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Perspectives on agriculturally used drained peat soils: Comparison of the socioeconomic and ecological business environments of six European regions

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ABSTRACT

In Northern, Eastern and Central European countries, peat soils drained for agriculture are a considerable source of greenhouse gas emissions. Since emissions from this source have high mitigation potential, they will likely be a focus of the European Union's future climate goals.

We describe and compare the similarities and differences in the socioeconomic and ecological business environment that policy makers, planners and farmers are confronted with when developing tailored proposals for low emission land use alternatives on peat land. The analysis is based on interviews with 33 typical farmers cultivating organic soils and on expert group discussions held in six different Northern, Eastern and Central European regions.

Based on the Social-Ecological System Framework we identify and cluster important variables. Our results show that mainly hard economic variables determine preferred land use alternatives: the productivity of resource systems, the economic value of land and market incentives. Other variables, such as the heterogeneity of users and conflicts among them, are more important with respect to the implementation of alternatives. We point out possibilities to transfer solutions between regions and discuss an institutional framework for European Union, national and regional levels for facilitating implementation potential.

1. Introduction

Peatlands constitute the most efficient terrestrial ecosystem for carbon storage. Globally, they contain almost 30% of all land-stored carbon while only covering 3% of land area (Joosten et al., 2012). Peat stores as much carbon as all other terrestrial biomass in the world and twice as much as all forest biomass. Due to the wet conditions found in peatlands (precipitation and high ground or surface water tables), plant decomposition is slowed so that plant growth exceeds decay. In northern countries, low temperatures are a second cause of slow decomposition processes. As a consequence, peat accumulates and stores organic matter, meaning carbon (Parish et al., 2008).

When peatlands are drained for agriculture, for example, they change from a carbon sink to a greenhouse gas (GHG) source. The organic matter that has accumulated over centuries is decomposed, which leads to increased CO_2 emissions (Frolking et al., 2011). CH_4 emissions are usually reduced, but the net GHG effect is positive (Parish et al., 2008). In the European Union (EU), peatlands cover 7.7% of the land surface. They are mainly concentrated in Northern, Eastern and Central Europe where they cover up to 25% of the land surface (Tanneberger et al., 2017). In some of the EU member countries, GHG emissions from drained peatlands cause even more than one fifth of all emissions

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(UNFCCC, 2016)[1] .

Other problems accompanying drainage in peat soils include subsidence (Zeitz and Velty, 2002), decreased infiltration and ponding (Kechavarzi et al., 2010) and biodiversity loss (Wichtmann et al., 2016; Dierssen and Dierssen, 2001).

Despite the high mitigation potential in some EU member states, emissions from peat soils are currently not included in the EU Climate Framework's commitments (EC, 2018a). However, emissions from peat soils will be considered to some degree after 2020 (EC, 2018b, 2018c). As peat soils have high mitigation potential and low mitigation costs overall in comparison to other agricultural emission sources (Rebhann et al., 2016; Krimly et al., 2016; Schaller, 2015; Röder et al., 2014), they will likely be a focus of future political climate mitigation activities.

The greenhouse gas potential of peat soils depends on various factors, including climate. Under comparable climatic conditions, however, it is mainly determined by the water table (Drösler et al., 2013). The water table in turn determines the type of possible land uses. The higher the water table, the fewer types of use are feasible. Table 1 shows them in an overview. Rewetting implies a high water table. Blocking drainage ditches or building dams raises ground water table to the vicinity of soil surface, which brings back near-natural hydrological conditions. As a result, conventional agricultural use is no longer possible. Rewetting is considered an effective tool to reduce greenhouse gas emissions to the atmosphere. Differences between drained and rewetted organic soils are fundamental, e.g. rewetting diminished the global warming potential of temperate deeply drained nutrient rich grassland from 30 to 13 t CO_2 equivalents per ha and year (Wilson et al., 2016). Paludiculture is productive use of rewetted peatland where natural or cultivated biomass is harvested for biorefining, biomaterials or bioenergy (Wichtmann et al., 2016). Paludiculture has been approved in recent reports published by the Food and Agriculture Organization of the United Nations (Biancalani and Avagyan, 2014) and the Intergovernmental Panel on Climate Change (Hiraishi et al., 2014) as a GHG mitigation option and peat conserving action with emission factors similar to those of traditional wetland restoration (Wilson et al., 2016). Wet extensive pasture is shallowly drained and can be used for adapted breeds, such as water buffaloes. Dry extensive pasture is drained moderately so that it can be used extensively, e. g. for suckler cow husbandry (Drösler et al., 2013).

The land use alternatives mentioned above are all associated with a water table increase and therefore with a restriction of conventional use. Therefore in 2003, in the Netherlands an experiment was started with submerged drains about 20 cm below ditchwater table to infiltrate ditchwater into peat meadow parcels. Distances between the submerged drains are four to maximum six meters, so the infiltration into the parcel is improved considerably. Measurements show that subsidence rates can be halved in this way (van den Akker and Hendriks, 2017) whereby conventional intensive land use is possible. Because of the strong relation between subsidence and CO_2 emissions (Kasimir-Klemedtsson et al., 1997; Grønlund et al., 2008; Leifeld et al., 2011; Couwenberg and Hooijer, 2013), emission reduction of up to 50% can be derived (van den Akker et al., 2012).

The realization of mitigation measures for peatland often implies land use changes with important socioeconomic consequences (Schaller et al., 2011). At the same time, realization depends on the presence of specific regional socioeconomic and ecological conditions and on the consent of different actors (Rawlins and Morris, 2010). Nonetheless, few studies have researched ecological and socioeconomic conditions of peatland areas.

Rawlins and Morris (2010) conducted a stakeholder mapping analysis of two peatland regions in England via group workshops and face-

[1] Share of GHG from crop and grassland managed organic soils of total net GHG emissions. Net emissions include the sources and sinks of each country.

Table 1
Management options for peatland GHG mitigation (van den Akker et al., 2012; Drösler et al., 2013; Wilson et al., 2016).

Land use alternative	Water level below surface (in cm)	Tons of CO_2 equivalents per ha and year	Investment and operational costs	Commercialization
Rewetting (fallow area, wet forests or abandonment with maintenance cuts)	0 to −20	4 to 13	Low-Medium	(Nearly) no commercial value creation
Production of biomass for energy with wet adapted plants (paludiculture)	≤ 0	13	Medium-High	Bioenergy, biomaterial, biorefining
Wet extensive pasture (e.g., with water buffalo)	6 to −25	6 to 16	Low-Medium	Low productivity areas, products for a niche market
Dry extensive pasture	−14 to −40	20 to 31	Low	Low productivity areas, e. g. for suckler cow husbandry
Submerged drainage/subirrigation	−40 to −60	15 to 19	High	High productivity areas, sale of agricultural commodities

Emission data refer only to the temperate zone. Emissions for the boreal zone may be markedly lower, but are not available for all land use alternatives. Emission data for submerge drainage/subirrigation are based on derivation from subsidence reduction.

to-face interviews. They identify the main conflicts occurring between land owners representing the production function (especially farmers) and other stakeholders representing recreational and habitat functions such as the protection of biodiversity and water quality. The authors call for a multiobjective and integrative approach to solving such conflicts. At the same time, policies need to be tailored to each region so that they suit local conditions.

Schaller et al. (2011) investigate the implementation potential of mitigation measures on peatlands for six different regions in Germany and identify three key variables. A high level of cooperation between local stakeholders and the cost-effective technical feasibility of mitigation projects are advantageous for realization whereas the high agricultural profitability of current cultivation measures is disadvantageous.

Whereas Schaller et al. identify local factors that are crucial for mitigation in certain regions, Regina et al. (2016) determine general steps to implementing mitigation projects from four global case studies of Denmark, Finland, Norway and Indonesia. Furthermore, they identify a lack of policy coherence (e.g., climate and agricultural policies) as the main implementation obstacle.

In contrast to the national case study analyses of Rawlins and Morris and Schaller et al., we compare the socioeconomic contexts of six regions (Fig. 1) across Northern, Eastern and Central European countries emitting together 68% of the EU's emissions from organic soils under cropland or grassland management (UNFCCC, 2016). The study areas are located in the Netherlands, Germany, Denmark, Sweden, Estonia and Finland. In comparison to Regina et al. (2016), we concentrate on local factors but we also take up the role of policy coherence. With our European approach, we take into account that both agricultural and climate policies are predominantly regulated on the EU level. Future EU regulations for peat land use will need to fit the various contexts of different regions across Europe. If rules are not compatible with local conditions, they may not prove sustainable (Ostrom, 2009).

Our research aim is to compare the similarities and differences of various European contexts and to identify patterns across the examined regions. We use the Social-Ecological System Framework (SES) (Ostrom, 2009), which is a well-established tool for researching the management of natural resources (Hinkel et al., 2015). The next chapter describes the material that we used to explore the research regions. Then we describe how we applied Ostrom's framework in the method chapter. In the results section, we present each region and discuss land use alternatives. Thereafter, we discuss overall patterns and suggestions for an institutional framework through which to implement land use alternatives. The final chapter concludes the paper.

2. Material

The business environment of farmers cultivating organic soils is strongly shaped by local factors, and thus we decided to apply an explorative approach to analyze six different local contexts (case studies). For each of the six European countries at hand, national scientists with several years of experience in the field of alternative peatland use selected one study region that represents a typical context of peatland cultivation in the respective country. We furthermore made sure that the six regions represent different levels of cultivation from very intensive use in Krimpenerwaard (NL) to extensive use in Tartu county (EE). Table 2 presents most important characteristics of the research regions in an overview. Fig. 1 shows the geographical location of the regions.

In a first step, we interviewed typical farmers cultivating organic soils in each region (33 farmers overall). In the interviews, that took place from February to July 2016, we used mainly closed-ended questions. Farmers were selected by national scientists having local knowledge together with local experts (e.g. farm advisors) in the regions. As a qualitative study, the interviewees are not a statistically representative sample of the respective population, but they were selected to represent the main types of farms per region cultivating organic soils. As there are no exclusive statistics on farms that cultivate peat soils in the regions, the selection of farms could not be externally validated. The survey had multiple objectives: a) to describe the type of farms (e.g. size, production target), b) to find out the farmers' assessment of the importance of organic soils for their farm, c) to depict the farmers' experience with particular problems related to the management of these soils, and finally d) to elucidate the farmers' sensitivity to future problems in peat soil management and their willingness to implement alternative farming methods. Table 3 briefly portraits the key characteristics of the farm types that we interviewed.

In a second step, we investigated the broader context of each study region. We invited regional experts and stakeholders for a structured group discussion, i. e., the moderator asked the same predetermined interview questions in each round of discussion but he or she also allowed for open discussions guided by the participants. The discussions took place from September to November 2016. They were usually conducted in the same region where the interviews took place. Only in Sweden, for logistical reasons, did we not hold the expert discussion in Gotland but in Uppsala. This discussion related both to Gotland and to other Swedish peatland regions. We decided on a heterogeneous composition of participants with different institutional backgrounds, which allowed for a direct understanding of conflicts and contrasting perspectives (Lamnek, 2010). Between 5 to 18 stakeholders participated in the six workshops. The stakeholders had a background in academia, regional and supra-regional administration, water boards, nature protection, farming and farm advisory. The results of the farmer surveys were presented for discussion at the workshops and judged to be plausible by the various experts.

In our workshops, we first analyzed current conditions and then assessed land use alternatives against the background of local contexts. Land use alternatives can be put into practice in different ways. However, for the sake of simplicity, we presented the assumptions given in Table 1 with regard to water tables, greenhouse gas emissions, costs and commercialization options. We presented two very different paths of alternative peatland use: maintaining intensive use with submerged drainage on the one hand and alternatives with very high water tables on the other (rewetting, paludiculture and wet extensive pasture). Thus we excluded dry extensive pasture in order to clearly distinguish between two paths of alternatives. An intermediate solution could have led to a blurring of the scenarios. Further, Schaller (2015) identified intermediate solutions as those with the highest mitigation costs. This is because low mitigation potentials are combined with high costs of agricultural management changes. After presenting the land use alternatives we asked workshop participants for their preferred alternative and discussed institutional barriers and drivers to implementation.

3. Methods

For the analysis of the workshops and interviews we used the SES framework (Ostrom, 2009). This framework was originally designed to study common-pool resource and collective management problems (Amblard, 2012; Hinkel et al., 2015). Following the typology of goods developed by Ostrom et al. (1994), common-pool resources are distinguished as of low excludability and high subtractability. Low excludability means that it is difficult to exclude persons from using a resource. High subtractability means that there is considerable rivalry in resource use between different users. The classical example is that of a meadow where areas grazed by one user's animals cannot be grazed anymore by other users' animals (Hardin, 1968; Ostrom, 2007). In contrast, a public good is distinguished in terms of low excludability and low subtractability, i. e., low rivalry. Classical examples of public goods provided by agriculture are cultural landscapes and farmland biodiversity exemplified by farmland birds. Nobody can be excluded from enjoying them and one person's enjoyment does not reduce the enjoyment of others (Cooper et al., 2009).

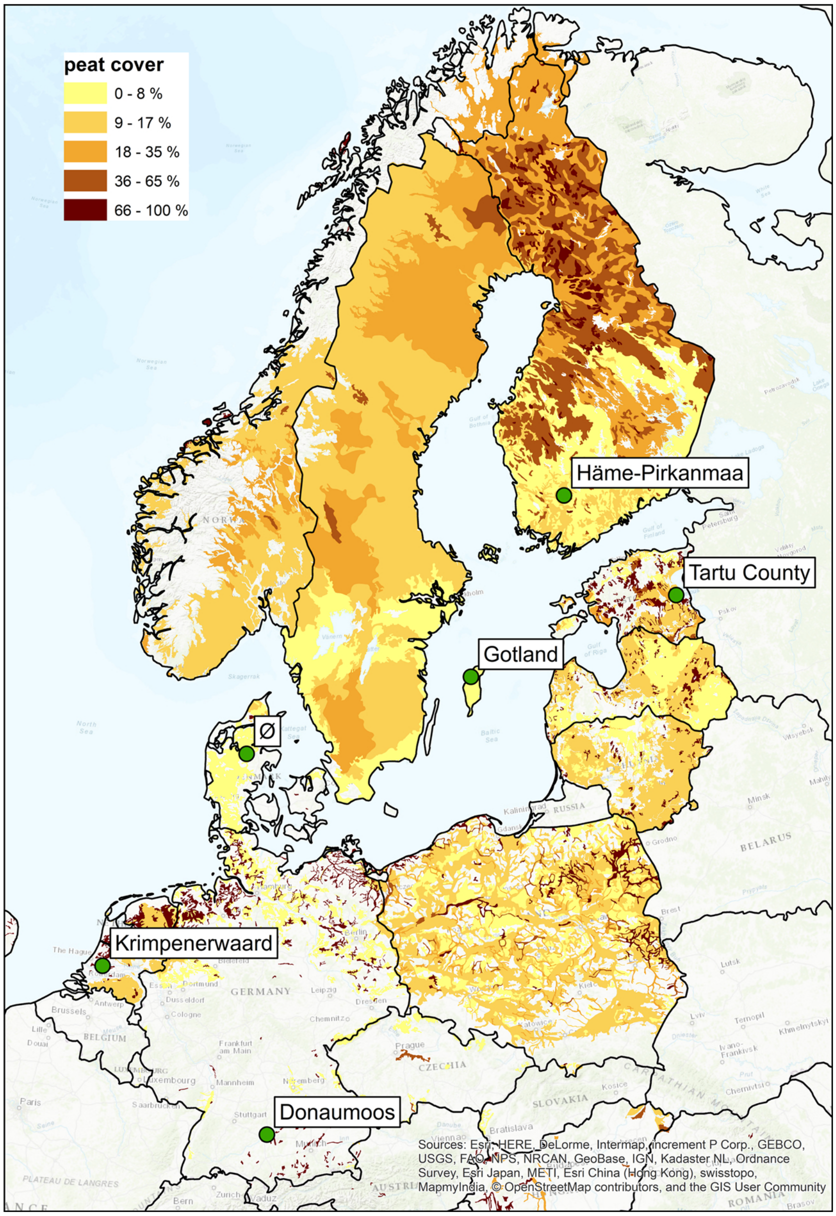

Fig. 1. Research regions (In Denmark, we analyze not one geographic region, but all river stream valleys).

The current drainage system is characterized by low excludability, because different land owners profit from it and single land owners cannot be excluded. With regard to subtractability, we do not observe a classical common-pool resource in the sense of substractable good where one user's drainage capacity would automatically reduce another user's drainage capacity. However, neighboring landowners are not independent of each other. If landowners were free to deepen their drainage channels as they please, they could obstruct each other. For example, shallow drainage channels of one landowner, e. g., for extensive grazing for suckler cows, could hamper a neighbor's drainage capacity in need of deep drainage for intensive dairy farming. Moreover, farmers could start a race to the bottom by deepening their drainage channels, leading to overexploitation in the sense that - with very deep drainage - land subsidence would proceed faster than necessary.

To conclude, current drainage systems are on a fuzzy border between common-pool resources and public goods. In line with Hinkel et al. (2015), they can be defined as a collective good, subsuming common-pool resources and public goods. Following Hinkel et al. (2015), the SES framework is a suitable tool for analyzing collective good problems and especially in connection with collective action. As is shown above, drainage systems require collective action to be managed. They require coordination between landowners to be maintained or to be changed into systems for alternative land uses. The SES framework helps to systematically identify and cluster relevant variables for collective management across the six case studies. Further, with the framework we are able set our cases to the contexts of variables and patterns determined by theories and empirical research elsewhere. The aim is to identify dependencies and patterns across the six case studies and to propose solutions to these cases and beyond.

Table 4 shows the framework with first-level core subsystems (in bold) which contain second-level variables. The table indicates those second-level variables that we selected for our analysis based on the workshops and the interviews with the farmers. In squared brackets we show in which case studies we used them.

In the following we explain why we selected which variable and which indicators we choose to represent them. Resource systems (RS) are land use systems using peat soils, i. e. agriculture. The sector (RS1)

Table 2
Summary of research region characteristics

Characteristic	Krimpener-waard (NL)	Schwäbisches Donaumoos (DE)	Häme-Pirkanmaa (FI)	Gotland (SE)	River stream valleys (DK)	Tartu county (EE)
Peatland size and type	27 km^2 fens	40 km^2 fens	20 km^2 fens and bogs	130 km^2 fens	~ 670 km^2 fens	860 km^2 fens and bogs
Peat soil depth	0.5 to 5 m	1 to 2 m	0.4 to 2.5 m	0.3 to 2 m	0.8 to 3.5 m	0.8 to 2.8 m
Drainage system	Ditches & submerged drains (controlled drainage & infiltration)	Ditches	Ditches & submerged drains (controlled drainage)	Ditches and pipes (subsurface drainage)	Ditches, pipes and pumps	Large ditch structures
Typical farm size	50 ha	50 ha	80 ha	50-100 ha	150 ha	400 ha
Main farm type and production intensity	Intensive dairy farming	Intensive arable & grassland use to extensive pasture	Intensive arable & extensive grassland use	Intensive arable & grassland use to extensive pasture	Intensive arable & extensive grassland use	Intensive arable & extensive grassland use
Population density	340 per km^2	200 per km^2	10-29 per km^2	18.5 per km^2	15 per km^2	~ 30 per km^2
Importance of agricultural production	High	Low	Low	High	Low	Leading activity

describes the farm production type (e. g. dairy farm) and the productivity of the system (RS5) implies the farms' production intensity, e. g. number of grassland cuts. Together they form the economic background of the case study. Human-constructed facilities (RS4) are of particular importance because they describe the current drainage system and thus the technical initial situation for land use alternatives.

Resource units (RU) are the land units (plots) used for farming (arable- or grassland). We analyze their economic value (RU4), because it gives an important indication of possible land use alternatives. A suitable indicator for mid-term valuation of agricultural land is the rent, which is defined as the proportion of the land yield that a tenant has to pay regularly to the landowner. In contrast to the land rent the land purchase price is at least in some regions strongly influenced by non-agricultural utilization option (e.g. for housing). We take the range of average renting prices in 2016 that the farmers communicated in the survey. These values were checked by national experts and if possible additionally cross-checked with regional rent price statistics. Rents refer to both mineral and organic soils as there are no rent price statistics specifically for organic soils.

Further second level variables that we analyzed in the German research region only are number of units (RU5) and their spatial distribution (RU7), as the land use in Schwäbisches Donaumoos is characterized by a very heterogeneous and fragmented plot structure. This structure poses a particular challenge to find common land use strategies between farmers.

Governance systems (GS) include both tangible organizations and intangible rules and structures with regard to the management of peat soils. In most case studies, land users join together in either government (e. g. water boards) (GS1) or non-government (e. g. land user association) (GS2) organizations to maintain the system of larger channels draining several fields of different owners. The organizations provide network structures (GS3) and determine operational rules (GS5) as they decide e. g. on ditch water tables, maintenance operations and investments. However, we considered network structures or operational rules only in those regions where they play a special role. In Häme-Pirkanmaa (FI) we additionally examined the property-rights-system (GS4), because in Finland farmers have more extensive property rights on their peat lands than in the other study regions.

Users (U) of the system are the farmers cultivating peat lands. In Schwäbisches Donaumoos, the high number of farms plays an important role, so that we considered the number of users (U1) there. In all study regions we examined knowledge about the SES (U7) since problem awareness is the basis for willingness to change land use. To this end, we use questions from the survey about current problems with organic soil management (especially yield losses) and about sensitivity to future problems (e. g. increasing waterlogging and decreasing soil fertility). Another important factor for the willingness to change land use is importance of the resource (U8), i. e. the farm's dependency on organic soils, which we investigate on the basis of the farmers' self-assessment.

Subsystems are embedded into social, economic and political settings and related ecosystems (in italic). Here we have examined special economic (quasi market) incentives that only apply in Germany and Denmark.

Subsystems influence each other and produce certain interactions (I) such as harvesting levels (I1) and conflict potential between users (I4). Harvesting levels relate to the homogeneity and heterogeneity of the farms' production intensities (e. g. number of grassland cuts). Conflicts between users play a major role in implementation of land use alternatives. This is because most farmers cannot decide on alternatives independently of their neighbors as water table changes usually affect neighboring fields. Many studies have shown that understanding conflicts can facilitate the implementation of collective action (Nagendra and Ostrom, 2014; Risvoll et al., 2014; Guimarães et al., 2018), for example, to make joint decisions on alternative land use.

Interactions lead to social and ecological outcomes (O). Since

Table 3
Short portraits of the farm types surveyed in the respective study regions.

Region	Interviewed farm types	Mean size in ha	N
Krimpenerwaard (NL)	Intensive dairy farms (120-260 dairy cows), high milk yield per animal, grassland-based	81	4
Donaumoos (D)	Mixed farms (dairy cattle, maize for bioenergy, market fruits)	108	10
Gotland (S)	Arable farms (cereals, potatoes, vegetables), animal farms (dairy and bull fattening)	550	5
Häme-Pirkanmaa (FI)	Arable farms (summer cereals) and mixed farms with extensive dairy cattle husbandry	139	5
Ø (DK)	Arable farms (cereals, maize)	219	5
Tartu county (EST)	Large arable farms with winter cereals (wheat and rapeseed) and summer cereals (wheat, barley), as well as peas and beans.	1070	4

Table 4
SES framework with first level core subsystems, selected second level variables (Ostrom, 2009) and the cases in which they were applied (in squared brackets)

Social, economic, and political settings (S) S5 Market incentives [DE, DK]	
Resource systems (RS)	**Governance systems (GS)**
RS1 Sector [all]	GS1 Government organizations [NL,FI,SE,DK,EE]
RS4 Human-constructed facilities [all]	GS2 Nongovernment organizations [DE,FI,SE,DK,EE]
RS5 Productivity of system [all]	GS3 Network structure [NL,DE,DK,EE]
	GS4 Property-rights systems [FI]
	GS5 Operational rules [NL,DE,FI]
Resource units (RU)	**Users (U)**
RU4 Economic value [all]	U1 Number of users [DE]
RU5 Number of units [DE]	U7 Knowledge of SES [all]
RU7 Spatial distribution [DE]	U8 Importance of resource [all]
Interactions (I) - >	**Outcomes (O)**
I1 Harvesting levels of divers users [all]	O1 Social performance measures [all]
I4 Conflicts among users [all]	O2 Ecological performance measures [all]

peatlands considered in our research cases are mainly used for agriculture, the key social outcome (O1) is the income that farmers generate from cultivating organic soils. We show farmers' levels of dependency on this income source. Interactions also lead to an ecological outcome (O2). Since this article primarily deals with climate mitigation, we will concentrate here on emissions of conventional drainage. We follow the global warming potential data according to the land use types given in Wilson et al. (2016) if no region-specific data are available and have them cross-checked with national experts.

4. Results

We examine second-level variables for each research region, propose land use alternatives and discuss barriers and drivers of the implementation potential. Since farmers play an important role in the implementation, we summarize their perspective at the end of this chapter.

We begin by discussing a highly productive resource system in the Netherlands, continue with a review of mixed systems in Germany, Finland and Sweden, and end with a review of rather low productive systems on marginal land in Denmark and Estonia.

4.1. Research regions

4.1.1. Krimpenerwaard (Netherlands)

Krimpenerwaard (Table 5) is nearly exclusively managed by intensive dairy farms (RS1) characterized by high levels of system productivity (RS5) leading to homogeneously high harvesting levels (I1). The high productivity in combination with high harvesting levels and the farmers' dependence on the resource (U8) are mirrored by the importance of peatland cultivation for the farmers' income as a social performance measure (O1).

The high productivity of the dairy sector, high average renting prices and the importance of current cultivation for farmers' incomes suggest that subsidized alternative peatland cultivation options such as those of paludiculture or extensive pasture are not economically viable in Krimpenerwaard. Land abandonment with the rewetting of areas is economically even more disadvantageous because such land would deliver no income at all. From the perspective of the workshop participants, submerged drainage is a favorable land use alternative with the lowest CO_2 abatement costs even when investment costs for submerged drains are comparably high.

When considering the implementation potential of this suggestion, we observe two drivers. First, there is low conflict potential (I4) among farmers, since land is homogeneously used and submerged drainage can, in most cases, be installed and managed plot-specifically without affecting neighboring fields. Second, we observe a certain pressure to react to soil subsidence of on average 8 mm per year (van den Born et al., 2016), which is especially problematic because approximately two-thirds of the Netherlands is located below sea water level. Currently, ditch water levels are adapted to subsidence every 5–10 years. However, over the long-term the continuous lowering of the ditch water level becomes more costly since ditch water must be pumped back into rivers, which have higher water levels (van den Born et al., 2016). The farmers surveyed are only partially aware of this problem (U7). They regard high water levels as an important cause of yield losses. But only in part do they see waterlogging and growing expenditure on the drainage system as increasing problems. None of the farmers fear decreasing soil fertility.

For the installation of large-scale submerged drainage systems, workshop participants suggest a "stick and carrot" policy instrument that must presumably be initiated and funded by the provinces, the responsible regional authorities (GS1). The "stick" means that by law, ditch water levels will be lowered more slowly. Farmers who do not reduce soil subsidence levels will have increasingly wetter fields. Thus, farmers are incentivized to slow soil subsidence with the installation of submerged drains. Investment costs would be partly subsidized, representing the "carrot" of this policy instrument.

4.1.2. Schwäbisches Donaumoos (Germany)

In contrast to those of Krimpenerwaard, harvesting levels (I1) in Schwäbisches Donaumoos (Table 6) in Germany are heterogeneous. Organic soils are cultivated both intensively and extensively on arable land and on grassland. As a consequence, workshop participants propose a portfolio of different land use alternatives for different contexts. For high-value land with intensive land use (purchase price: 60,000–70,000 € per ha arable land), submerged drains for subirrigation are the preferred alternative for the same reasons as those described for Krimpenerwaard. However, submerged drains and their effectivity have not yet been tested sufficiently in this area. They are, however, regarded as principally feasible.

For sites of moderate and low levels of productivity, returns are so low that investments in submerged drains are not worthwhile. At the same time, land abandonment is opposed by representatives of the administration. Abandonment usually comes along with land acquisition, which is currently difficult to achieve with limited public funds. Adapted land use with paludiculture or extensive grazing is regarded as the most favorable option for moderate and low productivity sites because neither expensive investments nor land acquisition are necessary.

Table 5
Variables for Krimpenerwaard.

Resource System (RS)		**Governance system (GS)**	
RS1 Sector	Homogeneous land use: Intensive dairy farming	*GS1 Government organizations*	Water boards, Provinces
RS4 Human constructed facilities	Drainage facilities: ditches and pipes (submerged drains)	*GS3 Network structure*	See GS1
RS5 Productivity of system	High	*GS5 Operational rules*	See GS1
Resource units (RU)		**Users (U)**	
RU4 Economic value	High. Average renting price: 650€/ha	*U7 Knowledge of SES*	Heterogeneous
		U8 Importance of resource	High (share of organic soils on farms: 100%)
Interactions (I)		**Outcomes (O)**	
I1 Harvesting levels of diverse users	High	*O1 Social Performance measures*	Income from peatland cultivation: High
I4 Conflict potential among users	Low	*O2 Ecological Performance measures*	17-30 t CO_2 equiv./ha/a Soil subsidence 8 mm/a

Table 6
Variables for Schwäbisches Donaumoos.

Social, economic, and political setting (S)			
S5 Market incentives	Subsidies for bioenergy and extensive agriculture		
Resource System (RS)		**Governance system (GS)**	
RS1 Sector	Mixed farms. Grassland: dairy, low input suckler cows. Arable land: cash crops, maize for biogas.	*GS2 Non-government organizations*	Different organizations in each municipality
RS4 Human constructed facilities	Ditches	*GS3 Network structure*	See GS2
RS5 Productivity of system	Heterogeneous: From intensive grassland and arable land management to extensive pasture. Some fields are set aside.	*GS5 Operational rules*	See GS2
Resource units (RU)		**Users (U)**	
RU4 Economic value	Heterogeneous. Renting prices: arable land: 400 to 1000 €/ha, grassland: 45 to 400 €/ha	*U1 Number of users*	High
RU5 Number of units	Large number of small plots	*U7 Knowledge of SES*	Heterogeneous
RU 7 Spatial distribution	Plots are broadly distributed	*U8 Importance of resource*	High
Interactions (I)		**Outcomes (O)**	
I1 Harvesting levels of diverse users	Heterogeneous	*O1 Social Performance measures*	Income from peatland cultivation: Frequently high
I4 Conflict potential among users	High	*O2 Ecological Performance measures*	17-38 t CO_2 equiv./ha/a

Additionally, in Germany there are subsidies for bioenergy[2] and for extensive agriculture, creating quasi-market incentives (S5).

With regard to the implementation of land use alternatives, the large number of users (U1) involved may be problematic due to the effort required for them to meet and agree on changes (Ostrom, 2009; Fleischman et al., 2010; Amblard, 2012; Guimarães et al., 2018). This creates numerous sources of conflict (I4). Heterogeneity in land use intensity and diversity in current land use leads to different water level objectives among farmers. The intensity of conflict between users is aggravated by two facts. First, peatland cultivation is essential to the incomes of most farmers (O1). Second, plots are small (RU5) and spatially distributed (RU7) so that plot-specific water level changes are hardly possible and neighboring landowners need to agree on a common strategy. What further complicates matters is that in comparison to Krimpenerwaard, different non-government organizations (GS2) are responsible for drainage management in different municipalities[3], and most of these organizations are run by volunteers and not by professionals as they are in the Netherlands. What could additionally hamper the implementation of land use alternatives is the only partial problem awareness on the part of farmers. Only half of the farmers surveyed regard waterlogging as an increasing problem. Increasing expenses for the drainage system, increasing drought damage and decreasing soil fertility are hardly or not at all considered to be a problem.

4.1.3. Häme-Pirkanmaa (Finland)

In Häme-Pirkanmaa (Table 7), harvesting levels are also heterogeneous as we find for both intensive and extensive land use. As in Donaumoos, different levels of site productivity require different land use alternatives. For the most productive sites, controlled (submerged) drainage is advisable. There is potential for controlled drainage because the most productive sites already include (uncontrolled) subsurface pipes. However, compared to Krimpenerwaard, there are obstacles to controlled drainage. First, this is the case because almost half of Finland's agricultural land area is rented. Farmers do not put effort in water table regulation, because they do not want to make expensive long-term investments into fields that are owned by someone else. Second, the installation of new drainage systems may be difficult to apply to many sites, as main drainage channels are often too shallow. Third, in Finland there is a high share of small farms that do not have enough resources for expensive investments. For the same reason, the costs of submerged drainage must remain low so that low-tech systems are advisable.

Regarding mid- and low-productivity sites, workshop participants argue for land abandonment and rewetting for hotspots with thick peat layers where mitigation is economically most efficient. Adapted land use, though, is viewed critically. There is hardly any demand for bioenergy from paludiculture, as forests provide an abundant source of comparatively inexpensive wood. This also means that there is hardly any infrastructure for processing. Workshop participants also express doubts on wet grazing, because there is a total lack of experience with this technique. The concept of extensive agriculture (e. g., seminatural pasture with low input grazing) is hardly known in Finland. Normally there is a hard line between agriculture and nature protection.

Concerning implementation potential, it is important to draw

[2] In principle, substrates from paludiculture are eligible.
[3] For example, in Günzburg the "Soil and Water Board" is responsible whereas in Leipheim it is the "Hunting Cooperative" (Jagdgenossenschaft).

Table 7
Variables for Häme-Pirkanmaa.

Resource System (RS)		**Governance system (GS)**	
RS1 Sector	Mixed farms and pure arable farms	*GS1 Government organizations*	Regional authorities
RS4 Human constructed facilities	Ditches and submerged pipes for controlled drainage	*GS2 Non-government organizations*	Local groups of land-owners
RS5 Productivity of system	Heterogeneous: Arable land use is intensive and grassland use is extensive	*GS4 Property rights systems*	Extensive property rights for land-owners
Resource units (RU)		**Users (U)**	
RU4 Economic value	Intermediate. Average renting prices: arable land: 335 €/ha grassland: 290 €/ha	*U7 Knowledge of SES*	Comparably high
		U8 Importance of resource	Heterogeneous
Interactions (I)		**Outcomes (O)**	
I1 Harvesting levels of diverse users	Heterogeneous	*O1 Social Performance measures*	Income from peatland cultivation: Moderate
I4 Conflict potential among users	Low	*O2 Ecological Performance measures*	25-35 t CO_2 equiv./ha/a

attention to the fact that conflict levels are low although land is used both extensively and intensively. Conflict levels are low because many fields are surrounded by forests, and so neighbors are not normally affected by rewetting projects. Furthermore, most farmers are only moderately dependent on income (O1) from cultivating organic soils. This is the case because most farms manage only a limited number of fields on peatland and part-time farming is common. In addition, the problem awareness of future peat soil management is comparatively high. All Finnish farmers surveyed expect waterlogging to increase, and most of them also expect the cost of the drainage system to increase. Moreover, half of the respondents believe that soil fertility will decrease.

However, in Finland, clearing and drainage of new peatland undermines any emission mitigation efforts. Land-owners may drain new peatland and convert it into arable land because they enjoy extensive property rights (GS4). According to the Water Act of Chapter 5, Section 3 (Finish Ministry of Agriculture and Forestry, 2011), land owners only require permits for ditch drainage when it may cause environmental pollution to a water body. In most cases, authorities do not see the need for a permit. New drainage is a frequent strategy for farmers who need new land for cultivation and manure distribution. This is partly aggravated by low levels of land mobility found in Finland. Some farmers who leave the sector keep their land and continue with maintenance practices (cutting once a year) to further receive EU direct payments. Overall, clearing new land is less expensive than buying it although fields cleared since 2004 have not been eligible for EU direct area-based payments (Regina et al., 2016). In Finland, the extent of agricultural land with peat soils has increased by approximately 2000 ha per year in the last years (Statistics Finland, 2017).

New drainage is obviously the most important issue to be addressed in Finland. Some workshop participants suggest that national laws be changed so that new drainage always requires a permit. This could lead to rising land prices so that farmers leaving the sector would be more willing to sell or rent out their land. In the end, a better working land market with more mobility could develop. The representative of the farmer's union, however, strongly opposes limitations to clearing. Other suggestions from workshop participants include the creation of manure markets and the facilitation of land exchange programs, which would diminish the need for clearing and new drainage.

4.1.4. Gotland (Sweden)

In Gotland (Table 8), land use is heterogeneous. There are areas that are highly productive, especially due to vegetable cultivation, and rents can be up to 700 €/ha. But there are also less intensive areas where land use is characterised by pastures and extensive dairy farming (1–3 cuts per year). Overall, however, harvesting levels and income from peatland cultivation are high. The ecological performance measures are characterized by high emissions and a strong degradation of soil and in some areas the peat is very shallow. Because of the thin layer of organic matter and the high land productivity, opportunity costs of land use alternatives, such as rewetting, are particularly high in Gotland. Some of the land use alternatives, such as submerge drainage, cannot be realised for technical reasons alone, because a high availability of water is necessary to steer the water table. This is not given in the dry Gotland soils because of low precipitation. Regulation of the water level is made in some of the bigger channels in areas where the peat is underlain by gyttja containing soils with permanent cracks that can transport the water into the field. For the above reasons, there is no land use alternative recommendable in Gotland. This is especially because there are peatland regions on Swedish mainland, which are managed extensively. Both the total agricultural area and the agricultural area on organic soils is declining in Sweden and there are extensive areas with abandoned formerly cultivated peatlands. Here, for example rewetting projects could be implemented at much lower opportunity costs.

At the national level there is an interest in rewetting drained peatland areas in order to reduce greenhouse gas emissions even if the implementation potential of rewetting projects is generally low in Sweden. First, there is a general public interest to keep areas open, and rewetted areas can become overgrown with trees and shrubs. Second, drainage level changes require the consensus of more than 50% of land owners (i. e., more than 50% of the area that will be affected by changes) according to Swedish Environmental Code Legislation (Swedish Ministry of the Environment and Energy, 2015). Small peatlands with only one owner are a better possibility. Furthermore, third party interests need to be considered and water management changes have to be legalized in court. In conclusion, many stakeholders in a region need to agree on the drainage level and show the necessary commitment to change it in court.

4.1.5. River stream valleys (Denmark)

In Denmark, the study region includes not one geographic region, but fen sites in stream valleys mostly located along the western peninsula (Jutland) (Table 9). System productivity (RS5) and harvesting levels (I1) are homogeneously low in the Danish stream valleys mainly because such areas are too wet for intensive use. In many cases, streams, which are public property, are not maintained frequently enough to drain agricultural fields sufficiently. This is due to environmental legislation. Thus, land use is extensive and subsidy-driven so that submerged drainage is not worthwhile. In comparison to Häme-Pirkanmaa though, adapted land uses such as paludiculture are conceivable because there is a subsidized market for bioenergy (S5) in Denmark. Furthermore, there are often biogas plants in sufficient proximity to fields. In addition, paludiculture offers a public co-benefit since the plants bind nutrients and remove them from the nutrient-rich water body. This would make a contribution to compliance with the Water Framework Directive and the Marine Strategy Framework Directive.

Wet grazing is in principle also possible as subsidized extensive

Table 8
Variables for Gotland.

Resource System (RS)		**Governance system (GS)**	
RS1 Sector	Arable farms (cereals and vegetables): 31 %, Animal farms (mainly dairy, bull fattening and sheep): 36 %, Mixed farms: 14 %, Part time farms (< 400 h/year): 19 %	*GS1 Government organizations*	Regional authorities (länsstyrelsen)
RS4 Human constructed facilities	Ditch and pipe drainage. Weirs (gates) in bigger channels	*GS2 Non-government organizations*	Associations of land owners Water management associations (manage the water level in the big channels)
RS5 Productivity of system	Mostly high		
Resource units (RU)		**Users (U)**	
RU4 Economic value	Heterogeneous: Renting prices: Arable land: 700-110 €/ha (average ~250 €/ha) Grassland: 150-300 €/ha (average ~200 €/ha)	*U7 Knowledge of SES*	Heterogeneous
		U8 Importance of resource	Mostly high
Interactions (I)		**Outcomes (O)**	
I1 Harvesting levels of diverse users	Mostly high	*O1 Social Performance measures*	Income from peatland cultivation: Mostly high
I4 Conflict potential among users	High	*O2 Ecological Performance measures*	17-38 t CO_2 equiv./ha/a High levels of land degradation

agriculture is a common and well-established instrument for nature protection in Denmark. Nevertheless, wet grazing needs to be tested under local conditions, as there is a lack of experience with this measure. Workshop participants argue for the use of different alternatives at appropriate sites: Extensive grazing on relatively dry land and paludiculture in wetter areas. Land abandonment should also be practiced but in swamp areas only.

There are good preconditions overall for the implementation of these low-emission land use alternatives. The EU Commission has proposed ambitious climate goals for Denmark's agriculture. There will be a strong focus on wetlands due to comparably low abatement costs. For the farmers this is only marginal land, so that the importance of the resource is low (U8). Danish farmers have made little comment on the issues of worsening problems of peatland management in the survey (U7), so no data are available. But overall potential for conflict is low (I4). It is reasonable to assume that peatlands are a burden for most farmers. Currently, some areas have been abandoned and more abandonment is expected in the future. However, in many cases land cannot be fully abandoned so that adapted land use is a viable alternative. Land abandonment is challenging for different reasons. First, the Danish "decree on the use of the soil resource for cultivation and nature" (Danish Ministry of Environment and Food, 2010) stipulates that land owners keep their land open unless it becomes too wet to drive traditional tractors on it. Second, most of such land forms part of a Natura 2000 area and land owners must comply with the habitat directive, which frequently requires that no trees grow on the land. These regulations may become obstacles for rewetting projects.

4.1.6. Tartu county (Estonia)

In Tartu county (Table 10), system productivity (RS5) and harvesting levels (I1) of peatland sites are also homogeneously low because they are too wet for intensive use as observed for the Danish stream valleys. Unlike Danish conditions, soil pH in Tartu county, as in many Estonian peatlands, is very low (2–3) rendering its traditional agricultural use uneconomic (Salm et al., 2012). In Soviet times regional agriculture specialized in dairy. However, after regaining independence the market and agricultural structure collapsed and sites are either extensively used for silage and hay production or are under minimal use (cut once a year for EU direct payments) (RS1). Other areas are vulnerable to abandonment. Peatland sites are wet because drainage facilities (RS4) were constructed in Soviet times when large ditch structures were built for collective farms. These structures prove to challenge shared service and management among landowners. Investments in reconstruction are not worthwhile overall, as there is a sufficient supply of agricultural land on mineral soil in Estonia.

Obviously, submerged drainage is not a viable alternative for Tartu county. Further, there is no demand and infrastructure for bioenergy from paludiculture. Regarding wet grazing there is limited experience with low-input agriculture. Thus, rewetting is the most viable option for Tartu county. This would be beneficial for ecosystem services such as regulation functions (climate, water, and soil) and cultural services (Kimmel and Mander, 2010).

Table 9
Variables for Danish river stream valleys.

Social, economic, and political setting (S)			
S5 Market incentives	Subsidies for bioenergy and extensive agriculture		
Resource System (RS)		**Governance system (GS)**	
RS1 Sector	Mostly marginal land with extensive grazing (cattle and dairy) and for biogas production. Some areas have been abandoned.	*GS1 Government organizations*	Municipalities
RS4 Human constructed facilities	Ditches, pipes and pumps	*GS2 Non-government organizations*	Associations of landowners
RS5 Productivity of system	Low	*GS3 Network structure*	See GS1 and GS2
Resource units (RU)		**Users (U)**	
RU4 Economic value	Low	*U7 Knowledge of SES*	-
		U8 Importance of resource	Low
Interactions (I)		**Outcomes (O)**	
I1 Harvesting levels of diverse users	Low	*O1 Social Performance measures*	Income from peatland cultivation: Low
I4 Conflict potential among users	Moderate	*O2 Ecological Performance measures*	17-30 t CO_2 equiv./ha/a

Table 10
Variables for Tartu county.

Resource System (RS)		**Governance system (GS)**	
RS1 Sector	Grassland for silage, hay and minimal use	*GS1 Government organizations*	State authority
RS4 Human constructed facilities	Large ditch structures	*GS2 Non-government organizations*	Melioration cooperatives
RS5 Productivity of system	Low	*GS3: Network structure*	Low
Resource units (RU)		**Users (U)**	
RU4 Economic value	Low: Renting prices: arable land: 5 to 30 €/ha grassland:0 to 20 €/ha	*U7 Knowledge of SES*	Comparably high
		U8 Importance of resource	Low
Interactions (I)		**Outcomes (O)**	
I1 Harvesting levels of diverse users	Low	*O1 Social Performance measures*	Income from peatland cultivation: Low
I4 Conflict potential among users	Low	*O2 Ecological Performance measures*	17 t CO_2 equiv./ha/a

Table 11
Summary of interactions, outcomes and suggested land use alternatives.

	Interactions			**Outcomes**			**Main suggested land use alternative**
	I1 Harvesting levels of diverse users	**I4 Conflict potential among users**		**O1 Social Performance measures:** Income from peatland cultivation	**O2 Ecological performance measures:** CO_2 equiv. of conventional use		
NL	High	Low	⇨	High	17-30 t/ha/a	⇨	High-tech submerged drainage
DE	Heterogeneous	High		Frequently high	17-38 t/ha/a		Submerged drainage and adapted land use
FI	Heterogeneous	Low		Moderate	25-35t/ha/a		Low-tech submerged drainage and rewetting at hot spots
SE	Mostly high	High		Mostly high	17-38 t/ha/a Severe land degradation		No alternative at reasonable mitigation costs
DK	Low	Moderate		Low	17-30 t/ha/a		Rewetting and adapted land use
EE	Low	Low		Low	17 t/ha/a		Rewetting

The overall conflict potential (I4) of rewetting projects is low. Due to the land's low profitability, it is reasonable to assume that neighboring land owners would agree on a joint strategy (high water table for rewetting) if the state were to offer a reasonable land acquisition price. When some land owners do not agree, land consolidation processes are presumably feasible, as there is sufficiently productive (non-peatland) agricultural land available. Further, farmers have a relatively high awareness of worsening problems. For the future, the farmers surveyed expect both high water levels and drought on organic land to increase. They also suspect that expenditure on the drainage system will rise.

For consolidation processes, network structures (GS3) need to be improved. Currently, there are melioration cooperatives (GS2) but only a limited number exist and their work has not been very successful. Overall network structures between land owners are weak and barely operating, which has proved to be disadvantageous for collective action (Fleischman et al., 2010; Guerrero and Wilson, 2017; Guimarães et al., 2018). Land owners have different backgrounds (farmers, older owners, and land inherited after restitution) and interest in peatlands is low due to their limited profitability.

4.2. *The farmers' perspective in summary*

Since the farmers' perspective is particularly crucial for land use alternative implementation, we conclude by summarizing which alternatives are already being implemented and the farmers' general willingness to implement such alternatives.

Currently land use alternatives play only a subordinate role. In the German Donaumoos, some areas are rewetted for nature conservation and farmers are engaged in extensive livestock farming (water buffalos) as a form of contractual nature conservation. Other agri-environmental and contract nature conservation programs for extensive farming are used in the Danish region Ø (where we did the interviews with the farmers). Submerged or controlled drainage is used by all Dutch farmers surveyed and one Finnish farmer.

When being asked for the willingness to implement land use alternatives in future, the most accepted ones were those in which the water level is kept constant or raised only moderately, e. g. submerged drainage. The most strongly rejected alternatives were those in which the water level rise significantly, e. g. paludiculture. Overall, land use alternatives were only accepted if at least yield losses or even yield losses and investment costs are financially compensated for. A pure compensation of investment costs, for example for submerge drainage, is not accepted by most of the interviewees.

We conclude that there is some sensitivity to worsening problems in status quo management of peat soils. But under current conditions the willingness to implement land use alternatives is - if at all - only given if water level changes are moderate, management practices can be maintained to a large extent and financial losses are compensated for.

5. Discussion

This chapter clusters variables and discusses patterns that can be transferred to other regions. We further present our results in relation to other research, draw conclusions for institutional changes and provide an overall interpretation of results.

5.1. *Land use choices and implementation potential*

Table 11 summarizes interactions, outcomes and proposed land use alternatives. We show how interactions and outcomes influence the preferences for land use alternatives and their respective implementation potential. The first interaction we would like to have a closer look at, is harvesting levels (I1). They can be derived mainly from productivity of systems (RS5) and value of land (RU4) and they determine income from peatland cultivation (O1). Harvesting levels describe land use intensity and are an indicator for the preferred land use alternative based on expert workshop results. They determine whether land use alternatives can be implemented at all at reasonable mitigation costs. In Gotland (SE) this is not the case, because high harvesting levels are combined with a low carbon stock. Harvesting levels further determine whether the installation of submerged drainage is worthwhile as in Krimpenerwaard (NL) and in parts of Donaumoos (DE). In other regions, workshop participants suggested adapted land use (wet grazing or paludiculture) or rewetting. When land is inexpensive and there are no market incentives (S5) for wet grazing or paludiculture, participants favor government acquisition of land and rewetting as in Tartu county (EE). Nevertheless, rewetting projects applied at marginal sites with high water tables must be of a sufficient size to steer the water table and to achieve a significant mitigation effect. When market incentives for wet grazing or paludiculture are given so that they deliver a positive gross margin, then low emission-adapted land use is a viable alternative. However, the gross margin level, for example for paludiculture, depends on assumptions of commercialization opportunities (Wichmann, 2017). These depend on the local context. In our discussions (expert workshops) on the selection of land use alternatives we considered other societal objectives such as the presence of open landscapes, biodiversity and water protection, but these have played a subordinate role overall. The focus was on emission mitigation costs and acceptance from farmers.

To conclude, hard economic variables, represented by harvesting levels (I1), determine the workshop participants' preferences for land use alternatives, but they do not indicate land use alternative implementation potential in connection with collective action. In other words, a highly valued resource is not an indicator of a high willingness to engage in collective action as Guimarães et al. (2018) note in reference to inter alia Baur and Binder (2013) and Fleischman et al. (2010). Regarding peatland drainage, the opposite is often the case. When the value of land is high, farmers' willingness to change land use is low, because this may involve the extensification of profitable land, leading to high income losses. This applies, for example, to intensive arable farms found in Häme-Pirkanmaa (FI). By contrast, when the value of land is low, as is the case for Danish river stream valleys, willingness to change land use is greater. This is in line with Schaller et al. (2011) who identify the low agricultural profitability of current cultivation measures as advantageous for the implementation potential of alternative land use. Rawlins and Morris (2010) also determined that stakeholders in regions with extensive land use are more open to climate-friendly land use alternatives than stakeholders in regions with intensive land use.

According to our results, though, the heterogeneity of harvesting levels (I1) also plays an important role in implementation potential, as it spurs internal conflicts. In other words, high heterogeneity in land use intensity, i. e., heterogeneity in water level requirements or acceptable water table levels, leads to high conflict potential (I4) and a low willingness to change land use as noted for example in Donaumoos (DE). Homogeneously high land use intensities, such as those observed in Krimpenerwaard (NL), do not necessarily lead to conflicts when farmers can maintain levels of intensity with appropriate technologies (subirrigation and submerged drainage).

Generally, we conclude that mainly conflicts among users (I4) or the respective potential are crucial to the implementation potential of alternative land use. This is in line with other research on collective action (Nagendra and Ostrom, 2014; Risvoll et al., 2014; Guimarães et al., 2018) and on alternative peatland use (Schaller et al., 2011). Our results show that conflict potential is partly due to heterogeneity in resource use and management intensities (I1) as mentioned above but also due to dependence on resource use (U8) matters. For example, in Häme-Pirkanmaa (FI) the potential for conflict is low among other reasons because most farms consist of only a limited share of peatland fields so that dependence on peatland use is limited. When looking at conflict mitigation or resolution, e. g., through land consolidation, we conclude that it is advantageous when network structures between users (GS3) already exist (Fleischman et al., 2010; Schaller et al., 2011; Guerrero and Wilson, 2017; Guimarães et al., 2018). Here, government and non-government organizations (GS1, GS2) are essential in providing these structures (Ostrom, 2009; Nagendra and Ostrom, 2014) (e. g. water boards).

5.2. Institutional frameworks of different levels

However, not only local socioeconomic contexts shape the implementation potential of land use alternatives, but institutions of different levels play an important role. From our workshops with experts we make the following suggestions on institutional changes applied at the EU, national and regional levels. We propose incentivizing mechanisms to be introduced by the EU since both agricultural and climate policies are predominantly regulated on the EU level. First, the incentive structure in connection with Commmon Agricultural Policy (CAP) direct payment needs to change so that farmers receive these payments for cultivating paludiculture. Second, 5-year temporary funding for agri-environmental and climate measures needs to be prolonged so that these measures sufficiently incentivize farmers to make long-term water level changes. Third, the EU could introduce new payment systems such as auctions for CO_2 equivalent mitigation quantities so that member states or regions where the least expensive mitigation measures can be implemented apply (Wissenschaftlicher Beirat Agrarpolitik, Ernährung und gesundheitlicher Verbraucherschutz und Wissenschaftlicher Beirat Waldpolitik beim BMEL, 2016). For example, Estonia could apply and acquire marginal peatland areas to rewet them at comparably low mitigation costs. The Netherlands could also participate in such an auction system to co-finance submerge drainage.

The pronounced differences in the mitigation costs induce some marked challenges for the use of alternative legal or support instruments. The EU Commission's proposal for the CAP past 2020 (COM, 2018) demands from the member states to define obligatory farm management standards to ensure the protection of peat land (Annex III, GAEC 2). These standards can only be effective w. r. t. climate mitigation if they demand an alteration of the water level. However, the associated costs will at least in intensively managed areas exceed the value of the CAP payments, inducing a high risk that strict and effective provisions will in the end only lead to an opt-out of the concerned farmers of the CAP. Despite this economic problem there is the legal challenge that farmers frequently will not have the decision-making authority w. r. t. setting the water table but this authority is exercised by land owners or water management authorities. We argue that the GAEC 2 standard would be much more effective and efficient if it would not address the single farmer but the member state, e. g. requiring that a certain share of the peat land must be rewetted. The task of the member state would be to define the appropriate policy mix. Using regulatory laws to promote a climate friendly management of peat soils does not face the problem of landowners and managers opting out. However, especially from areas with high mitigation costs a marked opposition can be expected slowing down the decision-making process.

At the national level, it is crucial to remove legal obstacles so that EU-level incentivizing mechanisms can work. For example, the difficult legal process involved in Sweden considerably impedes the implementation of water level changes. Moreover, in Finland the land users' right to drain new land contradicts peat protection measures and undermines the measures' legitimacy. As Guimarães et al. (2018) point out, property rights are not necessarily designed on purpose but have often evolved historically. However, when the abovementioned laws do not change, EU-level incentives are either unfeasible (Sweden) or ineffective with regard to emissions mitigation (Finland). In line with Regina et al.'s (2016) results, we observe that a lack of policy coherence stands as one of the main obstacles to mitigation implementation.

Regional institutions such as the water boards or provinces should assume a more central role in executing measures (e. g., water level determination under a “stick and carrot” system suggested in Krimpenerwaard (NL)). Regional institutions can also be central in creating and maintaining network structures as mentioned above and for land consolidation processes and manure markets as suggested in Häme-Pirkanmaa (FI), for example.

5.3. Overall interpretation

Overall our results provide an orientation point for policy makers, planners and local stakeholders developing means for reducing GHG emissions from managed peatland sites. We identified key variables structuring the solution space and highlight the boundary conditions under which a particular strategy might be preferable. These suggestions for the research regions at hand can be transferred to similar contexts elsewhere. Nonetheless, it is important to note that each site is different and needs to be analyzed thoroughly. Our suggested strategies may not work in comparable situations for various reasons. For example, submerged drainage may not be technically feasible or too costly for other high-productivity sites or land acquisition may not be feasible for less productive sites because farmers are reluctant to sell for noneconomic reasons such as for traditional reasons. Further research could go deeper into individual regions and, in particular, explore user-related variables more closely, e. g. knowledge of socio-ecological systems (U7), which we have captured with general survey questions on problems of current and future peat soil use. In-depth interviews could also provide a better understanding of the farmers’ motives by researching variables such as socioeconomic attributes (U2), history of use (U3) and norms (U6), which may play a role in implementation potential of management changes.

We surveyed farms that are larger than the average regional farm, because owners of such farms were more willing to participate in an interview. However, it can be argued that larger farms are more likely to survive in structural change and are therefore the better interviewees on the subject of future projects. The documented skepticism towards land use alternatives would probably be even greater among the smaller farms because they are more dependent on their land, especially as forage areas.

In general, we present a strictly qualitative analysis. For concrete mitigation projects, effects of land use alternatives will have to be estimated with quantitative methods. For example, emission reduction potential and costs depend on many factors and are site-specific (Wichtmann et al., 2016; Drösler et al., 2013). Farmers’ acceptance towards management changes could be estimated quantitatively for example with discrete choice experiments, determining how many farmers would be willing to change land use under which conditions and at which compensation prices.

6. Conclusion

The implementation of peatland protection measures such as the cultivation of wet-adapted crops or the restoration of natural conditions very much depends on local contexts and on the consent of local actors, and as such solutions must be tailor-made. However, to apply research findings to other regions and to scale pilot projects, it is important to identify variables and patterns that are transferable to other contexts.

Our research aim includes these two potentially conflicting objectives of suggesting tailor-made solutions for each research region and of identifying variables that can be used across all regions and beyond. From interviews with farmers and workshops with experts held in different European peatland regions, we propose land use alternatives that are mainly determined by economic variables. Other variables are crucial with respect to the implementation of alternatives such as network structures and conflict potential between different users. However, implementation depends not only on local factors but also on an institutional framework at different levels. Mainly EU-level incentives for alternative land use are necessary, since climate and agricultural policies are predominately regulated at the EU level. Nonetheless, national laws need to be changed and regional institutions must be adapted so that EU incentives are feasible and effective.

Declaration of Competing Interest

None.

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