Use of stratigraphic and pedogenetic information for the evaluation of carbon turnover in peatlands

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Summary

In contrast to mineral soils, peatland soils store significant amounts of carbon in their subsoil and bedrock. Currently there is both a lack of sufficient data and appropriate methods that would allow the evaluation of the effects of changes in peatlands utilisation on the carbon cycle. The German federal states Mecklenburg-Western Pomerania and Brandenburg, both rich in peatlands, were studied. Percolation mires and water rise mires are the most common hydrogenetic mire types in terms of area in these regions. The amount of carbon locked up in these mire types was calculated and the carbon release potentials for peat substrates of different degrees of decomposition were determined.

Key index words: Carbon turnover; peatlands; hydrogenetic mire type

Introduction

Global peatlands contain between 350 and 535 Gt of carbon (C) (Gorham, 1995) and unlike mineral soils, they have the capacity to store C in their subsoil and bedrock. Detailed knowledge of C in peatland soils is essential for the management of (i) land used for agricultural and forestry purposes, (ii) peatland protection measures and (iii) peatland renaturation. Under the Kyoto Protocol, the signatory countries have committed to cut their greenhouse gas emissions. The framework comprises reduction obligations and mechanisms to lower greenhouse gas emissions e.g. via biological sinks. One point of criticism is that so far not all carbon fluxes are taken into account for the evaluation of ecosystems, e.g. soil C fluxes. Furthermore, the Kyoto Protocol does not include incentives for the preservation of already existing effective carbon sinks such as peatlands, which might lead to the destruction of C storing ecosystems. The Protocol of 'Full Carbon Accounting', which also asks for the soil C stock to be preserved, might complement the Kyoto provisions in the future (Schulze and Freibauer, 2005). However, for 'Full Carbon Accounting', more data for existing as well as currently created C fluxes, C pools and C sinks is needed since the current data situation in Germany and throughout Europe is insufficient (Byrne *et al.*, 2004). This particularly applies to peatlands, which require a differentiated approach: Landscape location and the various mechanisms of water supply lead to different hydrogenetic mire types (hereafter referred to as mire types) (Wassen and Joosten, 1996), for which the amounts of carbon stored may differ by a factor of up to 10.

Besides improving the data situation for carbon storage in peatland soils, it is also essential to consider their C release potential. The authors' initial research shows that the various peat substrates found at the surface -and hence located in the area of drawdown when the land is used- have different C release potentials.

The objectives of the authors' research project were to calculate the typical carbon storage quantities for the percolation and water rise mire types based on existing profile and soil data and to make first predictions for C turnover and release potentials through determination of the hot water soluble C content.

Materials and methods

The research is based on the following concepts and hypotheses. According to the German classification, peatland soils are organic soils with a peat thickness of more than 30 cm. Peat substrates contain more than 30 % SOM, whereby it is recommended to multiply the C_{org} content with the factor 2.0. Peat substrates are classified by their main plant components and their degree of decomposition; this is comparable to international classifications. However, the German classification differs from the FAO and WRB classifications in that it also defines horizons for peat and gyttja substrates which were formed by pedogenetic processes. These take into account macromorphological peat characteristics that can be identified in the areas concerned (Zeitz and Velty, 2002). Hence peatland soil parameters such as C content depend on both the peat substrate and the horizons. For these so-called soil-horizon-combinations (SHC) it is assumed that pedogenetic processes in comparable peat substrates lead to comparable soil characteristics.

The profile and soil data analysis is based on the following hypotheses: (1) Every mire landscape is charac-

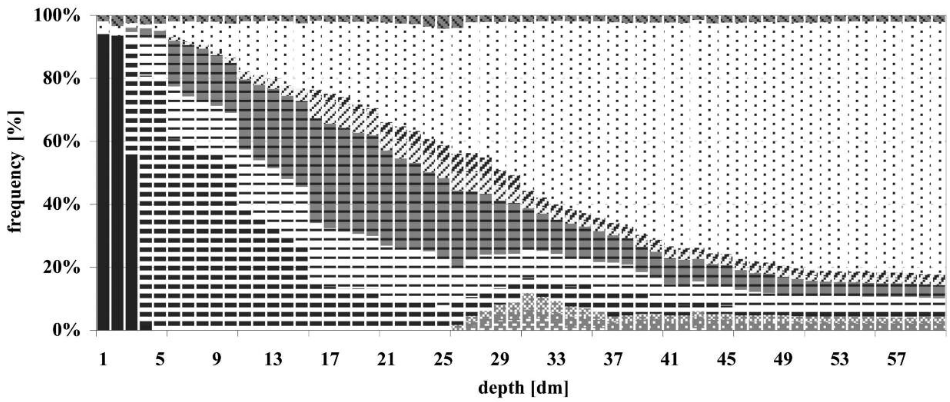

Figure 1. Frequency of peat substrates in percolation mires (n=1048) (legend see fig. 2)

terised by typical hydrogenetic mire types; (2) each mire type has a typical stratigraphy, i.e. a typical layering of peat and gyttja types with specific thicknesses, and the peat types have typical degrees of decomposition; (3) mire types influence the degree of pedogenesis and hence the soil type, and thus they consist of typical SHCs; (4) SHCs differ in C content and quality; (5) linking these causal relationships allows for the estimate of C storage quantities and turnover.

C storage quantities were calculated using peatland soil data (1954 profiles, 242 bulk density and C_{org} values) from the German federal states Mecklenburg-Western Pomerania and Brandenburg. Bulk densities were determined with 100 cm^3 soil sample rings, C_{org} values via CNS analyser (Variomax 2 Elementar). Hot water-extraction (HWE) method widely has been used for prediction of mineralizable C and N pools in different soils (Körschens *et al.* 1998; Landgraf *et al.*, 2006; Müller *et al.*, 2007). The analysis was made using the SPSS 14 statistics software programme.

Results and discussion

Hydrogenetic mire types

In central European fen areas, percolation, terrestrialisation and water rise mires are the most common mire types. Kettle hole mires have a smaller area share, but they are of outstanding importance for nature conservation and very common especially in the younger moraine landscape.

Percolation mires are found in landscapes with abundant and continuous water availability. The water percolates through the whole peat body (Wassen and Joosten, 1996). The mire surface is sloped towards a body of flowing water in the centre. Percolation mires are large entities covering wide areas with peat deposits, which are often several metres thick. They contain large amounts of carbon and have very high and thus hydrologically effective peat porosities of more than 90 vol. % (Zeitz and Kühn, 2000).

These descriptive elements could be confirmed and further detailed through the authors‘ analyses. Percolation mires in the younger glacial drift area of north-eastern Germany are composed of several metres thick sedge peat deposits; average thickness is 3-4 m, some profiles are thicker than 6 m. They contain no or only insignificant quantities of gyttja. Percolation mires in Brandenburg show higher degrees of decomposition in their bedrock than comparable mires in Mecklenburg (Fig. 1).

Water rise mires develop when the water table rises but does not create an open body of water. Peat deposits usually have a low thickness and are highly decomposed. Thin gyttja layers may occur as underlying substrates, thus reducing both upward and downward hydraulic conductivity, i.e. capillary rise and seepage. The frequency distribution of the soil profiles analysed shows that highly decomposed mixed peat types predominate prevail (Fig. 2). Water rise mire thickness rarely is more than 1.5 m. The gyttja types present in rather thin layers are calcareous and clay gyttja.

In both mire types, fine- to medium-grained sand is found underneath the peat substrates. These results confirm hypotheses 1 and 2.

Profiles of the dominant soil of the soil mapping unit - typical soil profiles

Profiles of the dominant soil of the soil mapping unit (hereafter called typical soil profile) describe part of a landscape with a profile. It can either be a ‘benchmark profile’ defined in situ by experts or an average profile obtained via statistical methods, i.e. a profile not actually existing but describing a given homogeneous part of a landscape. Out of the large number of datasets, the authors gathered all identically structured SHC descriptions. Using statistical methods, the 2 or 3 most frequent profiles were determined. Experts then selected a typical soil profile for each case. Based on 417 profiles, percolation mires are characterised by an earthified horizon of only 20 cm and an aggregated horizon of 10 cm (Table 1a). Because of the conditions of the mire development and the extensive land use percolation mires has moderately degraded soils. Drainage has led to shrinkage cracks in the subsoil between 40 and 90 cm depth. Peat types differ mainly in their degree of decomposition, which decreases with depth. By contrast, the two typical soil profiles for water rise mires show severe degradation and have a 30 cm strongly earthified topsoil (Table 1b and 1c).

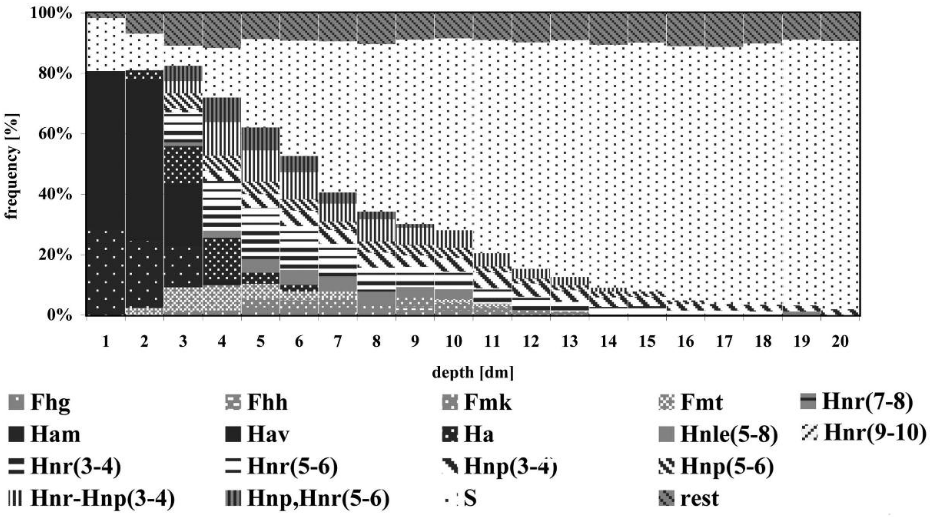

Figure 2. Frequency of peat substrates in water rise mires (n=408) (abbreviations: Hav – earthified peat, Haa – aggregated peat, Hnr – sedge peat, Ham – strongly earthified peat, Hnp – reed peat, Hnle – alder peat, S – sand, Fhg – detritus gyttja, Fhh - peat gyttja, Fmk – calcareous gyttja, Fmt – clay gyttja)

C storage

C storage quantities were obtained by linking the typical soil profiles data for the respective mire type and calculating the C storage quantity for each SHC (median values were used) (Table 2).

Pedogenesis leads to a considerable increase of peat bulk density. Values are 3 – 4 times higher in the topsoil than in the continuously water-saturated subsoil (nHr-horizon). Mineralisation in the aerated part of the topsoil decreases C content. The relationship between bulk density and C_{org} content is quite tight (R^2= 0.68) and applies to all SHCs (Fig. 3).

Hypothesising two test areas of 100 ha each, the following C storage quantities can be calculated: a percolation mire stores 477 000 t C and a water rise mire stores 97 000 t C.

C release potential

The hot water soluble organic carbon content (HWE-C) was significantly related to the state of soil development and also to the kind of peat substrate. The authors' study showed that the concentration of HWE-C is increasing with the degree of decomposition (Fig. 4). The highest absolute contents of HWE-C were found in strongly decomposed peat.peat.

Conclusion

The hypotheses made in this paper could be confirmed with peatland soil data of two northeastern German federal states. When the mire type is known, typical soil profiles and their typical SHCs can be assigned to a given mire body for depths up to 2 m. Statistically obtained bulk density and C_{org} values for SHCs allow for a very precise calculation of carbon storage

Table 1a-1c. typical soil profiles for a) Percolation mire and b) and c)water rise mire (abbreviations: nHv – earthified peat horizon, nHa – peat-crumb horizon, nHt – peat shrinkage horizon, nHr – peat horizon below groundwater table, reduced state, nHmp –strongly earthified horizon; ploughed, Gr – groundwater horizon, reduced state, DD – degree of decomposition)

a)

Profiles:	417		
depth [dm]	horizon	substrate	DD
1	nHv	Hav	
2			
3	nHa	Haa	7- 8
4	nHt	Hnr	5- 6
5			
6			
7			
8	nHt	Hnr	3- 4
9			
10	nHr	Hnr	3- 4
11			
12			

b)

Profiles:	20		
depth [dm]	horizon	substrate	DD
1	nHmp	Ham	
2			
3			
4	nHa	Haa	
5			
6			
7	nHt	Hnr or Hnp	5-6
8			
9			
10	Gr	s	
11			
12			

c)

Profiles:	27		
depth [dm]	horizon	substrate	DD
1	nHmp	Ham	
2			
3			
4	nHa	Haa	
5	nHt	Hnp	3- 4
6	Gr	s	
7			
8			
9			
10			
11			
12			

SHC	Area ha	N	Thickness m	BD kg/m_	C_{org} %	1.QU. %	3. QU. %	C_{org} t	C_{org} (min) t	C_{org} (max) t
Hav/nHv	100	32	0,20	440,0	28,47	18,90	33,15	25055	16632	29169
Haa/nHa 7-8	100	28	0,10	250,0	38,00	27,75	41,18	9499	6939	10294
Hnr/nHt 5-6	100	48	0,40	170,0	43,25	38,02	44,92	29410	25853	30545
Hnr/nHt 3-4	100	24	0,20	120,0	41,97	36,16	44,22	10072	8678	10612
Hnr/nHr 3-4	100	26	6,60	140,0	43,60	42,90	46,76	402864	396396	432044
Total								476900	454497	512664

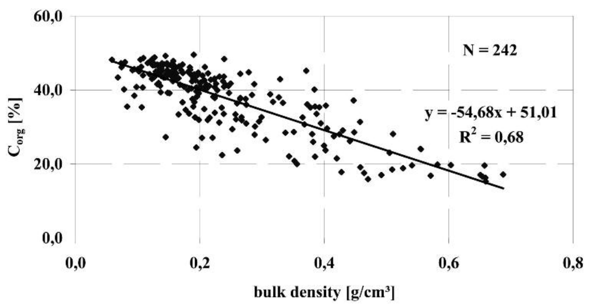

Figure 3. Correlation between organic carbon and bulk density

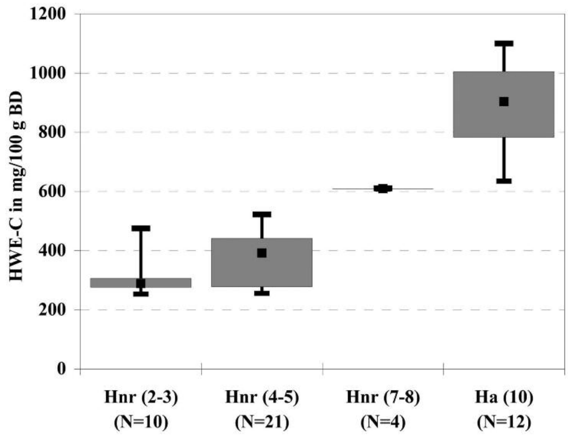

Figure 4. HWE-C (mg/100g BD) content of different peat substrates (with DD= degree of decomposition)

quantities for depths up to 2 m, and quantities for greater depths can be estimated. The authors' study showed that the concentration of HWE-C is increasing with the degree of decomposition. The hypothesis claiming that peat substrate according to the hydrological type of mire is a significant factor determining chemical and biological properties of fen soils was confirmed. Overall, peatland areas could therefore be more precisely evaluated in terms of their vulnerability or classified as 'risk area' according to the EU soil protection strategy.

Acknowledgements

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