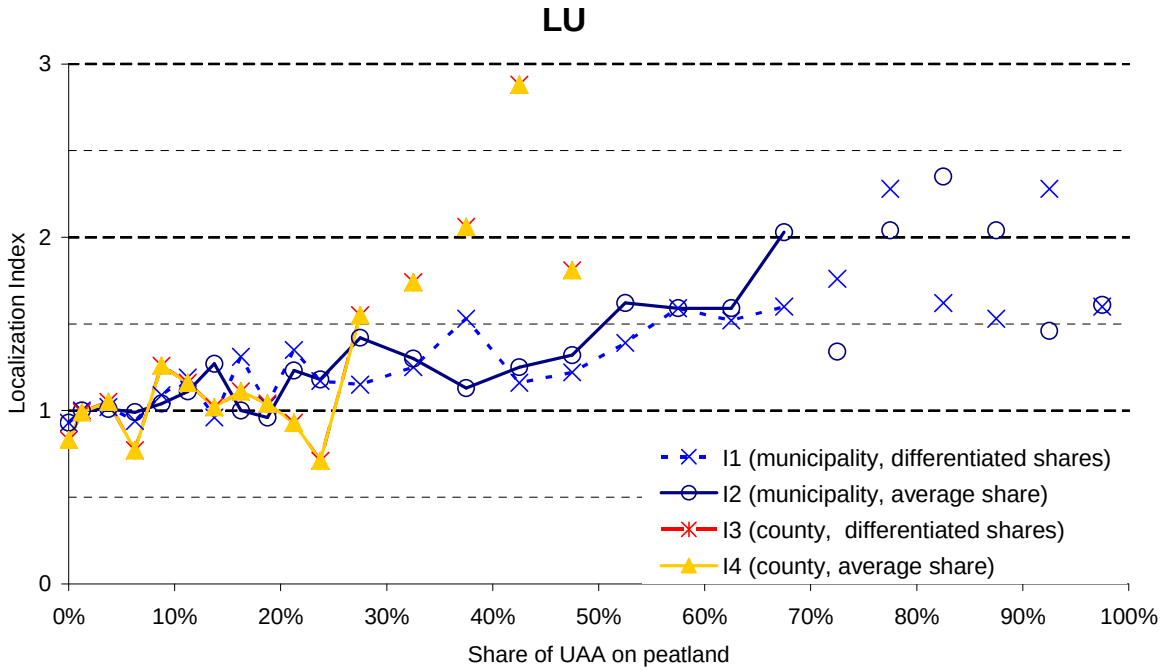

Figure 5: Localization index for the stocking in livestostock units (LU) as a function of the share of UAA on peatland for different types of spatial data aggregation

Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

The distribution of grazing livestock kept at low input levels (i.e. suckler cows and their offspring, sheep and horses) indicates that grasslands on peatlands are managed as intensive as on mineral soils, as these types of livestock husbandry barely respond to a shift in the share of peatland (Figure 6).

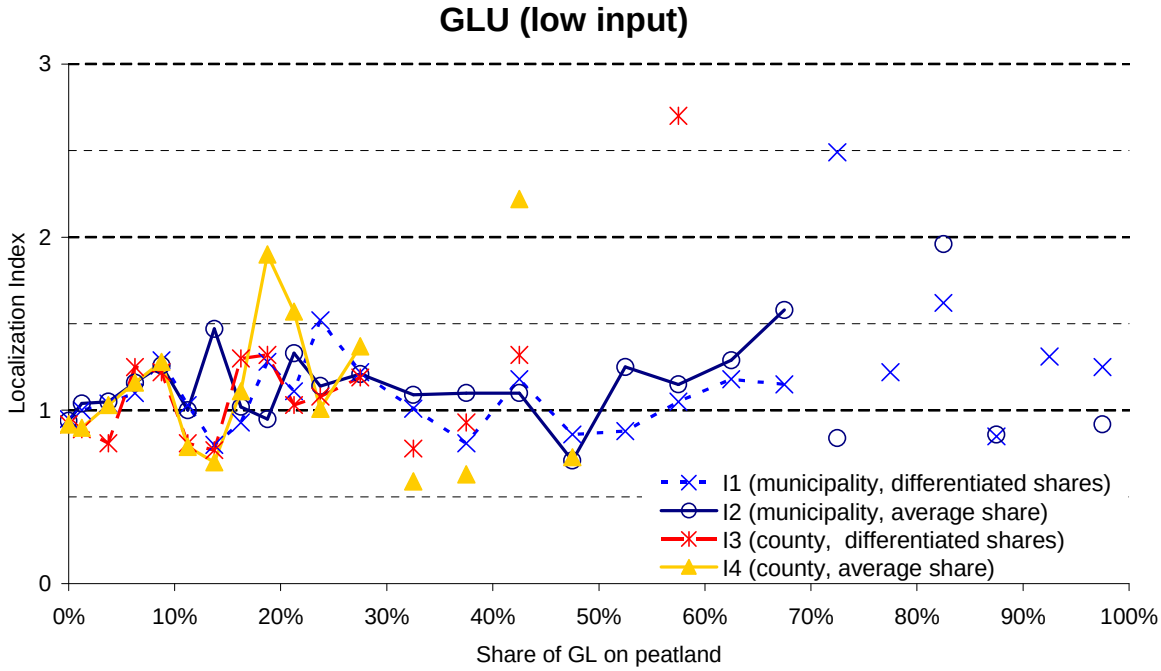

Figure 6: Localization index for the stocking of grazing livestock units (GLU) kept at low input levels as a function of the share of grassland (GL) on peatland for different types of spatial data aggregation

Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

Regarding the utilization of arable land the increasing importance of dairy farming is mirrored by the positive correlation between the share of maize and the share of arable land on peat land. Even if the data are interpreted cautiously, one can see that in areas with high shares of peatland maize is two to three times as frequent as on the national average. This means maize reaches on average shares of 30% to 50% in the crop rotation.

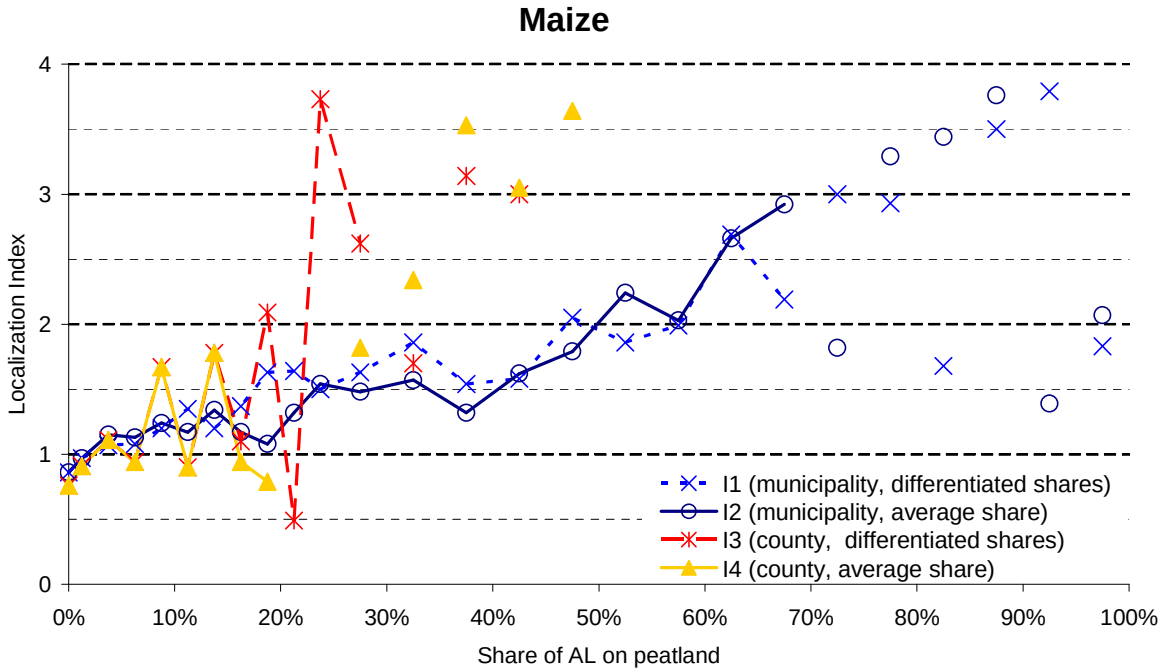

Figure 7: Localization index for maize as a function of the share of arable land (AL) on peatland for different types of spatial data aggregation
Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

Cumulative density distribution

In the following section we present the results of the analysis of the cumulative density distribution (CDD). Apart from the analysis of the tenure the data refer always to the year 2007. The data for the study area **CE** are just presented for completeness and will not be analysed in detail, as this study region summarizes *Laender* with a completely divergent farm structure in West and East Germany. Generally, the way of delimiting the area of UAA on peatland had negligible impact on the results and the data aggregated at municipalities lie between the bounds defined by the aggregation at farm or county level. Therefore we will present only the two most extreme options. The data at farm level are based on differentiated shares of UAA on peatland while for the data at county level an intermediate value is used. 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 standard gross margin (SGM) as indicator for the short term opportunity costs of abandoning the utilization of peatlands, shows great differences between the study areas (Figure 8). The lowest median values are found in **NE** (770 € per ha) while the median

reaches 1,800 € per ha in **NW** and **SO**. 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 quantil range (IQR) of roughly 550 € ha. In contrast the IQR in **SO** is nearly twice 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.

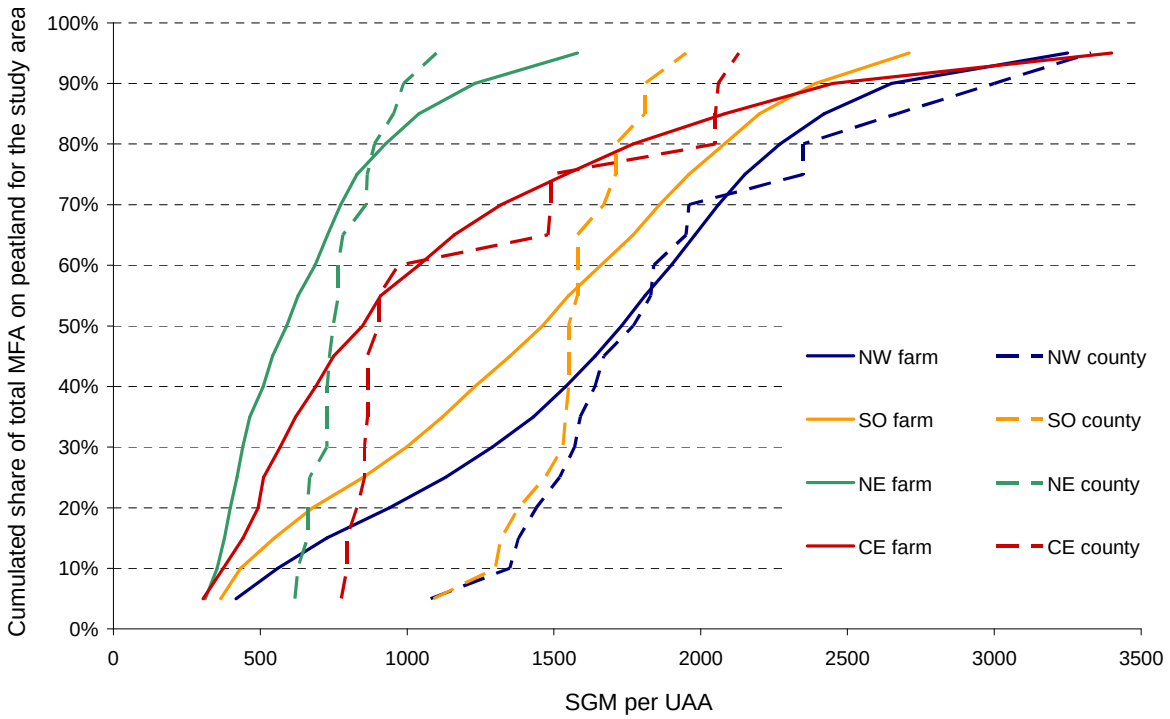

Figure 8: Cumulated density distribution of UAA on peatland as a function of the standard gross margin (SGM) (€ per UAA ha) in the four study areas in 2007 at farm and county level
Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

The differences in the level and distribution are mirrored by the CDD of the stocking densities (Figure 9). The highest stocking densities can be found in **NW** followed by **SO** (median values of 1.5 and 1.2 LU per ha**),** while the median stocking density reaches just 0.5 LU per ha in **NE**. Large differences among the farms can be observed in **NW** and **SO** with IQRs of 1.1 and 1.3 LU per ha, respectively. Also at county level the CDD of stocking levels for **NW** is relatively flat. This indicates large regional differences regarding the importance of animal husbandry between the different areas with peatland in this study area.

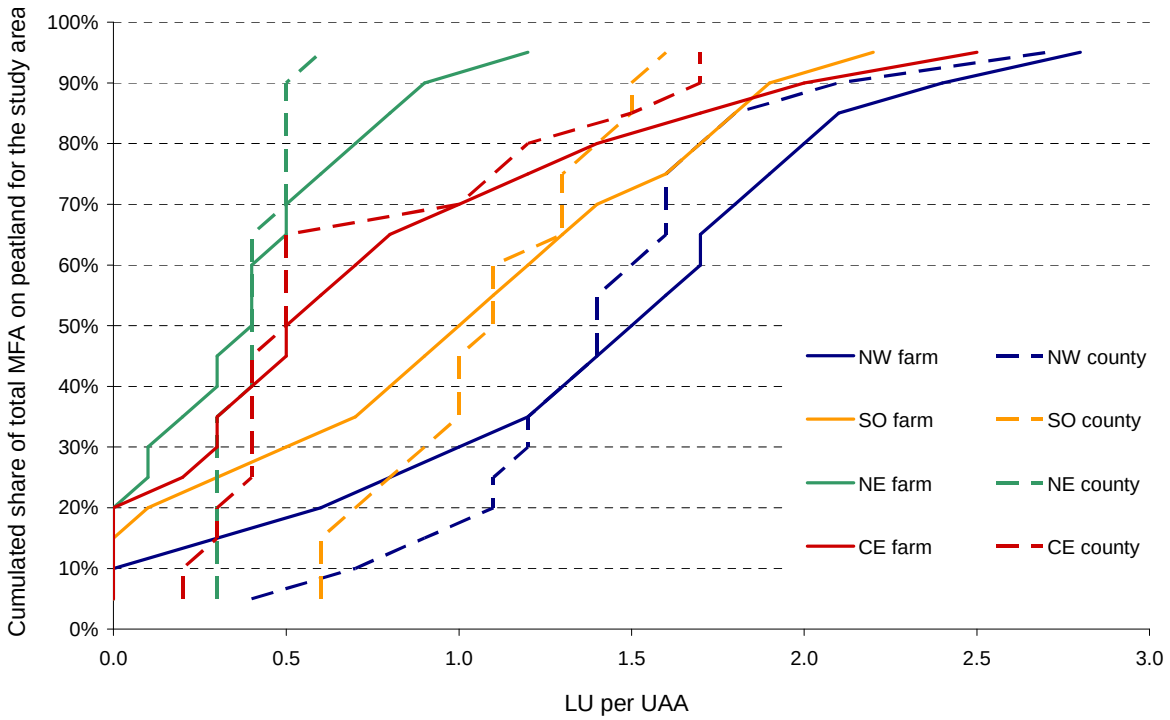

Figure 9: Cumulated density distribution of UAA on peatland as a function of the stocking density (LU per ha UAA) in the four study areas in 2007 at farm and county level

Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

The picture is rather similar if only the stocking density of grazing livestock (cattle, sheep, horses) is put in relation to the main forage area (MFA) (Figure 10). In all study areas 5% to 10% of the MFA on peatland is in farms without any grazing livestock. The difference in the stocking levels between **NW** and **SO** is much smaller than a LU per ha base. The higher difference for the LU per ha indicator is due to high importance of pig and poultry production in the **NW**. The CDD on county data shows barely a gradient in **NE** and **NW**, meaning that an intensity gradient exists mainly below the county level.

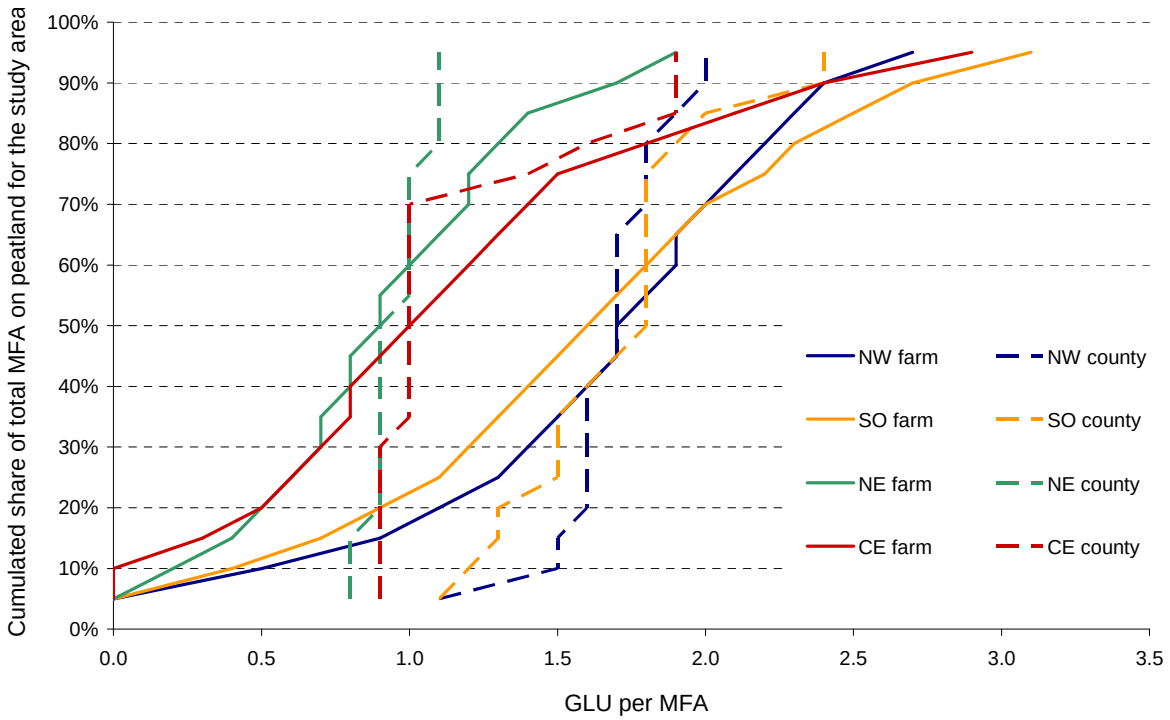

Figure 10: Cumulated density distribution of MFA on peatland as a function of the stocking density (GLU per ha MFA) in the four study areas in 2007 at farm and county level
Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

Between the study areas the intensity of the forage cropping, and its distribution, differs not only with respect to the stocking density but also regarding the composition of the stock. In NE 55% of the MFA on peatland is managed in farms without any dairy cattle (Figure 11). This is more than twice the share of NW and SO.

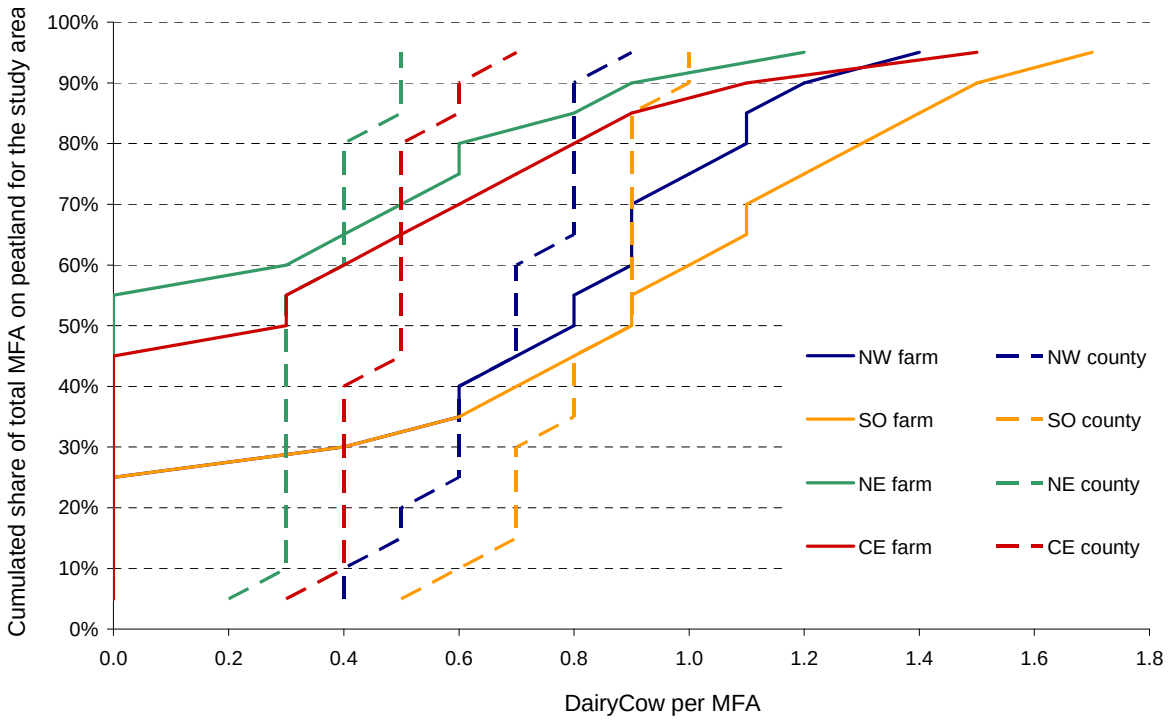

Figure 11: Cumulated density distribution of MFA on peatland as a function of the stocking density (dairy cow per ha MFA) in the four study areas in 2007 at farm and county level
Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

Between 1999 and 2007 we observe a reduction of the stocking density (left shift of the curve) (Figure 12). Reduced densities are mainly observed for farms with low and intermediate stocking densities (up to 1 LU per ha), while the share of MFA on peatland managed by more intensive farms is stable. A destocking could especially be observed in **NE** and **CE**.

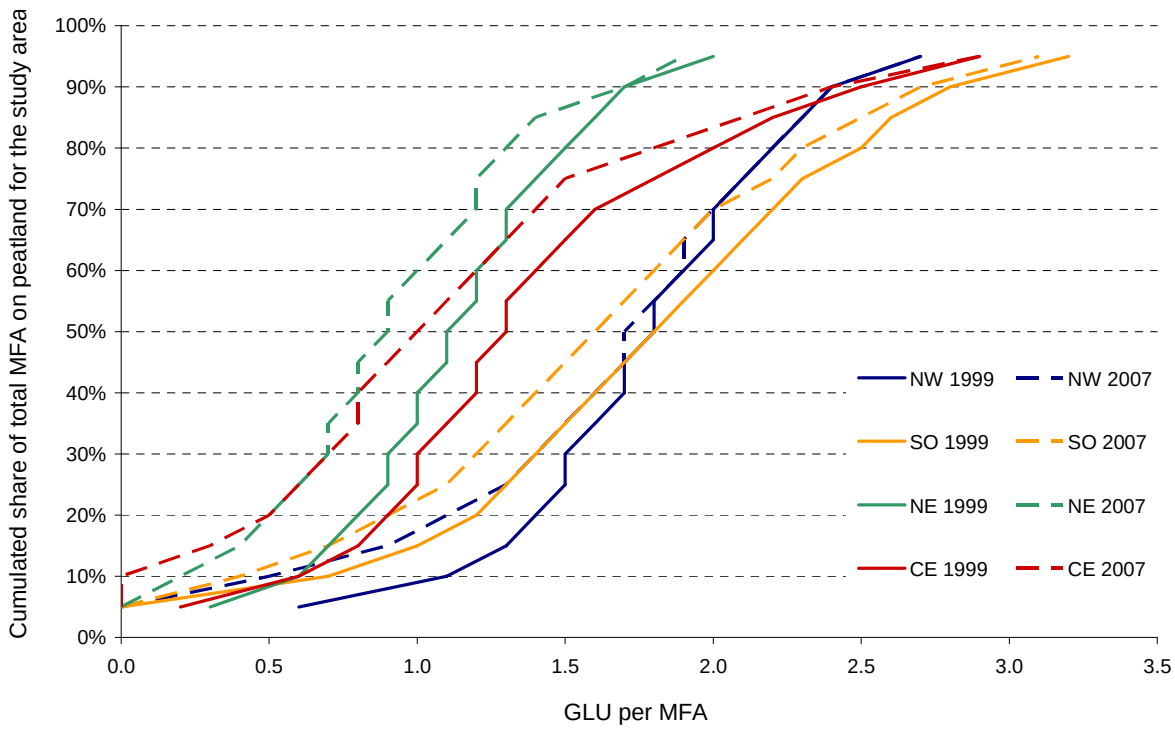

Figure 12: Cumulated density distribution of MFA on peatland as a function of stocking density (GLU per ha MFA) in the four study areas in 1999 and 2007 at farm level
Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

In contrast to the SGM presented in Figure 8 the land rental payment per hectare (tenure) is an indicator for the long 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 13). This can be explained by the fact that in 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 160 in **NW** and **SO**. Also the tenure varies much less in the **NE** (IQR of 80 €) compared to the **SO** and **NW** (IQR of 250 €). 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.

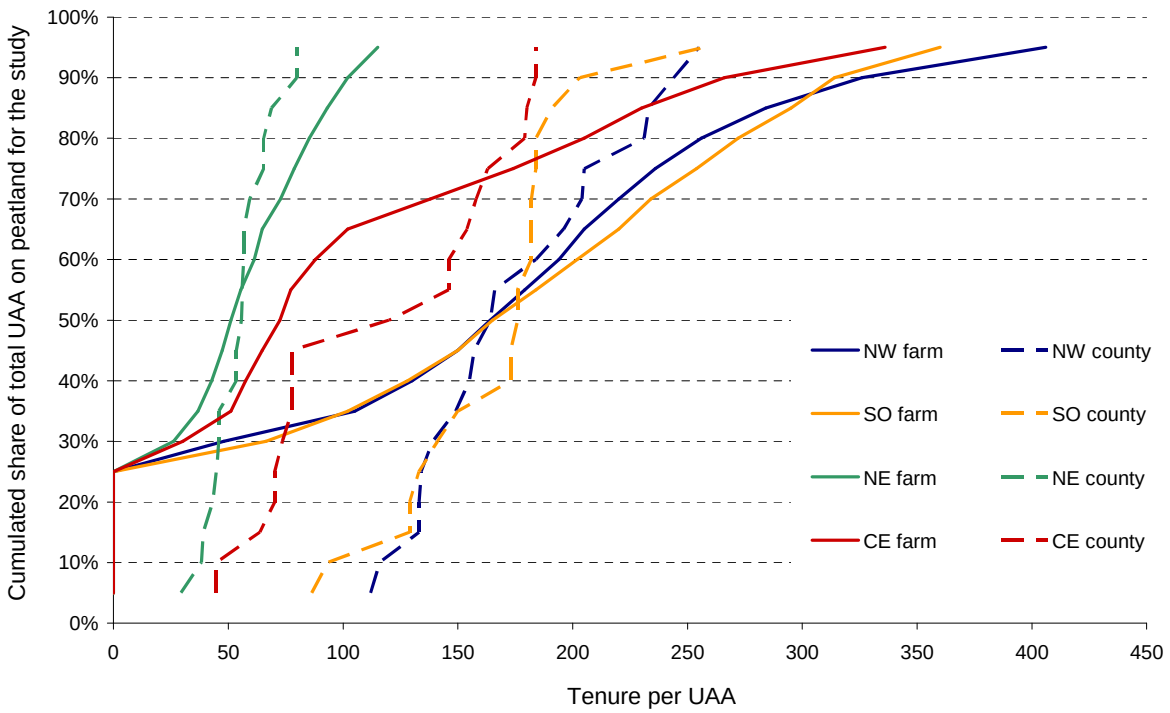

Figure 13: Cumulated density distribution of UAA on peatland as a function of the average tenure in the four study areas in 1999 at farm and county level
Source: Own calculation based on BUEK 1000, BASIS-DLM and ASE

For most of the analyzed variables and study areas the cumulative density distribution for municipality aggregates is located between farm and county aggregates, and the distribution is more similar to county aggregates than to the distribution derived from individual farm data. The only exemptions refer to the distributions of LU and SGM per UAA in the study area **NW** for the years 1999 and 2003. In these case the values for the municipality aggregates lie frequently above the corridor defined by the county and farm data. This can be likely attributed to the high frequency of farms in this area which operate with very high stocking levels (mainly poultry and pigs) and consequently high SGM per ha. As these very intensive farms use less than 5% of the study area's UAA on peatland, their values do not appear in the cumulated density distribution at farm level. However, these farms are likely to rely on regional UAA available for manure application, thus indirectly affecting peatland use.

A generally observed feature was that while the intensity distribution was stable, the size of the reference area (UAA, AL, GL and MFA on peatland) varied markedly in dependence of the chosen calculation procedure. In most cases the differences between the algorithms reached 10%.

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 mobilising 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 14). 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 also more competitive land uses have to be reduced. For example, green maize is a comparatively competitive crop, as it is also used for subsidized biogas production, and is increasingly reduced only at higher tax rates.

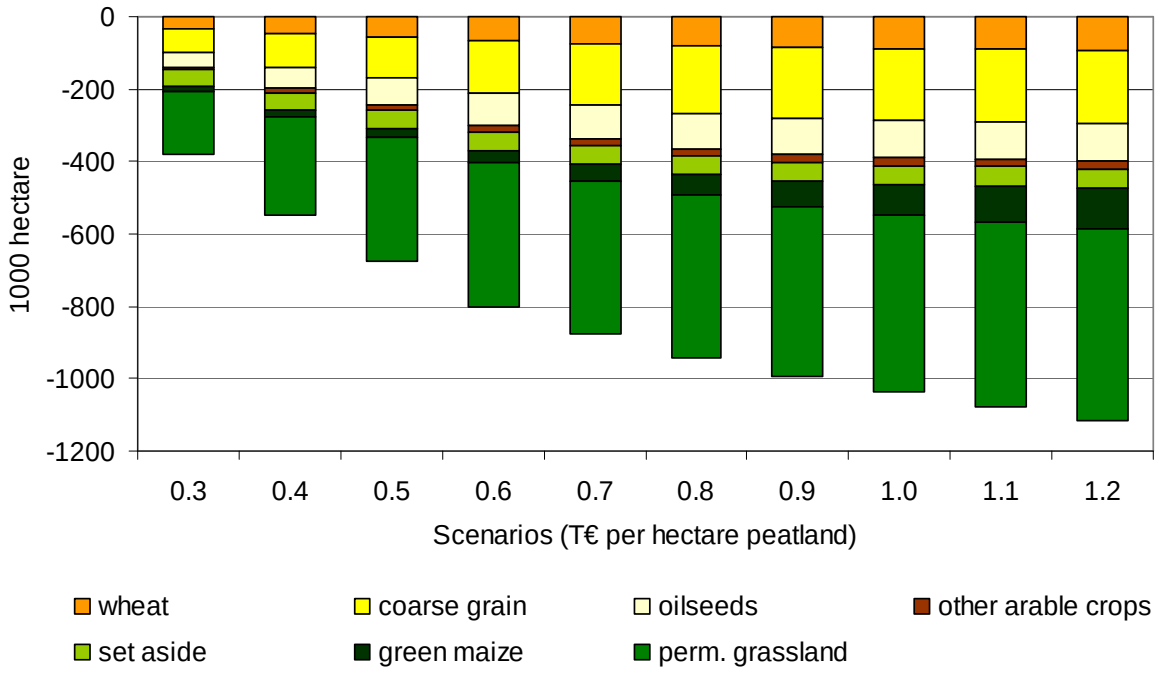

Figure 14: Area changes in 1000 hectare as a function of an incremental tax on peatland
Source: Own calculation based on RAUMIS.

Figure 15 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. While the suckler cow herd is reduced at lower tax rates up to 600 €, the dairy herd remains stable. Instead, other cattle such as suckler cows and heifers are reduced in the affected regions, and forage production on remaining land is intensified at 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 6 % of the agricultural land is abandoned. The sectoral labour force is reduced by only 1.5 %.

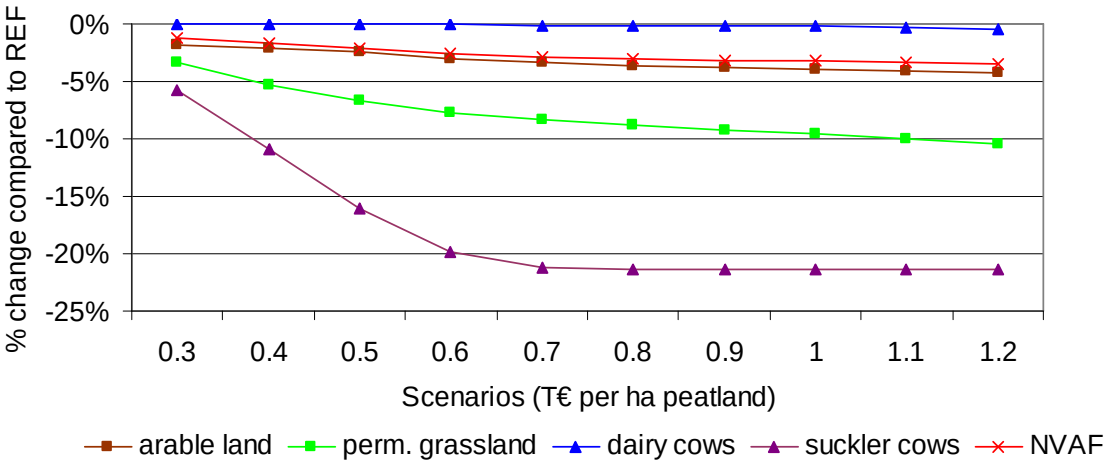

Figure 15: Adaptation path of an incremental tax on peatland (NVAF = Net Value Added at Factor cost)
Source: Own calculation based on RAUMIS.

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% ot 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.

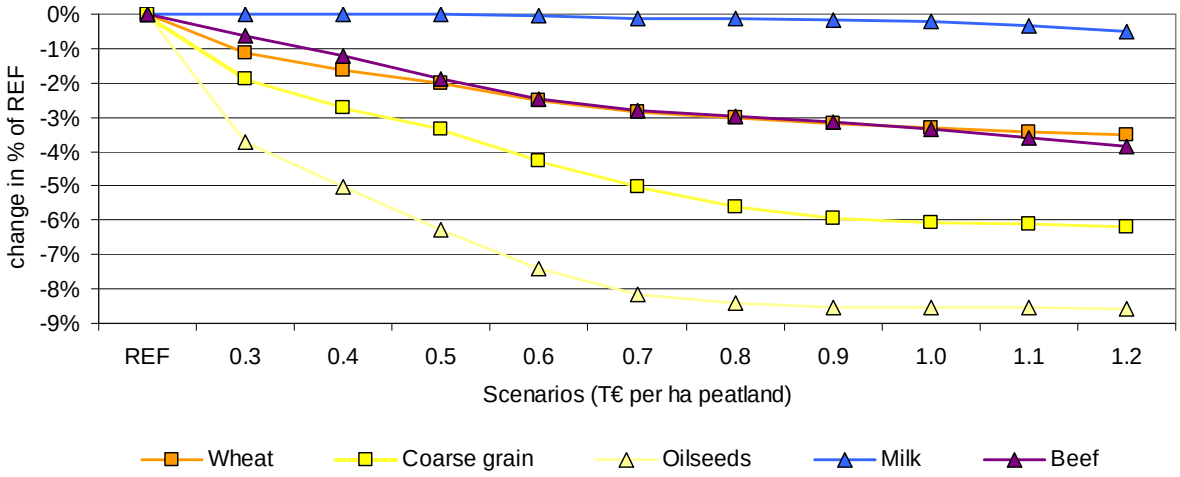

Figure 16: Impacts of an incremental tax on peatland on agricultural outputs
Source: Own calculation based on RAUMIS.

Discussion and Outlook:

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 small as only 7,000 agricultural working units (1,5 % of the agricultural work force) are laid off.

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. 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, higher or lower remains open. Consequently, the impact of this bias on the cost estimate is unknown.

The mitigation of results from the utilization of peatlands does not only require an abandonment of the normal agriculture use but in addition a rewetting of the area. However, the rewetting can only start after the utilization on the last plot in a hydrologically contiguous area has stopped. This implies that intermediate tax rates overestimate the area that could be rewetted. This problem is especially pronounced if farms / plots with a different profitability are located next to each other.

In contrast to the simulation results the empirical standard gross margins provide an upper bound for the mitigation costs. Delimiting the mitigations costs on the standard gross margin 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}.

Neither the simulation nor the empirical results include some additional costs as the engineering costs for rewetting the peatlands or transaction costs.

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.

Literature

(BGR) Bundesanstalt für Geowissenschaften und Rohstoffe (2010): BUEK 1000 (Bodenuebersichtskarte von Deutschland 1:1 000 000). Hannover.

BKG (Bundesamt für Kartographie und Geodäsie) (2008): Basis-DLM (Digitales Basis-Landschaftsmodell) 1:25 000. Frankfurt / Main.

FAOSTAT (2010): Global agricultural area in 2007. URL: http://faostat.fao.org/site/377/DesktopDefault.aspx?PageID=377#ancor. Lastly updated: 30.04.2009.

FDZ (Forschungsdatenzentrum der Statistischen Ämter des Bundes und der Länder) (2010): AFiD-Panel: ASE (Agrarstrukturerhebung) (Farm structure survey): 1999, 2003, 2007.

Haenel H. D. (ed.) (2010): Calculation of Emissions from German Agriculture – National Emission Inventory Report (NIR) 2010 for 2008. Lanbauforschung Völkenrode. Special Issue 334. p. 430.

Hartmann M., Hediger W., Lehmann B., Peter S. (2005): The contribution of agriculture to Swiss climate policy: results of an economic analysis. Agrarwirtschaft und Agrarsoziologie (1): 41-56.

Joosten H. (2009): The Global Peatland CO2 Picture – Peatland status and drainage related emissions in all countries of the world. URL: http://www.wetlands.org/LinkClick.aspx?fileticket=UyS7LBOOJa4%3d&tabid=56. Lastly modified: 27.11.2009. p. 35.

Kantelhardt J, Hoffmann H. (2001): Economic evaluation of ecological management instructions for agriculture - the example of the Donauried. Berichte über Landwirtschaft: (79): 415-436.

Offermann F, Gömann H, Kleinhanß W, Kreins P, Ledebur O von, Osterburg B, Pelikan J, Salamon P, Sanders J (2010): vTI-Baseline 2009 - 2019: Agrarökonomische Projektionen für Deutschland. Braunschweig : vTI, 88 p, Landbauforsch. SH 333.

Oleszczuk R., Regina K., Szajdak L., Höper H., Maryganova V. (2008): Impacts of agricultural utilization of peat soils on the greenhouse gas balance. In Maria Strack (ed.): Peatlands and Climate Change. URL: http://library.wur.nl/ebooks/1882312.pdf. Lastly modified: 26.05.2008: 70-97.

Roedenbeck I. (2004): Bewertungskonzepte für eine nachhaltige und umweltverträgliche Landwirtschaft. Fünft Verfahren im Vergleich. BIOGUM-Forschungsbericht, FG Landwirtschaft Nr. 8. Universität Hamburg.

Schaller L., Kantelhardt, J. (2009): Prospects for climate friendly peatland management – Results of a socioeconomic case study in Germany. Paper presented at the 83rd Annual Conference of the Agricultural Economics Society, March 30 - April 1, 2009, Dublin. URL: http://purl.umn.edu/51074. Lastly modified: 16.03.2009. p. 23.

Schmidt C., Rounsevell M. La Jeunesse I. (2006) : the limitations of spatial land use data in environmental analysis. Environmental Science and Policy (9): 174-188.

UBA (2009): Nationaler Inventarbericht zum Deutschen Treibhausgasinventar 1990 – 2007. URL: http://www.umweltdaten.de/publikationen/fpdf-l/3727.pdf. Lastly modified: 22.04.2009.

USEPA (2006): Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990-2020. URL: http://www.epa.gov/climatechange/economics/downloads/GlobalAnthroEmissionsReport.pdf. Lastly modified: 09.08.2006. p. 274.

Weingarten P. (1995): The Regionalized Agricultural and Environmental Information-System for Germany (RAUMIS). Berichte über Landwirtschaft (73):, 272-302.