GHG EMISSIONS FROM AGRICULTURALLY MANAGED PEATLANDS – EMISSION MITIGATION VERSUS MICROECONOMIC INCOME EFFECTS

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Abstract

Increasing Greenhouse-gas emissions and related climate effects require mitigation strategies. Also emissions caused by agriculture are brought into the focus of political debate. Particularly peatland cultivation, inducing significant CO_2 emissions is being discussed more and more. Our study aims to answer the question of whether changes of peatland management can serve as cost-efficient emission- mitigation strategy. We have built an economic model in which farm-individual and plot-specific CO2-abatement costs of selected landuse strategies are calculated by contrasting effects on the agricultural income with the related reduction in greenhouse-gas emissions. With respect to microeconomic data we use a dataset collected in six German regions while data on emission-factors originates from own measurements. Results show that CO_2-abatement costs vary due to different levels of land-use reorganisation. Reasonable emission reductions are mainly achieved when agricultural intensity is clearly decreased. Agricultural income forgone varies significantly due to production conditions and mitigation strategies. However, even when economic costs are high they may be balanced by high emission reductions and may not result in high abatement costs. Nevertheless, CO_2-reductions benefits appear to be social and costs private. Agro-environmental programmes must be implemented to compensate resulting income losses.

Keywords: agricultural GHG emissions, agricultural CO_2 mitigation cost, climate-friendly peatland management

1. Introduction

The increase of carbon dioxide emissions and the resulting effects on the climate are at the heart of political discussion. Agricultural production, as a major source of greenhouse gases (GHG), is increasingly put into focus and the question is raised how agriculture can contribute to emission-mitigation. The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) specifies that the most prominent options for GHG mitigation in agriculture are improved crop- and grazing-land management (e.g. nutrient use, tillage, etc.), the restoration of degraded lands and the restoration of peatlands drained for crop production. (Smith et al., 2007) Our study focuses on the last of these alternatives. Peatlands have stored carbon over centuries, as under flooded conditions soil-decomposition is suppressed by the absence of oxygen. Cultivation and draining of peatlands initiates the process of decomposition; large fluxes of potential GHGs going back into the atmosphere are the consequence (Smith et al, 2007). In Germany emissions from drained peatlands account for 5,1% of overall German GHG-emission and are the largest single emission source outside the energy sector (NIR, 2010). As regards agriculture, cultivated peatlands contribute with 30% to the overall agricultural emissions while covering only 8% of the Utilized Agricultural Area (UAA) (cf. Byrne et al. 2004; Hirschfeld et al., 2008). Consequently, by focusing only on peatlands, agriculture could reduce its emissions significantly while production on only few UAA was affected.

In our study we model GHG-fluxes of representative land-use strategies and derive climate friendly management recommendations. To analyse whether our recommendations are cost-efficient, we model farm- and plot-specific income effects resulting from the implementation of the recommended strategies and contrast them with the related reductions in greenhouse-gas emissions. We conduct our study in five German peatland regions, described in Chapter 2. Chapter 3 introduces our database and method while the results of our study are presented in Chapter 4. Here we show the economic consequences and cost efficiency of different measures considering the impact of regional conditions. When discussing our results in Chapter 5 we widen our perspective and compare the performance of our study objects with results from non-agricultural fields. A conclusion is drawn in Chapter 6.

2. Regions of study

Our study regions represent typical natural and agro-economic conditions in the north-west, east and south of Germany. R1 is a bog covering about 4,000 ha; peatland is exclusively used as intensive grassland for forage production for dairy cattle husbandry. R2 consists of bog and fen sites covering 6.000 ha. Agricultural land is used by intensive pig-fattening farms for the production of mainly maize for forage and biogas. R3 stands for an extensive fen region covering ca. 30.000 ha. R4 is a fen site fed by a continuous groundwater stream with an extension of about 600 ha. In R3 and R4 agricultural land-use ranges from low to high intensive grassland for suckler cow and dairy cattle husbandry; furthermore peatland is used as arable land for cash crop, energy-crop and forage production. R5 is representative for bog and fen-sites at the foothills of the Bavarian Alps, peatland is exclusively used as low- to medium-intensive grassland for forage-production for dairy cattle husbandry.

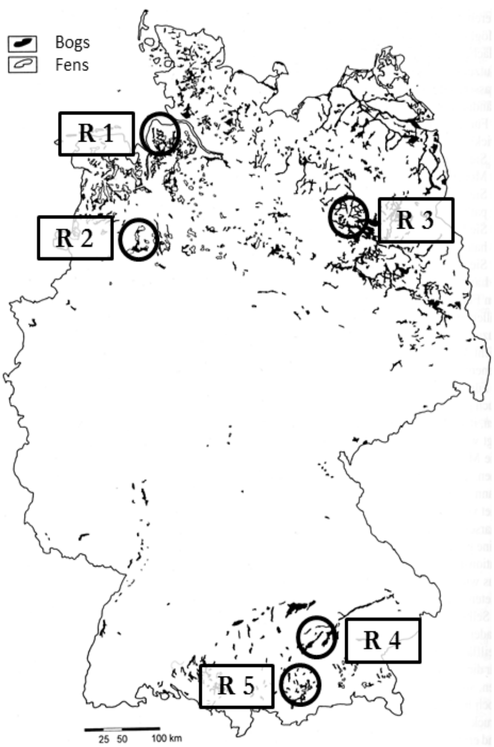

Figure 1. Location of the study regions in Germany (modified from Schopp-Guth 1999)

3. Method and database

Data to identify potential climate friendly landuse-strategies originates from own measurements of GHG-fluxes of common land-use strategies. Measurements are conducted in all regions using portable and automatic chamber systems described in Drösler (2005). The measurements consider fluxes of carbon dioxide- (CO_2), methane- (CH_4) and nitrous oxide- (N_2O) and the import and export of C. On basis of the measurements, we model Global Warming Potentials (GWP) (measured over the timescale of 100 years) for different land-use strategies (Droesler, 2005; Förster, in prep.). Consequently, the mitigation potentials of management changes are determined by comparing the specific GWPs of the single land-use types. Analysing the extent of mitigation achievable, recommendations of relevant climate-effective land-use conversions are developed.

The economic database to calculate farmers' income forgone we collect in comprehensive regional farm surveys, described by Schaller & Kantelhardt (2009). To calculate microeconomic costs we analyse annual agricultural income forgone resulting from a change of value added on the peatland sites. We carry out farm-individual and plot-specific calculations of "gross margin" for market-crop production and "processing value" for forage production, described in Schaller et al. (2012). To identify cost-efficient strategies of climate-friendly peatland management, costs of GWP reduction for the chosen land-use strategies are calculated. For this, we contrast income forgone with the related reduction in greenhouse-gas emissions. (Schaller et al., 2012)

4. Results

Our results show that achievable GHG-mitigations directly depend on the height of the groundwater tables: Peat profiles with high water tables are characterised by mainly anaerobic conditions, while aerobic conditions are limited to a shallow upper layer. With low water tables the aerobic zone in the profile extends, resulting in rising soil respiration and mineralisation. The degradation of the carbon and nitrogen stocks in the peat transforms the peatland from a C and N sink to a potentially very strong C and N source in terms of CO_2 and N_2O emissions.

Consequently, agricultural land-use types necessitating the lowest water tables, namely arable land and high-intensive grassland, are accompanied by the highest emissions. Significantly lower emissions occur on grassland sites with high water tables, managed with low agricultural intensity (1 to 2 cuts) or kept under maintenance. Quasi zero emissions occur on sites which have been restored by withdrawing any land use and enhancing the water table to an annual average of about 10 cm below ground surface. Flooding of peatlands in contrast is a "suboptimal" restoration

Table 1. Average GWP for different peatland-and landuse- types (Minimum to Maximum) [Number of study regions]

	Fen	Bog	Watertable
	$tCO_2 - Aq/ha \cdot a$		cm
Arable land	33,8 (14,2 to 50,0) [4]	No data	-70 (-29 to -102)
Grasland Intensity middle/high	30,9 (21,3 to 40,7) [5]	28,3 [1]	-49 (-39 to -98)
Grassland Intensity low, dry	22,5 (19,5 to 30,9) [4]	20,1 [1]	-28 (-14 to -39)
Grassland Intensity low, wet	10,3 (5,8 to 16,3) [4]	2,2 (0 to 4,4) [2]	-11 (6 to -25)
Close to nature/restored	3,3 (-4,3 to 11,9) [5]	0,1 (-1,8 to 2,9) [3]	-10 (-7 to -14)
Flodded conditions	28,3 (10,6 to 71,7) [4]	8,3 (6,2 to 10,4) [2]	14 (-8 to 36)

measure, as high emissions of CH_4 outnumber savings on C and N and lead to high GWPs (see Table 1). The results suggest that only a significant enhancement of the water tables and – as a result – a drastic reduction of agricultural intensity lead to significant emission reductions. High mitigation potentials are seen in a change of arable land and intensive grassland into “wet” grassland kept under maintenance measures or the change from agricultural land use to complete and adapted restoration – resulting in complete abandonment of agriculture (Figure 2).

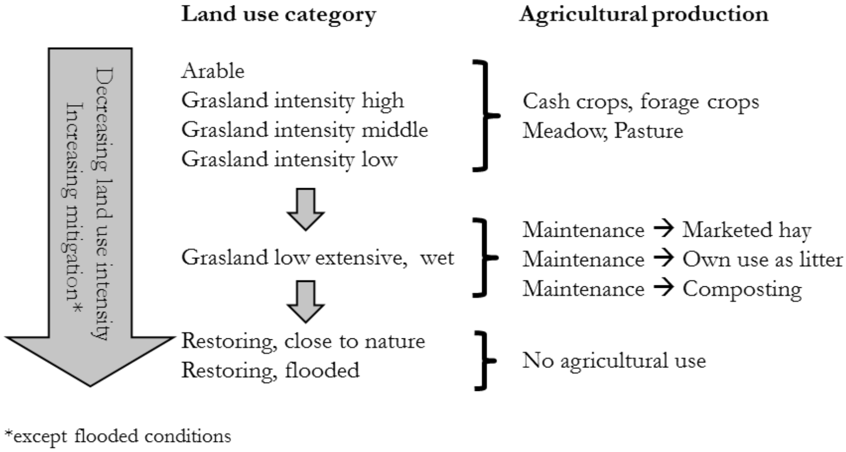

Figure 2. Recommended land-use changes

How strong such mitigation steps impact on the micro-economic situation of affected farms depends on the farms’ current organisation and management strategies and the amount of area affected. In our study regions, substantial differences in farm organisation and type of farming are observable. While R1 and R5 are pronounced dairy cattle regions, the great diversity of farming types managing peatland area becomes obvious when looking at R2, R3 and R4. Also the management of peatland varies clearly: while in R1 and R5 peatland is basically used as grassland, in R2, R3 and R4 a high percentage of peatland area is used as arable land for forage and cash crop production. As regards grassland use, R1 and R5 show the highest intensities to produce the quantity and high quality of forage needed in dairy cattle production (see Table 2).

Along with the differences in farm organisation and management strategy, value added on peatland sites varies significantly (see Table 3). As regards values generated via animal husbandry, the primary causes of variety are the different types and intensity levels of animal husbandry. Processing values on intensive area in R1 and R5 is exclusively derived from gross margins of dairy-cattle husbandry: high levels of milk performance creating high gross margins per dairy cattle, combined with high level of land-use intensity, allowing for feeding more than one dairy cattle per hectare, lead to high value added on forage sites; outstanding performer is arable land used for silage maize production for dairy cattle husbandry. In regions like R3, where processing values are driven by animal husbandry creating lower gross margin (e.g.: cattle fattening, suckler cows, dairy husbandry with lower milk performance) the value of forage area consequently is lower.

Table 2. Characteristic of agriculture in the study regions

Farm organisation, type of farming (%)	R1	R2	R3	R4	R5
Full time farms	100	100	95	95	86
Organic farm:	-	-	10	26	19
Specialist field crops	-	-	15	26	-
Specialist granivores	-	70	-	5	-
Specialist dairying	100	20	30	32	86
Cattle fattening	-	5	-	5	-
Suckler cows	-	-	15	-	10
Mixed livestock/field crops	-	5	35	21	-
Non classifiable	-	-	5	11	5
Peatland use (% of peatland total)	R1	R2	R3	R4	R5
Arable forage	1,5	28	19,5	17	1,5
Arable cash crop	-	2	20	20	-
Grassland intensity high	73	11	5,5	20	41
Grassland intensity moderate	20	8	30	21	9
Grassland intensity low	5,5	51	25	20	2
Litter meadow	-	-	-	2	46,5
Average farms' peatland area (%)[1]	89	53	63	36	27

[1]Share of peatland in the interviewed farms' total UAA

Table 3. Average value added of forage-and cash-crop land-use types (€/ha*a)

Landuse-types	R1	R2	R3	R4	R5
Arable exclusively forage[2]	3.877	1.414	2.039	2.868	3.366
Arable exclusively cash crops[3]	-	840	346	464	-
Arable forage/cash crops[4]	-	946	750	1.275	-
Grassland intensity high	1.894	2.773	1.631	1.526	1.837
Grassland intensity moderate	1.706	2.201	1.207	851	930
Grassland intensity low: (agricultural utilisation)	867	612	681	479	763
Grassland intensity low: (maintenance hay)	388	388	336	390	-
Grassland intensity low: (maintenance litter)	-	-	-	-	213
Grassland intensity low: (maintenance compost)	158	158	106	161	161

[1]weighted by amount of area, area payment included (federal target values 2013), cash-crops include winter wheat, winter barley, summer barley, winter rye, corn and oat, considered are machine costs, costs of harvest, costs/profits of product utilisation (eg, composting or marketing of litter or hay);
[2]PC values of arable land of farms carrying out exclusively forage production on arable land (silage, maize)
[3]GM values on arable land of farms carrying out exclusively cash crop production on arable land
[4]PC/GM values on arable land of farms carrying out cash crop and forage production on arable land

Table 4 presents the study's results on the question if our recommendations on climate friendly management reorganisation are cost-efficient and can compete with alternative agricultural mitigation strategies. The table shows the outcome of contrasting agricultural income forgone with emission savings for the most promising mitigation steps as well as the farm-individual span of costs per ton CO_2-equiv. saving.

Across all regions average income forgone per t CO_2 equivalent of landuse-changes targeting "maintenance" ranges between €3 and €158. At this, costs appear not to be excessively high. Even for the reorganization of the most intensive and "highest-prized" landuse-types, such as high intensive grassland and arable land for forage production costs lie within a range between €47 and €158. The reason for the considerably low costs for high-prized landuse-types are the high mitigation potentials accompanying the mitigation steps, which start at a minimum of 12t saving of CO_2-C eq.$ha^{-1}a^{-1}$ for the reorganization of intensive grassland into maintenance in R2 and finish with a maximum of 41t saving for the reorganization of arable land into maintenance in R3. However, the displayed costs/t CO_2 eq. for maintenance measures reflect the "optimal" assumption, that farms are able to either market the harvest product as hay or use it as litter in their own stables. If the farms have to compost the sites' products, income losses per t CO_2-eq. can increase up to 40%.

Income forgone per t CO2-eqivalent of landuse-changes targeting close-to-nature "restoration" tends to be higher than for maintenance and ranges between €8 and €481, even if the mitigation potentials of complete restoration are significantly higher than for maintenance: for restoration of the intensive and dry landuse-types, mitigation potentials vary between 18t (reorganization of intensive grassland into restoration in Region R2) and 44t saving of CO2-C equiv. ha-1a-1 (reorganization of arable land into restoration in Region R3). The higher costs result from the

Table 4. Income forgone of recommended management changes per ton saving of CO2-C equiv. [regional average; (regional, farm-individual minimum to regional, farmindividual maximum)

		R1	R2	R3	R4	R5
Initial use*	Target use	Eur/t CO_2eqivalent				
Arable CC	Maintenance	-	31 (-11 to 38)	0 (-4 to 5)	3 (-5 to 15)	-
Arable FG		124 (95 to 138)	69 (30 to 153)	42 (46 to 35)	102 (51 to 107)	95 (86 to 101)
Arable FG/CC		-	38 (9 to 77)	10 (0 to 29)	36 (30 to 45)	-
GL high int.		53 (30 to 89)	158 (61 to 209)	47 (31 to 92)	67 (39 to 146)	51 (34 to 72)
GL med.. int.		47 (24 to 55)	108 (31 to 161)	32 (4 to 67)	27 (5 to 49)	22 (0 to 42)
GL low int.		24 (13 to 48)	23 (-22 to 114)	15 (-20 to 52)	19 (-17 to 49)	33 (10 to 40)
Arable CC	Restoration	-	40 (15 to 42)	8 (5 to 10)	16 (12 to 24)	-
Arable FG		134 (109 to 145)	68 (4 to 44)	46 (41 to 49)	99 (59 to 100)	98 (89 to 103)
Arable FG/CC		-	45 (2 to 29)	17 (10 to 33)	44 (41 to 49)	-
GL high int.		65 (45 to 97)	126 (5 to 67)	53 (41 to 90)	71 (52 to 128)	55 (40 to 75)
GL med.. Int.		59 (40 to 64)	93 (4 to 47)	39 (17 to 68)	39 (26 to 53)	28 (7 to 47)
GL low int.		42 (35 to 61)	38 (2 to 16)	26 (-2 to 55)	52 (42 to 58)	43 (22 to 49)
Maintenance		481 (383 to 578)	65 (1 to 51)	101 (77 to 124)	83 (66 to 100)	183 (174 to 193)

*Arable CC: Arable land of farms carrying out exclusively cash crop production on arable land; Arable FG: Arable land of farms carrying out exclusively forage production on arable land; Arable FG/CC: Arable land of farms carrying out cash crop and forage production on arable land complete abandonment of agricultural use and the involved loss of CAP's 1st Pillar area payment on the peatland sites. Nevertheless, even for restoration measures, the costs per t CO2 appear comparatively low. This is yet only the case, if restoration can be carried out in a technically optimized way, leading to close-to-nature conditions with watertables averaging at about -10cm below surface. As soon as restoration leads to flooded conditions, mitigation potentials significantly decrease while costs per t CO2-eqivalent increase at about 90%.

To summarise briefly the results of our study, one can say that climate-friendly peatland management, under the assumptions of the usability of the harvest product of maintenance area and an optimal technical implementation of water table enhancement on restoration area, leads to microeconomic (farm-level) costs per t CO2 savings that appear comparable low. As soon as losses of agricultural income can be balanced by high total emission savings, on micro-economic level changes of peatland management can be a cost-efficient strategy to mitigate GHG emissions.

5. Discussion

Our results show that income losses per ton CO2 saving can identify cost-efficient measures of climate-friendly peatland management. However, there are different points to be considered when interpreting our results. By choosing gross margin and processing value to derive agricultural income forgone, we made the clear decision to look at short-term costs. Insofar, the results show site-specific costs which would occur in the concrete moment of an implementation of management changes – for farms which are in a status-quo situation of farm organisation, type of farming and land-use strategy. In contrast to a long-term consideration, possible adaptation strategies (eg. changes in farm organisation or shifts of production to alternative areas) are unconsidered. Furthermore, the use of gross margin and processing value represents "the ceiling" of valuing agricultural area. Agricultural area could also be associated with lower values such as the market price of forage (if it exists) or the regional rent paid for adequate area. However, it should be noted that in the case of extensive management reorganisation forage prices and land rents cannot be considered statically low values. If large-scale management changes should be implemented, the scarcity of rentable land and the increasing demand on the forage market will most likely increase also those values considerably.

With respect to the cost and benefit positions we investigate, it is obvious that they do not cover the variety of positions associated with land-use changes targeting climate protection. Up to now we only consider farmers' income forgone and benefits from emission mitigation. Additional costs and benefits, such as costs of technical implementation and water supply, increases or decreases in biodiversity, macro-economic follow-up costs like damage to buildings or infrastructure or effects on regional development or tourism, are not considered yet.

Another area to draw attention to, are the system boundaries within which our study is conducted. At the moment we calculate farm-individual costs which specifically occur on agricultural sites within a peatland area. By doing so, the effects of management changes which emerge beyond these system boundaries are not considered. Production limitations on peatland sites can cause production-"exports" or an intensification of production on alternative area. Naturally such adaptation measures can also show negative climate effects (eg. intensified fertilisation, enhanced transport, land-use changes for the creation of alternative UAA, etc.). For the derivation of macroeconomic and even global cost-benefit relations of climate-friendly peatland management, profound scenarios involving effects within much broader system-boundaries must be analysed.

Finally, looking at our results, it should be noted that the time courses of emission-reduction measurements are still short; therefore also the derived emission factors have to be treated with caution.

Nevertheless, our results show that regional basic conditions influence the costs of CO_2 mitigation. On the one hand agricultural value added, on the other hand natural mitigation potentials drive the cost-efficiency of management strategies. Our results show that even "expensive" land-use changes can result in comparatively low costs per ton CO_2 equivalent if costs are balanced with high mitigation potentials. Comparing the socio-economic status-quo situation in the single regions, we can estimate where climate friendly peatland management appears to be more cost-efficient or expensive. Particularly in regions where peatland is managed with high intensity, involving high-grade and capital-intensive animal husbandry, management changes are likely to turn out costly. Furthermore, if the share of peatland area is high, farmers' flexibility to adapt is limited and management changes will presumably be refused. In contrast, an implementation of management changes in regions characterised by low-intensive agriculture appears to be more promising. Especially if accompanied by low shares of peatland area and high mitigation potentials, within such regions CO_2 mitigation via adapted peatland management seems reasonable. Generally, (again being aware of the limited system boundaries) compared to alternative techniques, the abatement costs we derived still display an acceptable range. Abatement costs of common agricultural strategies, e.g. biodiesel, plant oils, cellulose-bioethanol, biogas, etc., vary from 20 to 480 €/t$CO_{2\text{ equiv. (WBA, 2007).}}$

Despite this potential competitiveness, as a final note it should be pointed out that in the case of CO_2 reductions, benefits appear to be social whereas costs are private. Farmers have to bear the costs of adaptation and do not directly profit from climate-friendly peatland management. Consequently, in order to successfully implement measures to reduce GHG emissions from peatlands, it is necessary to implement adequate agro-environmental programmes to compensate resulting income losses.

6. Summary and conclusions

Natural peatlands are the only ecosystems which continuously and durably store carbon. Agricultural land use changes the peatlands' function as carbon sinks and leads to high emissions greenhouse gases. In order to lower these greenhouse-gas emissions, a reduction in land-use intensity is necessary. Our study analyses whether this option of GHG mitigation is a cost-efficient measure to be recommended for implementation. We investigate agricultural peatland management in five German peatland areas. To determine cost-efficiency, we carry out farm-individual and plot-specific calculations of agricultural income forgone resulting from promising climate friendly landuse changes. By contrasting income forgone with CO_2 savings, we derive income losses per ton CO_2 equivalent. Our results show that income forgone per t CO_2 equivalent varies due to the regional variability of agricultural structures and natural mitigation potentials. Compared to alternative common abatement strategies, the costs we derive (ranging mainly between 0 and 480 €/t CO_2 equiv.) appear competitive. However, our results are created within narrow system boundaries which do not allow for consideration of further relevant macro-economic cost and benefit positions taken to have a significant influence on abatement costs. In order to fill these gaps, future research is planned. Our study shows that the re-organisation of peatland use could provide fundamental benefits for society. However, in the case of CO_2 reductions, benefits appear to be social whereas costs are private. Against this background, the question arises how either social benefits can be monetarized in order to finance climate-friendly peatland cultivation strategies, or in which way common instruments of agricultural politic can be used to subsidise the farmers' losses.

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