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Worldwide peatland degradations and the related carbon dioxide emissions: the importance of policy regulations

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ABSTRACT

Peatlands cover *cca* 3% of the planet‘s surface, yet have disproportional role in carbon stocking. Our goal is to understand the world peatland degradation and it's possible CO_2 emissions for two time periods: 2025 and 2050. First we modeled the future degradation of peatlands and the associated carbon emissions. Second, a conceptual representation was developed to understand the most important socio-political factors behind the observed peatland degradation. We found an increase of the degraded peatland surfaces by 17% till in the period of 2008–2025 (summing *cca* 559,519 km^2) and 26% till 2050 (summing 626,048 km^2). The highest degradation levels expected for Asia (about 472,197 km^2 until 2050). The global carbon emission resulting from peatland degradation was 1,052.79 Mtone in 1990 and 1298 Mtone in 2008, the differences being largely related to the Asian emissions (47.8% increase from 345 Mtone in 1990 to 722 Mtone in 2008). We expect an increase of carbon emission due to peatland degradation from 2008 to 1582 Mtone until 2025 and to 2118 Mtone until 2050. The model shows that 25% of the current peatlands will be degraded until 2050 and will be responsible for about 8% of the global anthropogenic carbon dioxide emissions.

1. Introduction

Peatlands have disproportional role in carbon stocking worldwide. Although their overall surface area is relatively small (*cca* 3% including forested peatlands), they stock more carbon than the tropical forests (Joosten, 2015). Physical disturbance (e.g. drainage) releases massive amounts of carbon and nitrogen from peatlands, contributing to the atmospheric greenhouse gases and nitrates to the surface water systems. It is not surprising therefore, that peatland degradation has been considered as being between the most important carbon emissions sources (Joosten, 2015). Human activities such as agricultural exploitation, peat firings, drainage systems, combined with extreme climate maniphestations, contributed to the degradation of about 65 million ha of peatland area globally (Boyd, 1990a, 1990b; Pemberton, 2005; Stranck, 2008; Couwenberg, 2009; Hooijer et al., 2010; Husen et al., 2014; Carlson et al., 2015). The above changes alters the peatland hydrology accelerating the peat oxidation processes, altering the greenhouse gas balance of the peatland (Stranck, 2008; Couwenberg, 2009; Hooijer et al., 2010; Husen et al., 2014; Carlson et al., 2015). Peatland fires (with human or 'natural' sources) double the carbon emissions of peatlands, fires currently representing 5% of the total anthropogenic CO_2-emissions (Joosten, 2015). Although several conservation efforts were made to protect peatlands (e.g. Ramsar site declaration, EC Council Directive on the Conservation of Natural Habitats and of Wild Flora and Fauna, Directive 92/43/EEC) still, human use threatens about 14–20% of peatlands worldwide (e.g. through agricultural practices) (Wösten et al., 2006, 2008; Chokkalingam et al., 2007; Stranck, 2008; Harrison et al., 2009; Hirano et al., 2009; Page et al., 2009; Moore et al., 2010). Peatlands have exceptional value for nature conservation; they harbor several rare, endemic and protected organisms, some of them surviving glaciations in these habitat systems. Typical examples of such important organisms includes sphagnum mosses, rushes and sedges, bog cotton, ling heather bog rosemary, bog asphodel and sundew (Braun-Blanquet, 1932; Wheeler et al., 1983; Anderson et al., 1990, 1996; Anderson, 1990; Davis and Anderson, 1991; Bridgham et al., 1996). Among the most endangered animals related to peatlands are the Irish hare, otter,

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hen harrier, Greenland white fronted goose, peregrine falcon, golden plover and merlin (Bider and Matte, 1994; Biggs et al., 2001; Joosten and Clarke, 2002; Kalkman et al., 2002; Koponen, 1994, 2002; Hokkanen, 2004).

In the present study we employed two frameworks for a better understanding the world peatland degradation and its possible CO_2 emissions for two time periods: 2025 and 2050. First we modelled the future degradation of peatlands and the associated carbon emissions. Second, we built a conceptual representation using the most important social and policy related factors for each modeled region in order to explore the potential socio-political causes behind the observed peatland degradation. Our assumption was that the different geopolitical factors on each continent will influence the future degradation of peatlands and the associated carbon emissions. We are aware about the unpredictable and potentially unstable nature of peatland conservation policies for the future; the aim of the conceptual approach was to complement the mathematical model and to provide a better policy context for their interpretation.

2. Methods

2.1. Data sources

Data were collected with a personally developed data mining software. Two types of data were collected for the mathematical modelling. First, we collected available data about the surface of peatlands in each country (expressed in km^2). We define as ‘peatland’ according to Schumann and Joosten (2008) the areas with a naturally accumulated peat layer at the surface. A total of 7,686,092.3 of km^2 for 1990 and a total of 7,558,759.6 of km^2 for 2008 were used for analyses (see Supplementary materials, overall peatland data excel table). Boreal areas were preferentially searched by countries but certainly not the total peatland areas from these regions were used for this study because surfaces of forested peat areas (1,872,928.04 of km^2 from 1990 and 1,322,234.04 of km^2 from 2008) were excluded from analysis. This was because high differences were reported for these peat areas especially from Asia. Information about the property of each peatland such as peatland area, peat carbon stock, the amount of degrading peatlands (km^2), CO_2 emission (Mton CO_2/a) by degrading peatlands were collected (data for 1990 and 2008 are presented as Supplementary Online Materials 2 excel file). Altogether about 30 important web pages were searched (see Supplementary Online Materials 1 – webpages) and the data mining software used an algorithm that searched data from three homepages simultaneously according to specific keywords. The most comprehensive data were available for the years 1990 and 2008 (Global peatland database IMCG, 2008; Schumann and Joosten, 2008); therefore we used these data in our further analyses. After collecting the basic information for the world-wide distribution of peatlands; the database was screened for duplications and contradictory data for the same region. In such cases the last validated data available were used. The searching targeted all continents (e.g. Asia; Americas; Europe; Africa; Australasia & Pacific Isles and Antarctica & Sub-Antarctic Isles) with covering 167 countries.

2.2. Mathematical modelling

Previous empirical studies indicate a positive relationship between the decrease of the level of water table and the soil carbon loss rate in peatlands (Stephens et al., 1984; Andriesse, 1988; Clymo and Pearce, 1995; The et al., 2005; Jauhiainen et al., 2008; Couwenberg, 2009; Hooijer et al., 2010; Husen et al., 2014; Carlson et al., 2015). We used a method developed by Hooijer et al. (2010) to estimate the carbon loss and emission for 2025 and 2050, using the water table level as predictor. Relationship between groundwater depth and CO_2 emission for peatlands was derived from the results of two types of emission studies. The first type of study is CO_2 emission monitoring in relation to water table depth in peatlands (see also Murayama and Bakar, 1996; Jauhiainen et al., 2004; Melling et al., 2005; Ali et al., 2006; Carlson et al., 2015). The second is a long term estimation of peat subsidence in drained peatlands, combined with peat carbon content and bulk density assessments to divide the contribution of compaction from the total subsidence rate; the remainder is attributed to CO_2 emission (as reviewed by Wosten et al., 1997; Wosten and Ritzema, 2001; Carlson et al., 2015). Carlson et al. (2015) described in detail the analysis and found the following regression: CO_2 emission = 91 Groundwater depth [R^2 = 0.71, n = 8], where CO_2 emission is expressed in t/ha $^{-1}$ y^{-1} and groundwater depth is the average depth of the water table below peat surface (in meters). This linear regression relation implies that every 10 cm water table drawdown will result in an increase in CO_2 emission rate of 9.1 t CO_2 ha^{-1} y^{-1} at global scale (Carlson et al., 2015). An example of calculation is given considering the carbon content of Southeast Asian peat, where data was taken to be 60 kg m − 3 (Kanapathy, 1976; Neuzil, 1997; Shimada et al., 2001). If similar data were not available for appropriate peatlands this value was applied to all areas. Using the

Table 1
Estimated peatland degradation (km^2) (upper, unbolded values) and CO_2 emission (bolded under values) (Mton CO_2/a) for 2025 and for 2050 by deduction from existed data of 1990 and 2008 and from model used for “minimum”, “likely” and “maximum” emission rates for the land use classes for 2025 and 2050.

	Estimated peatland degradation (km^2) and CO_2 emission (Mton CO_2/a) for 2025				Estimated peatland degradation (km^2) and CO_2 emission (Mton CO_2/a) for 2050			
	deduction	minimum	likely	maximum	deduction	minimum	likely	maximum
Americas	23,913.6	23,913.9	23,914.2	23,914.5	24,126.4	24,126.7	24,127	24,127.3
	108.2	**108.5**	**108.8**	**109.1**	**109.5**	**109.8**	**110**	**110.4**
Asia	311,616.1	311,616.43	311,617	311,617.1	462,197.3	472,197.6	472,197.9	472,198.3
	1142.4	**1142.8**	**1143**	**1143.4**	**1735.7**	**1736**	**1736.3**	**1736.7**
Europe	93,039.1	93,038.7	93,038.5	93,038.1	90,000	89,999.6	89,999.4	89,999
	220	**219.6**	**219.4**	**219**	**130**	**129.6**	**129.4**	**129**
Africa	17,305.6	17,306	17,306.3	17,306.6	20,189.4	20,189.9	20,190.2	20,190.6
	69.4	**69.7**	**70**	**70.3**	**81.1**	**81.4**	**81.7**	**82**
Australasia & Pacific Isl.	12,597.1	12,597.4	12,597.7	12,598	18,480.4	18,480.7	18,481	18,481.4
	41	**41.2**	**41.5**	**42**	**52.5**	**52.8**	**53.1**	**53.4**
Antarct & Subantarc Isl.	1,047.4	1,047.8	1048	1,048.4	1,054.7	1055	1,055.3	1,055.6
	0.9	**1.3**	**1.5**	**1.9**	**1.9**	**2.3**	**2.5**	**2.9**