Carbon storage in the peatlands of Mecklenburg-Western Pomerania, north-east Germany

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SUMMARY

Peatlands are becoming increasingly important in the context of climate change because they store large amounts of carbon, but information regarding the exact amount of carbon is scarce. In their natural state (as mires), they sequester and store organic carbon (C_{org}), but they emit CO_2 when drained. In calculating C_{org} storage, little attention has been paid to the fact that many peatlands have been intensively drained and used for more than 200 years, such that their soil characteristics have changed. Recent estimates of peatland carbon storage are based on simplified data for peat thickness, bulk density and C_{org} content. This paper offers an alternative method for estimating the amount of carbon stored which takes into account peatland type and secondary soil development. Peatlands that originated as different hydrogenetic mire types (HGMTs) store different amounts of carbon due to stratigraphical differences. It is estimated that 430 Mt of C_{org} is stored in peatlands belonging to the three dominant HGMTs in Mecklenburg-Western Pomerania (north-east Germany), and that percolation-mire peatlands store up to ten times more C_{org} than water-rise-mire peatlands. It is also demonstrated that gyttja soils make a significant contribution to C_{org} storage in terrestrialisation-mire peatlands; thus, after peats, these are the next most important soils for C_{org} stocks.

KEY WORDS: carbon stocks, climate change, gyttja soils, hydrogenetic mire type.

INTRODUCTION

As part of the pedosphere, peatlands cover no more than 3% of the earth's surface but store 16–24% of its soil carbon (Koppisch 2001, Bridgham *et al.* 2006). The quantity of carbon involved amounts to 350–535 Gt C globally (Gorham 1995), exceeding that in forests (Epple 2006) and almost matching the total amount stored in terrestrial biomass (Joosten & Clarke 2002). Moreover, the fact that peatlands can function as both sinks and sources of carbon is a key issue in the global climate-change debate (UNFCCC 1997, Ciais 1999, Garnett *et al.* 2001, Janssens *et al.* 2005).

Montanarella *et al.* (2006) have estimated the extent of peatland in Europe, but their data cannot yield estimates of carbon storage unless supplemented with information about peat thickness and stratigraphy. Such calculations usually assume an average peat thickness of 1.5–2.0 m and a bulk density of 0.09–0.2 t m^{-3} (g cm^{-3}) (Gorham 1991, Höper 2002, Byrne *et al.* 2004, Bradley *et al*. 2005). For example, Höper (2002) uses an average peat thickness of 2 m, a bulk density of 0.20 t m^{-3} and a C content of 54% to calculate carbon storage for all fens in Germany at 2.3 Gt C (total area *ca*. 10,580 km²). On the other hand, Kuntze (1993) estimates that Germany's peatlands store only 1.8 Gt C in total. The significant variation amongst existing calculations and estimates of the peatland carbon store (Joosten & Couwenberg 2008) arises partly because estimates of total carbon content (C_t) for different types of peat range from 18% to 63% (Succow 1988, Naucke 1990). It follows that the accuracy of the calculations could be improved by taking into account the differences between peat types.

According to the German soil classification, peat soils are organic soils which contain more than 30% organic matter (dry weight basis) and are more than 0.3 m thick. Different types of peat are distinguished according to their main plant components and degree of decomposition. The approach generally reflects the well-known international classifications, but differs from the FAO-UNESCO (1974) and WRB (FAO-IUSS-ISRIC 2006) classifications in that gyttja generated by pedogenetic processes can be defined as peat horizons. It also incorporates provision for distinguishing peat that has undergone secondary soil development or "earthification" (Schwaerzel & Bohl 2003, Mueller *et al*. 2007a, 2007b; also termed "moorschung" by Oleszczuk *et al*. 2008) due to the intensive agricultural utilisation that has affected approximately 98% of the (mostly fen) peatlands in central Europe over the last 200 years. The accompanying drainage initially causes settlement and shrinkage of the peat. Subsequently, the peat mineralises and undergoes structural changes (earthifies) due to increasing aeration. At the end of this process of secondary decomposition, the upper peat layers are strongly decomposed with altered physical characteristics. The German classification distinguishes two stages of earthification. In the first stage, the peat has a crumbly, grainy structure; and after further degradation under long-term drainage and intensive land use, it loses all structure and becomes strongly hydrophobic (Zeitz & Velty 2002). For the latter situation, the German soil taxonomy uses the term "strongly earthified". Bulk densities of 0.4 t m^{-3} are quite normal (Zeitz & Velty 2002, Schindler *et al.* 2003). Earthified peat probably contributes substantially to the average bulk density value of 0.27 t m^{-3} quoted by Leifeld *et al.* (2003) for peatlands under agricultural use in Switzerland.

Another relevant source of variation amongst peat types is the variety of natural peatland (mire) types which originally formed the peat. One method for classifying this variety involves assigning peatlands to different 'hydrogenetic mire types' (HGMTs) (Succow & Joosten 2001). Hydro-geomorphological (abiotic) characteristics, as opposed to ecological (biotic) features, are particularly useful for distinguishing between mire types when an overview is required, because they allow supra-regional comparisons (Semeniuk & Semeniuk 1997); for example, Succow & Lange (1984) were the first to coherently define HGMTs for North Germany and Poland. The three most extensive HGMTs in central Europe are 'percolation mires', 'terrestrialisation mires' and 'water-rise mires' (termed 'paludification mires' by Steiner (1992)). Around 86% of the peatlands in our study area originated as one of these three mire types (Berg *et al.* 2000).

It is possible to differentiate HGMTs on the basis of their characteristics and functions. Existing knowledge indicates that both the thickness of the peat layer and its stratigraphy are strongly dependent upon the HGMT (Succow & Lange 1984, Wassen & Joosten 1996, Joosten 2008). For example, the peat layers of terrestrialisation and percolation mires are often more than 6 m, and sometimes up to 12 m thick (Succow 1988, Succow 2001a, Succow 2001b); whereas water-rise mires are mostly shallow and rarely thicker than 2 m (Succow 1988). Therefore, we may expect substantial differences in carbon storage between HGMTs.

This article describes the development of a method capable of significantly improving the accuracy of national and regional peatland carbon stock estimates by estimating carbon storage in peatlands taking into account not only soil development processes but also the differences between the peat deposits formed within different HGMTs. Our approach involves combining information about extent, peat thickness and stratigraphy, land use and soil condition within a separate calculation for each HGMT.

METHODS

Study area and existing data

The study area is the German Federal Land of Mecklenburg-Western Pomerania (MWP). The *Map of Peatlands for MWP* (Lenschow 1997) shows the locations and areas of approximately 12,000 individual peatland sites (Figure 1), and usually identifies the HGMT. Data for approximately 2,000 peat profiles were gathered as part of a general surveying and mapping effort in the mid-1990s. For the determination of bulk density, soil sample rings with a volume of 100 cm^3 were used to take undisturbed samples in triplicate. Carbon contents were determined using a CNS Analyser (Variomax 2 Elementar, double determination). The total extent of each of the three HGMTs was established from the *Map of Peatlands for MWP* (Lenschow 1997), supplemented by direct reference to the soils database for HGMT specifications that were missing from the map.

Derivation of modal profiles

As there are no soils data for more than 10,000 individual peatland sites in MWP, the existing data were used to deduce the profile of the dominant soil of the soil mapping unit for each HGMT. The evaluation of soil profile data was based on the following hypotheses:

(1) every landscape is characterised by a typical HGMT;
(2) each mire type has a typical stratigraphy, i.e. a typical layering of peat and gyttja soils with specific thickness, and the peat types have typical degrees of decomposition;
(3) the HGMT influences the degree of pedogenesis so that the soil type consists of a typical horizon-substrate combination (HSC);
(4) HSCs differ in C content and quality; and
(5) linking the causal relationships allows the estimation of C storage and turnover.

A profile that describes part of a landscape (Bauriegel 2004) may either be defined as a 'modal profile' by experts during fieldwork or established by statistical analysis (Zeitz & Kühn 2000), and we chose the latter approach. The profiles were classified according to depth (≤ 0.7 m, ≤ 1.2 m, ≤ 2 m and > 2 m) and HGMT. Then, all profiles for

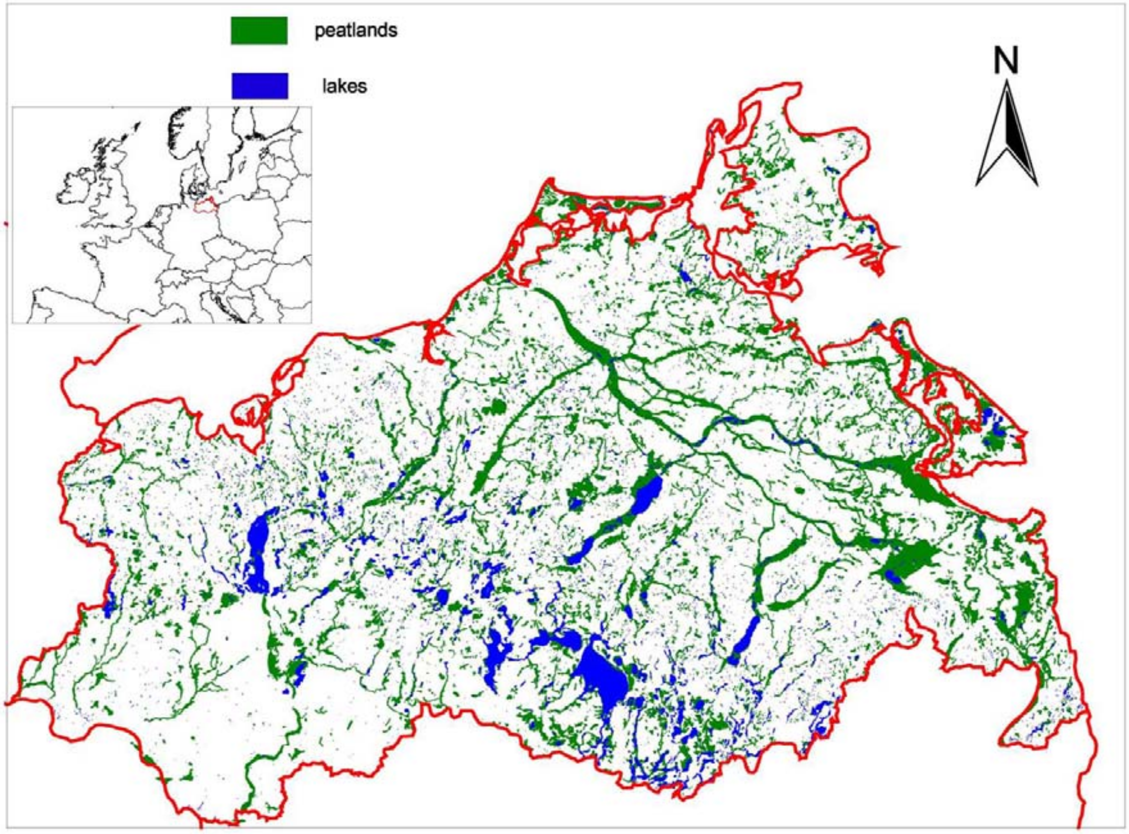

Figure 1. Distribution of peatlands (and lakes) in Mecklenburg-Western Pomerania. The inset map shows the location of Mecklenburg-Western Pomerania (outlined in red) within Europe.

each class were divided into horizons 0.1 m thick, the most frequent HSC for each horizon was established, and on this basis the modal profile for the HGMT was deduced. The 'typical' profiles were verified by expert judgement. The fraction of strongly earthified sites for each HGMT was obtained from the profile information. It was assumed that the effect of pedogenetic processes (shrinkage, swelling, biological oxidation) on soil properties was consistent for each peat type (Zeitz & Kühn 2000, Bauriegel 2004).

The amount of carbon stored in the area which is represented by a particular profile of the dominant soil of the soil mapping unit ($C_{org\ P}$) can be calculated as follows:

$$C_{org\ P} = \sum A_{HSC} * D_{HSC} * DBD_{HSC} * C_{org\ HSC} \qquad (1)$$

where A_{HSC} is the area (m²), D_{HSC} the thickness (m), DBD_{HSC} the bulk density (t m^{-3}) and $C_{org\ HSC}$ the organic carbon content (%) of the relevant HSC. The C storage of a HGMT is the sum of $C_{org\ P}$ for all dominant soils of the soil mapping units pertaining to the HGMT.

RESULTS

HSC properties

The bulk densities of strongly earthified and earthified HSCs (nHm/Ha and nHv/Ha) are 0.33–0.44 g cm^{-3}, and those of the peat crumb horizons which can often be found beneath, 0.25–0.41 g cm^{-3}. The values for peat shrinkage horizons at depths of 0.3–0.7 m are 0.14–0.17 g cm^{-3}; and for the slightly decomposed subsoil peats, 0.12–0.14 g cm^{-3} (Table 1). Finally, the bulk density of the gyttja soils found in terrestrialisation mires is typically 0.46 g cm^{-3} (0.25–0.82 g cm^{-3}). The median C_{org} content of individual HSCs varies between 22.1% and 45.7%. The degraded topsoil HSC has the lowest C_{org} content (22.1–28.5%), and the C_{org} content of the peat crumb horizons is 38.0–40.3%. The C_{org} content of deeper peats varies between 42.0 and 45.7%, and the median C_{org} content of the gyttja soils is 14.3% (Figure 2). Figure 3 shows the correlation between bulk density and C_{org} content (R^2= 0.645), omitting the data for gyttja soils. The C_{org} content (%) declines with increasing bulk density.

Table 1. Bulk density data for different horizon-substrate combinations (HSCs). Abbreviations for horizons: nHa: peat-crumb horizon; nHm: strongly earthified horizon; nHmp: strongly earthified horizon, ploughed; nHr: peat horizon below water table, reduced state; nHt: peat shrinkage horizon; nHv: earthified peat horizon. Abbreviations for substrates: Ha: amorphous peat; Hnr: sedge peat; Hnp: reed peat. N: number of samples; DD: Degree of Decomposition (von Post & Granlund 1926).

depth (m)	horizon	substrate	DD	N	bulk density values (g cm^{-3})				
					median	quartiles		range	
						lower	upper	min	max
0–0.4	nHa	Ha	H7–8	28	0.25	0.20	0.37	0.15	0.51
	nHm	Ha	H10	23	0.33	0.29	0.39	0.17	0.66
	nHmp	Ha	H10	28	0.41	0.36	0.49	0.21	0.69
	nHv	Ha	H10	32	0.44	0.33	0.53	0.20	0.69
0.3–0.7	nHa	Ha	H7–8	10	0.31	0.22	0.41	0.16	0.46
	nHr	Hnr	H3–4	15	0.15	0.14	0.17	0.11	0.27
	nHt	Hnr		60	0.14	0.12	0.16	0.06	0.30
			H5–6	48	0.17	0.14	0.19	0.07	0.30
0.7–1.2	nHr	Hnp	H3–4	14	0.13	0.12	0.13	0.07	0.16
		Hnr		26	0.14	0.12	0.15	0.07	0.19
	nHt			24	0.12	0.10	0.13	0.06	0.16
		Hnp	H5–6	8	0.15	0.14	0.17	0.10	0.20

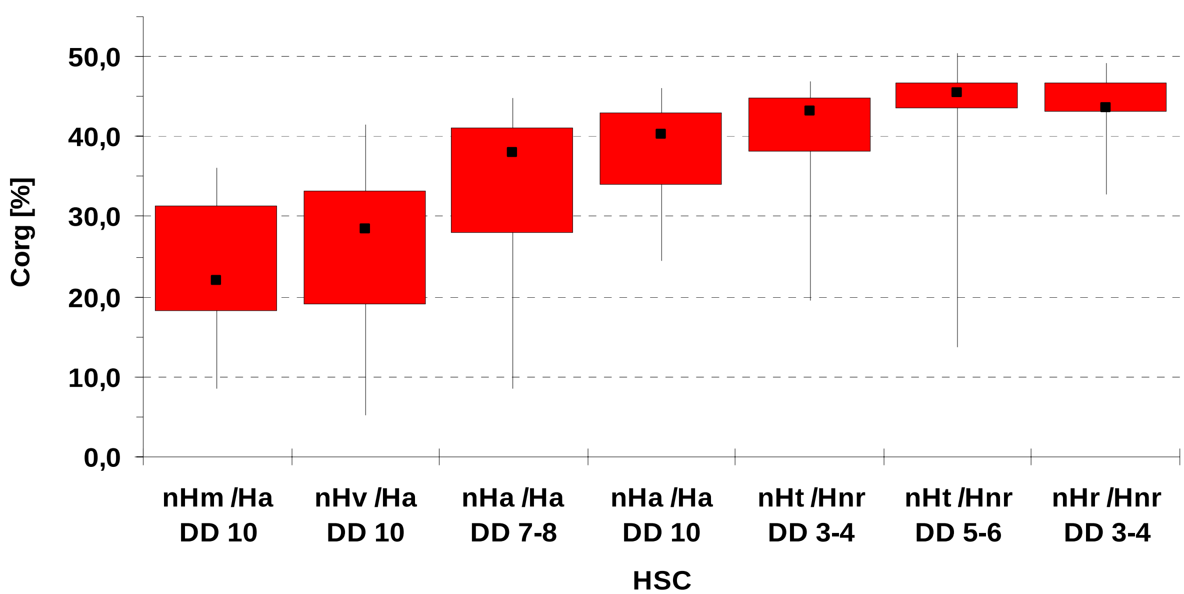

Figure 2. C_{org} values for fen HSCs in Mecklenburg-Western Pomerania. For key to HSCs, see legend to Table 1.

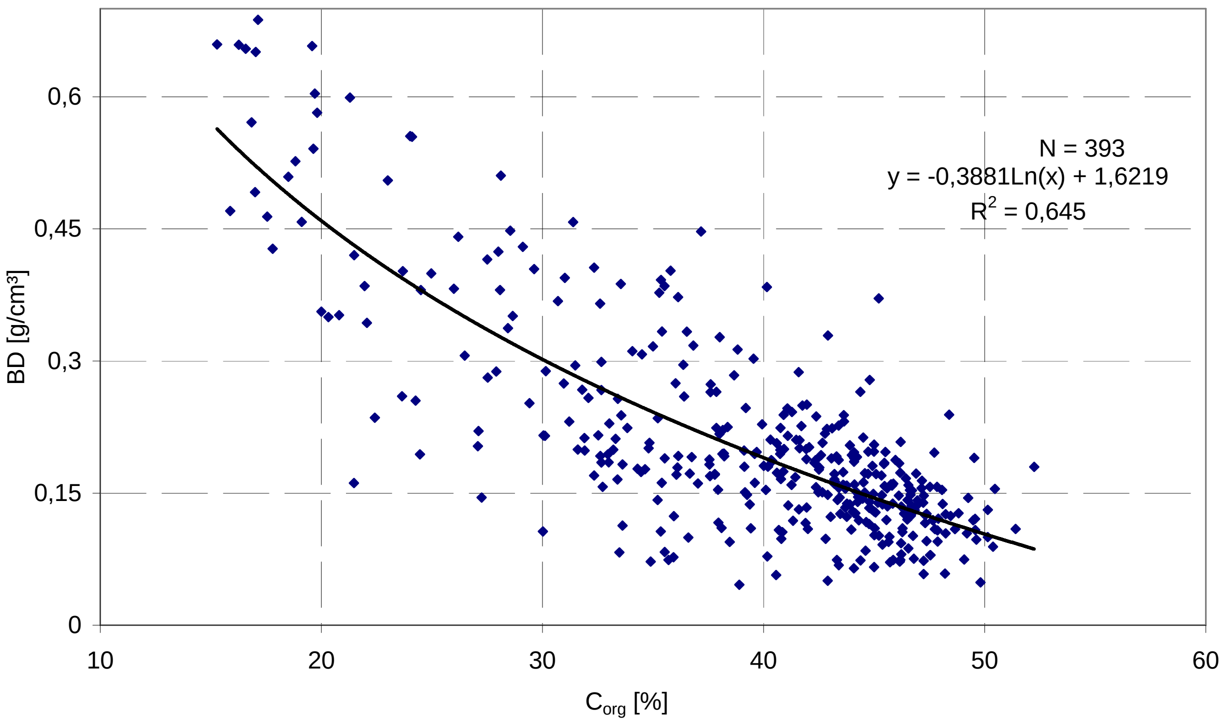

Figure 3. Correlation between dry bulk density and C_{org} content of peat (gyttja soils not included).

Characteristics of the HGMTs

Percolation-mire peatlands

Peatlands which originated as percolation mires occupy a total area of 112,685 ha, which is approximately 37% of the total peatland area in MWP. The peat layer on 22,618 ha of this area is no thicker than 1.2 m, and 1,262 ha remain in a condition close to the natural state. Five modal profiles for dominant soils of the soil mapping unit were identified. Earthified topsoils characterise 103,535 ha of the percolation-mire peatland, and strongly earthified topsoils occur on 7,888 ha. Beneath these layers (0.2 m thick), there are 0.1 m peat crumb horizons of highly decomposed, amorphous peat, which are underlain in turn by slightly to moderately decomposed sedge peat with shrinkage cracks up to 0.7 m depth (Table 2).

Table 2. Example modal profile for percolation-mire peatland.

Profiles: N=417			
depth (m)	**horizon**	**substrate**	**DD**
0.1	nHv	Hav	
0.2			
0.3	nHa	Haa	7–8
0.4	nHt	Hnr	5–6
0.5			
0.6			
0.7			
0.8	nHt	Hnr	3–4
0.9			
1.0	nHr	Hnr	3–4
1.1			
1.2			

Terrestrialisation-mire peatlands

The total area of peatlands which originated as terrestrialisation mires in MWP is 85,448 ha, and 3,332 ha remain in their natural state. Peat thickness exceeds 1.2 m on 59,616 ha. Of the degraded peatlands, 63,916 ha have earthified and 18,201 ha have strongly earthified upper layers (0.2 m thick). These are underlain successively by layers of (a) amorphous peat and (b) sedge peat with shrinkage cracks. Gyttjas occur at 0.8 m depth in areas with shallow peat (< 1.2 m thick), but usually at 1.0 m depth in thicker deposits. Seven modal profiles were identified for this HGMT. An example modal profile is given in Table 3, and Figure 4 shows a real profile which corresponds to the derived profile described in Table 3.

Table 3. Example modal profile for drained terrestrialisation mire.

Profiles: N=23			
depth (m)	**horizon**	**substrate**	**DD**
0.1	nHv	Hav	
0.2			
0.3	nHa	Ha	
0.4			
0.5	nHt	Hnr	3- 4
0.6	F	F	
0.7			
0.8			
0.9			
1.0			
1.1	Gr	s	
1.2			

Figure 4. Typical soil profile for a drained terrestrialisation mire, consisting of peat over calcareous gyttia.

Water-rise-mire peatlands

The total area of water-rise-mire peatlands in MWP is 47,019 ha, of which 34,110 ha have shallow peat layers and 11,310 ha have more than 1.2 m of peat. An area of 658 ha remains in a condition close to the natural state, but 15,281 ha have earthified topsoils and 30,139 ha have strongly earthified topsoils. Below the strongly and deeply degraded topsoils (0.3 m), there are horizons up to 0.3 m thick of amorphous peat with crumb structures. These are underlain by reed or sedge peats with shrinkage cracks due to drainage. Five modal profiles were identified for water-rise-mire peatlands. One of the derived profiles is shown in Table 4 and the corresponding real profile in Figure 5.

Table 4. Example modal profile for drained water-rise mire.

Profiles: N=27			
depth (m)	**Horizon**	**substrate**	**DD**
0.1	nHmp	Ham	
0.2			
0.3			
0.4	nHa	Haa	
0.5	nHt	Hnp	3- 4
0.6	Gr	s	
0.7			
0.8			
0.9			
1.0			
1.1			
1.2			

Figure 5. Typical soil profile of a drained water-rise mire.

Carbon storage in HGMTs

The percolation-mire peatlands store a total of 228 (208.4–246.2) Mt C_{org} (Figure 6, Table 5), of which 210.2 Mt C_{org} are allotted to earthified sites, 15.8 Mt C_{org} to strongly earthified sites and only 2.7 Mt C_{org} to natural percolation mires. Thus, the percolation-mire peatlands store 2,024 (1,925–2,136) t C_{org} ha^{-1} (Table 6). Carbon storage in the parts of the peat layers which are permanently or temporarily drained (the uppermost 70 cm only) is 70.4 Mt C_{org}. This is 30.9% of the total C_{org} contained in percolation-mire peatlands, even though the proportional volume is no more than 20%.

Carbon storage in terrestrialisation-mire peatlands (176.4 Mt) is similar to that in percolation-mire peatlands, but the range (83.4–238.2 Mt) is very high. Earthified terrestrialisation-mire peatlands store 132.9 Mt C_{org}, strongly earthified terrestrialisation-mire peatlands store 35.9 Mt C_{org}, and those which still are in a condition close to their natural state store 7.5 Mt C_{org}. Thus, terrestrialisation-mire peatlands store 2,068 (978–2,788) t C_{org} ha^{-1}. As in the case of percolation-mire peatlands, approximately one third (51.1 Mt, 28.8%) of the C_{org} in degraded terrestrialisation-mire peatlands is stored in the uppermost 70 cm of the peat layer.

Water-rise-mire peatlands store no more than 25.8 (20.5–30.9) Mt C_{org}, which corresponds to 548 (437–658) t C_{org} ha^{-1}. Most (22.8 Mt or 88.8%) of the C_{org} in water-rise-mire peatlands is stored in the uppermost 70 cm of the peat layer. Of this, 14.0 Mt is located in sites with strongly earthified topsoils, 8.7 Mt in earthified mires, and 0.6 Mt in those which remain in natural condition.

Altogether, the three most extensive HGMTs in MWP currently store approximately 430.3 Mt C_{org}. Roughly one-third of the carbon present on 80% of the total peatland area (144.4 Mt C_{org}) is stored in topsoil horizons which are influenced by mineralisation.

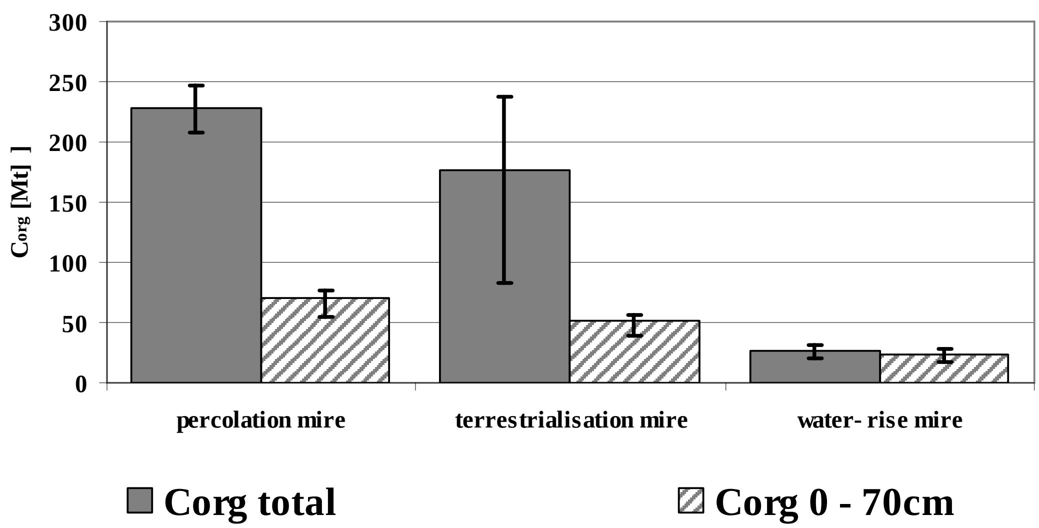

Figure 6. C_{org} storage (total and in the uppermost 70 cm) of different HGMTs in MWP.

Table 5. C_{org} storage in different hydrogenetic mire types (HGMTs).

HGMT	Total area (ha)	Total C_{org} (Mt)	C_{org} min (Mt)	C_{org} max (Mt)
Percolation mire	112,684	228.1	208.4	246.2
Terrestrialisation mire	85,448	176.4	83.4	238.2
Water-rise mire	47,018	25.8	20.5	30.9
Total	245,152	430.3	312.4	515.3

Table 6. C_{org} storage (t C_{org} ha^{-1}) in natural, earthified and strongly earthified sites belonging to the different hydrogenetic mire types (HGMTs).

HGMT	mean	natural	earthified	strongly earthified
Percolation mire	2,024	2,136	2,030	1,925
Terrestrialisation mire	2,068	2,263	2,080	1,975
Water-rise-mire	548	915	623	519

DISCUSSION

Stratigraphy

Most of the peatlands in MWP have been subject to intensive utilisation for at least two centuries. This is reflected in the horizon series and the soil characteristics. The results of profile analysis show quite clearly that water-rise mires are subject to particularly intensive utilisation. They are mostly shallow and, in contrast to percolation mires, easily drained. At drained sites, there is often no water table within the peat body in summer and early autumn, and consequently these peatlands are strongly degraded with extensive strongly earthified topsoils and highly decomposed amorphous peats to 60 cm depth. Percolation mires, which are constantly supplied with water from their catchments, are generally less intensively utilised, predominantly as grassland, and less degraded. The topsoils of utilised sites are mostly earthified, but there are often thick layers of slightly decomposed sedge peat beneath. Of the three HGMTs, terrestrialisation mires have the greatest proportion of surviving natural peatland, which is mostly located in small mires linked to inland water bodies. Other terrestrialisation mires have been intensively utilised in the past, sometimes agronomically, and these sites are mostly earthified. Approximately 18,000 ha are strongly earthified and typically have calcareous gyttja close to the surface.

Soil parameters

Peatland topsoils store large amounts of C_{org} due to their high bulk densities, even though half of their initial C_{org} content has been lost by mineralisation. Thus, more C_{org} is stored at depths of 0–70 cm than at 70–140 cm. Considerable amounts of carbon remain stored in areas which are temporarily drained even if they are subjected to intensive agricultural utilisation. This shows clearly how important it is to take soil development into account when estimating carbon storage. The C_{org} contents of the topsoils are well below the values of 50–54% which are usually quoted in other publications (compare e.g. Succow 1988, Naucke 1990, Gorham 1991, Kuntze 1993, Höper 2002, Byrne *et al.* 2004, Bradley *et al*. 2005 and Leifeld *et al.* 2003). Our results show that the topsoils of degraded peatlands - which make up 98% of all peatlands in Germany (Berg *et al.* 2000) - have C_{org} contents of 22–41%. The C_{org} contents of slightly to moderately decomposed peats which are influenced by drainage are also clearly lower than assumed by other authors. There are two reasons. First, the predominant HGMTs in MWP are fens dominated by more highly decomposed peats (H3–H6 according to von Post (1924)) with inherently low C_{org} content, partly due to enhanced mineralisation during their formation. Secondly, the alkaline groundwater which feeds these mires enhances mineralisation (Mueller *et al.* 2007a, 2007b). As a result of utilisation and, therefore, of settling and shrinkage processes due to drainage, the bulk densities of the topsoils are 2–4 times those assumed by other authors (Gorham 1991, Byrne *et al.* 2004, Bradley *et al*. 2005, Höper 2002) and 3–4 times those of the uninfluenced deep-subsoil peat layers (Schwärzel *et al.* 2002).

Other authors have already pointed out that there is a strong correlation between the bulk density and C_{org} content of peats (Leifeld *et al*. 2003, Konopatzky 2005, Chapman 2008). This correlation can be used to fill data gaps with the help of pedotransfer functions (Chapman 2008). However, the extrapolation process must take into account the significant differences between bog and fen peats.

Methodology

The extent of each peatland type was obtained from the *Map of Peatlands for MWP* (Lenschow 1997) which assigns polygons of different areas to the various HGMTs, and the data were verified using the soils database. However, because these sources contain no information about the distribution of peat thickness and the profile data cover only part of the focus area, we also referred to literature sources (Berg *et al.* 2000). Thus, the peat thickness distribution for each HGMT cannot be verified at present and the assumptions adopted must be regarded as possible sources of error in the carbon storage calculations. Furthermore, the different HGMTs are often strongly interlocked within the landscape; for example, percolation mires often develop on top of terrestrialisation mires, peatlands on river banks are often influenced by flooding, and small spring fens are often located at the margins of fen complexes. Our working scale precluded incorporation of these small-scale variations in the data, and the dominant HGMT was assumed to represent the whole of each mapped polygon.

The advantage of basing carbon stock calculations on the profile of the dominant soil of each mapping unit is that it can be used for all sub-areas, so that carbon storage can be estimated with little effort. However, these profiles are no more than generalisations of possible HSCs and do not represent the actual heterogeneity of peatlands. The inaccuracy can be corrected only by using data which allow each polygon to be represented in three dimensions.

Carbon storage in the HGMTs

As expected, most C_{org} is stored in percolation-mire and terrestrialisation-mire peatlands, and the storage per unit area is almost identical for these two HGMTs (2.024 and 2.068 t C_{org} ha^{-1} respectively). Almost all of the carbon in percolation mires is stored in peats, whereas limnic sediments are important for carbon storage in terrestrialisation mires (Kortelainen *et al.* 2004). Although the role of gyttja soils in carbon storage within peatlands and lakes has been long neglected (Einsele *et al.* 2001, Kortelainen *et al.* 2004, Cole *et al.* 2007), the median bulk density (0.46 g cm^{-3}) and C_{org} content (14.3%) values determined here are comparable to those quoted by other authors (Chmieleski 2006). On an area basis, the carbon storage in water-rise-mire peatlands (548 t ha^{-1}) is no more than 25% that in the other two HGMTs. However, this HGMT is extremely important in terms of carbon release potential because water-rise mires become highly degraded under the typical intensive uses with water table 40–70 cm below the ground surface (Berg *et al.* 2000).

The values for carbon stocks in percolation-mire and terrestrialisation-mire peatlands returned by the present study are considerably larger than those calculated previously (see Joosten & Couwenberg 2008 for a summary). As pointed out by Chapman (2008) in calculating the carbon storage of Scottish peatlands, the two crucial factors are peat thickness and pedogenesis, which in turn influences bulk density and C_{org} content.

CONCLUSIONS

The results show that substantially better-differentiated estimates of carbon storage in peatlands can be derived if HGMT and pedogenesis are taken into account. This approach makes it possible to calculate the specific stratigraphy of the HGMT and how the C_{org} content has been altered through pedogenesis and changes in bulk density. The percentage carbon content of degraded topsoils is considerably smaller than that of less decomposed peats; on the other hand, this is partly compensated by their very high bulk densities which arise through settling and shrinking processes due to drainage. Thus, the topsoils of degraded peatlands still contain very high amounts of carbon, and indeed much more than is present in the unaffected peat beneath.

Published calculations of carbon storage based on bulk density and carbon content values representative of near-natural sites noticeably under-estimate the true carbon content of peatlands. Calculations of carbon stocks in central European peatlands should better incorporate information on soil development and HGMT, which allows the derivation of considerably more precise estimates of total peatland carbon stocks, as well as breakdowns to provide e.g. an estimate of how much carbon is stored in the areas affected by drainage and increased peat mineralisation.

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