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CARBSTOR – A NEW METHOD QUANTIFYING C-STORAGE AND EVALUATING C-RELEASE POTENTIALS OF SPECIFIC PEATLAND TYPES

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SUMMARY

Existing data, concerning carbon (C) budgets of peatland soils, vary significantly and often do not consider differences in peat quality and quantity. The new developed CARBSTOR tool takes these differences into account. A GIS-based mire type classification was developed to classify different peatland polygons into dominant hydrogenetic mire types (HGMT). By using idealized soil profiles, classified HGMT can be combined with typical amounts of stored C and potential C loss. These amounts were determined by own laboratory work and data analyses. CARBSTOR provides an innovative, helpful tool to estimate amounts of stored C and potential C-release of specific peatland landscapes.

KEY WORDS: peatland soils, hydrogenetic mire types, GIS-based peatland classification, C-vulnerability, soil-horizon-combination

INTRODUCTION

Considering individual positions within a certain landscape, peatlands can be classified into different hydrogenetic mire types (HGMT) (Succow & Joosten 2001, Joosten & Clarke 2002, Koster & Favier 2005, Mueller et al. 2007, Zauft et al. 2010). This classification system is based on individual hydrogeologic quality which controls water regime, nutrient and oxygen supply and determines the peat forming vegetation and the quality and quantity of peat deposits and soil organic matter (SOM) (Couwenberg & Joosten 2001). These deposits vary in specific stratigraphic sequences, peat thicknesses, stages of primary peat decomposition during formation, botanical origin of peat and chemical quality (e.g. Cameron et al. 1989).
Beside natural local influences of site on SOM quality during mire formation, anthropogenic impact (e.g. through drainage, peat-cutting and/or agricultural use) can influence and alter peat and SOM quality and quantity drastically. Especially in densely populated Middle and Western Europe, most of the former natural peatlands are strongly influenced by anthropogenic impact. In Germany about 1% of formerly pristine and undisturbed peatland areas are still intact (Joosten & Couwenberg 2001).

This leads to rapid carbon (C) losses out of peatlands and increased net releases of greenhouse gases (GHG) into the atmosphere. By using adapted management strategies it is attempted to curb these increased emissions. Therefore, detailed knowledge and reliable data of C-storage and C-release are required. Previous estimations of C-cycling in peatlands differ widely. In

Germany, estimated amounts of C stored in peatlands vary between 1.2 and 2.4 Gt (Drösler et al. 2009). Actual calculated rates of GHG emissions out of German peatlands are assumed to represent 2.8 % (Höper 2007) to 5.1 % (Drösler et al. 2011) of total national emissions. The vast majority of these studies do not consider soil forming processes and/or stratigraphy. Great differences in individual C storage between different HGMT can be explained by different peat thicknesses, e.g. typical 'percolation mires' store up to 10 times more carbon than shallow peats of 'paludification mires' (Zauft et al. 2010). Thus, individual HGMT's and their actual pedogenetic attributes have to be taken into account to create accurate C budgets. Time and money consuming, detailed soil mapping and laboratory analyses are often infeasible. As a consequence, a tool has to be developed to classify peatlands into different HGMT and different classes of vulnerability (according to Succow & Joosten 2001, Michaelis 2002). The aim of this study is to introduce the CARBSTOR (CARBon STORage) procedure. This new method contains a web-based decision support system to classify unknown peatland (GIS-) polygons into dominant HGMT's and tries to specify their substrate dependent C-storage and potential C-release.

MATERIALS AND METHODS

Development of GIS-based mire type classification

The GIS-based mire type classification was developed iteratively by the implementation of algorithms. At first, different landscape characteristics of HGMT's were analysed and assessed, with respect to digital implementation. This was done by using geodata and existing literature ('*cognitive algorithm*'). In a second step, the resulting classification algorithm was tested and modified by using geostatistical analyses ('*empirical algorithm*'). This was done by evaluation of existing soil mapping data, containing information about dominant HGMT's. The classification criteria were tested and evaluated with regard to significance and hierarchy by explorative data analyses (frequency and cluster analyses). As a result, a 'harmonized algorithm' was received, which was validated through randomly chosen peatland polygons. This mire type classification system has been developed as decision support system for application in Germany.

Soil profiles

With help of previous studies, dealing with peatland classification (Eggelsmann 1967, Zeitz et al. 2005), evaluation of backfile drilling data and additional expert knowledge, idealized soil profiles (ISP) for important German HGMT's were identified. These ISP represent the most frequently occurring fen types ('terrestrialization mires', 'percolation mires' and 'paludification mires') as well as three different bog types. The ISP differ in peat thickness, stratigraphy and quality (botanical origin, stages of decomposition, intensity of drainage). Every peat horizon was diagnostically described through 'horizon-substrate combinations' ('HSC', for details see Zauft et al. 2010), including peat quality and degree of decomposition according to von Post (1924).

C-storage and C-release potentials

Amounts of stored C in HSC of the idealized soil profiles were calculated through determination of total organic carbon (TOC) concentrations and bulk densities. This was done by own field work, laboratory analyses and data from other studies. Through representative landscape analysis we tried to identify different sampling sites, including the evaluation of backfile data with more than 30.000 ha and 3.000 soil profiles (for details see Schultz-Sternberg et al. 2000 and Zeitz et al. 2008). Afterwards, calculated C amounts can be combined with the identified ISP and the individual area size (e.g. mire polygon) to get information about amounts of stored C in different peatland landscapes.

To estimate potential C-release of a peatland landscape, concentrations of hot-water soluble carbon (C_{hwe}) were determined instead of TOC concentrations. For that purpose, a modified extraction procedure (according to Schulz et al. 2004) was carried out (Heller & Zeitz 2012). The potential C-release was estimated for the topmost meter of the ISP, due to land-use induced influences, which generally occur in upper soil layers.

RESULTS

GIS-based mire type classification

The following parameters were important to characterize HGMT: Peat substrate, position within a geographical landscape (young or old morainic landscape, marine/limnic/fluviatile systems, floodplains, mountainous topography), peat thickness, occurrence of gyttja, information of subsoil (obstructed permeability), slope, pressurized water or springs.

All parameters described above can be defined by available basic geodata, like geological maps, soil maps, digital terrain model (slope). If additional digital drilling data or mapping data existed, further information were used for the particular mire polygon.

Clearly defined GIS methods are required to ensure comparability in the application of this mire type classification system. As a result, a dichotomous decision system (decision tree with Yes/No queries) was developed. In order to prevent the problem of incomplete covering of available geodata, a successive algorithm was created. Thus, a step-by-step classification into a dominant HGMT which is easy to follow was possible. Queries about easily available information (basic geodata), e.g. geographical position, have highest priority. Special information of scarcely existing digital drilling or peatland mapping data will be integrated after several decision steps. The mire type classification system is strongly dependent on the quality and availability of digital data. Thus, conversion of analogue data into digital databases is necessary. Furthermore, precise documentation during soil mapping campaigns (e.g. accurate recording throughout a complete peat profile until the mineral subsoil is reached) should be considered for future field works.

Idealized soil profiles (ISP)

As an example, ISP of three important fen types are shown in Fig. 1. The identified ISP reflect an average of specific peat deposits (expressed as HSC), typically occurring in HGMT. They differ in peat thicknesses and stratigraphy. All ISP are characterized by anthropogenic impact through drainage which led to degradation of topsoils. A ‘secondary soil development’ changed soil chemical and physical characteristics (for details see e.g. Zeitz & Velty 2002, Illnicki & Zeitz 2003, Holden et al. 2006). Beneath the degraded topsoils, *Carex*-peats in different states of soil development can be observed.

1a: Percolation mire (idealized soil profile)

Depth [dm]	Horizon	Substrate	DD
1	earthified	amorphous peat	9-10
2			
3	aggregated	*Carex*-peat	7-8
4	shrinked	*Carex* -peat	5-6
5			
6			
7			
8	shrinked	*Carex* -peat	3-4
9			
10	permanently water-saturated	*Carex* -peat	3-4
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
… 40	permanently water-saturated	… *Carex* -peat	… 3-4

1b: Terrestrialization mire (idealized soil profile)

Depth [dm]	Horizon	Substrate	DD
1	earthified	amorphous peat	9-10
2			
3	aggregated	*Carex* -peat	7-8
4			
5	shrinked	*Carex* -peat	3-8
6			
7			
8			
9			
10			

1c: Paludification mire (idealized soil profile)

Depth [dm]	Horizon	Substrate	DD
1	strongly earthified	amorphous peat	9-10
2			
3			
4	aggregated	amorphous peat	(9-10)
5			
6			
7	shrinked	*Carex* -peat	5-6
8			
9			

Fig. 1a-c: Idealized soil profiles of most frequently occurring fen types, expresses as horizon-substrate combinations together with degree of decomposition (DD) according to von Post (1924).

C-Storage and potential C-release

Average C-storage (calculated from bulk densities and TOC-concentrations) and potential C-release (calculated from bulk densities and C_{hwe}-concentrations) for the HSC of a terrestrialization mire are displayed in Fig. 2 and Fig. 3. All data is presented on a dry mass basis for peat layers of 1 dm thickness and one hectare area size.

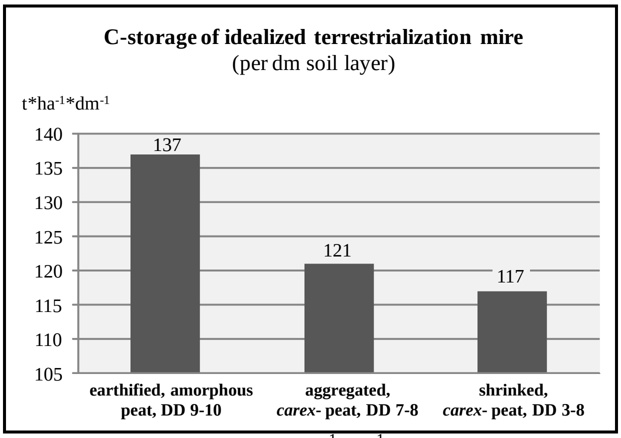

Fig. 2: Average C-storage [$t*dm^{-1}*ha^{-1}$] of different peat horizons, occurring in an idealized soil profile of a terrestrialization mire. All data is presented for peat layers of 1 dm thickness and one hectare area size.

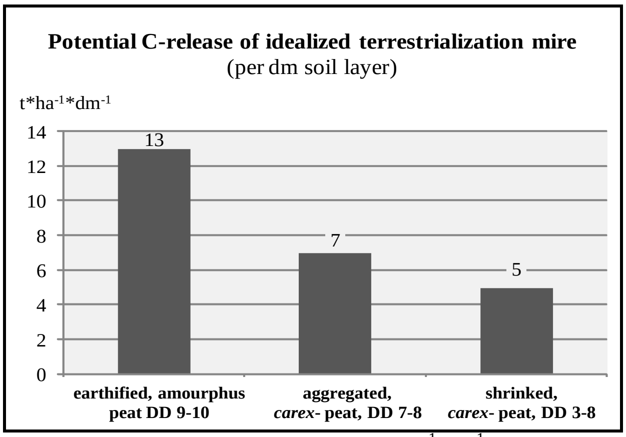

Fig. 3: Average potential C-release [$t*dm^{-1}*ha^{-1}$] of different peat horizons, occurring in an idealized soil profile of a terrestrialization mire. All data is presented for peat layers of 1 dm thickness and one hectare area size.

Despite of lower relative TOC concentrations (data not shown), the degraded topsoils show higher amounts of stored C and potential C-release than the loose, porous and less decomposed subsoils, due to higher bulk densities. By multiplication of C-storages and potential C-releases of HSC (see Fig. 2 and 3) with given peat thicknesses of a ‘terrestrialization mire’ (see Fig. 1), this HGMT has an average C-storage of 1218 $t*ha^{-1}$ and a potential C-release of 70 $t*ha^{-1}$. To estimate C budgets of particular terrestrialization mires, these data can be multiplied with individual surface area.

Due to relatively adequate data quality and quantity for bulk densities and TOC concentrations (more than 1200 backfile data records and own analyses), CARBSTOR allows quite clear statements for C-storage. Quality of information about potential C-releases in different peatlands leaves much to be desired due to insufficient data for C_{hwe} (no backfile data available).

CONCLUSION

The new CARBSTOR method allows to estimate amounts of stored C and a potential C-release of specific HGMT. Estimation of vulnerability and identification of risk areas for certain peatlands becomes possible. Thus, CARBSTOR provides a helpful tool and a decision support for execution authorities and landscape planners within the framework of required climate reporting and carbon fixation. An increase in available data (e.g. conversion of analogue backfile data into digital data, increase of data on TOC and C_{hwe} concentrations) should be the aim of future research to strengthen quality improvement of C budgeting in peatlands. An increased database enables identification of different C-release classes and a stronger preciseness supporting the CARBSTOR method.

The CARBSTOR tool is a web-based application. It will be available online, together with additional and more detailed information, with open access to the public in spring 2012 (www.carbstor.de).

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REFERENCES

Berg E, Jeschke L, Lenschow U (2000) Das Moorschutzkonzept Mecklenburg-Vorpommern. TELMA 30:173-220 (in German)

Cameron CC, Esterle JS, Palmer CA (1989) The geology, botany and chemistry of selected peat-forming environments from temperate and tropical latitudes. Int J Coal Geol 12:105-156

Couwenberg J, Joosten H (2001) Das Beispiel Deutschland. In: Succow M, Joosten H (eds) Landschaftsökologische Moorkunde, 2nd edn. Schweizerbart, Stuttgart, pp 409–411 (in German)

Drösler M, Freibauer A, Gensior A, Adelmann W, Augustin J, Bergmann L, Beyer M, Förster C, Giebels M, Hahn M, Höper H, Kantel-hardt J, Liebersbach H, Minke M, Petschow U, Schaller L, Schägner P, Sommer M, Wehrhan M (2009) Schutz vorhandener Kohlenstoffspeicher: Klimafreundliche Moornutzung. In: Aktiver Klimaschutz und Anpassung an den Klimawandel - Beiträge der Agrar- und Forstwirtschaft. Tagungsband vTI 15./16. Juni 2009, Braunschweig, pp 26-27 (in German)

Drösler M, Freibauer A, Adelmann W, Augustin J, Bergman L, Beyer C, Chojnicki B, Förster C, Giebels M, Görlitz S, Höper H, Kantelhardt J, Liebersbach H, Hahn-Schöfl M, Minke M, Petschow U, Pfadenhauer J, Schaller L, Schägner P, Sommer M, Thuille A, Wehrhan M (2011) Klimaschutz durch Moorschutz in der Praxis. Ergebnisse aus dem BMBF-Verbundprojekt „Klimaschutz-Moorschutzstrategien“ 2006-2010 (in German)

Eggelsmann R (1967) Oberflächengefälle und Abflussregime der Hochmoore. Wasser und Boden 19:247–252 (in German)

Heller C, Zeitz J (2012) Stability of soil organic matter in two northeast German fens: The influence of site and soil development. J Soil Sediment. DOI: 10.1007/s11368-012-0500-6

Holden J, Chapman PJ, Lane SN, Brookes C (2006) Impacts of artificial drainage of peatlands on runoff production and water quality. In: Martini IP, Martínez CA, Chesworth W (eds) Peatlands: Evolution and records of environmental and climate changes. Elsevier, Amsterdam, pp 501-528

Höper H (2007) Freisetzung von Treibhausgasen aus deutschen Mooren. Telma 37:85-116 (in German)

Ilnicki P, Zeitz J (2003): Irreversible loss of organic soil functions after reclamation. In: Etienne LE, Ilnicki P (eds) Organic soils and peat materials for sustainable agriculture. CRC Press, Boca Raton, pp 15–32.

Joosten H, Clarke D (2002) Wise use of mires and peatlands. International Mire Conservation Group and International Peat Society, Totnes, Devon

Joosten H, Couwenberg J (2001) Das Beispiel Europa. In: Succow M, Joosten H (eds) Landschaftsökologische Moorkunde, 2nd edn, Schweizerbart, Stuttgart, pp 406–409 (in German)

Koster EA, Favier T (2005) Peatlands, past and present. In: Koster, EA (ed.): The physical geography of Western Europe. Oxford University Press, Oxford, pp 161–182

Landgraf L (2009) Moore in Brandenburg und Berlin. Naturmagazin Berlin-Brandenburg, 3:4-8 (in German)

Michaelis D (2002) Die spät- und nacheiszeitliche Entwicklung der natürlichen Vegetation von Durchströmungsmooren in Mecklenburg-Vorpommern am Beispiel der Recknitz. Dissertationes Botanicae, vol. 365, Berlin (in German)

Mueller L, Wirth S, Schulz E, Behrendt A, Hoehn A, Schindler U (2007): Implications of soil substrate and land use for properties of fen soils in North-East Germany Part I: Basic soil conditions, chemical and biological properties of topsoils. Arch Agron Soil Sci 53(2):113–126

Rosskopf N, Zeitz J (2009) C-Speicherung und C-Freisetzungspotential der hydrologisch-genetischen Moortypen „Durchströmungsmoor“ und „Versumpfungsmoor“. In: Tagungsbeitrag zur Jahrestagung der DBG, Kommission V: Böden - Eine endliche Ressource. DBG, Bonn (in German)

Schulz E, Deller B, Hoffman G (2004) Heißwasserextrahierbarer Kohlenstoff und Stickstoff. In: VDLUFA (ed) Methodenbuch I, VDLUFA – Verlag, Bonn (in German)

Schultz-Sternberg R, Zeitz J, Landgraf L, Hoffmann E, Lehrkamp H, Luthardt V, Kühn D (2000): Niedermoore in Brandenburg. TELMA 30:1-34 (in German)

Succow M (1988) Landschaftsökologische Moorkunde (1st edn). VEB Fischer, Jena (in German)

Succow M & Joosten H (2001): Landschaftsökologische Moorkunde (2nd edn). Schweizerbart, Stuttgart (in German)

von Post L (1924) Das genetische System der organogenen Bildungen Schwedens. Comité international de Pédologie, IVème commission pour l‘Europe. 22:287–304 (in German)

Zauft M, Fell H, Glaßer F, Roßkopf N, Zeitz J (2010) Carbon storage in the peatlands of Mecklenburg- Western Pomerania, northeast Germany. Mires and Peat 6:1-12

Zeitz J, Fell H, Zauft M (2005) Entwicklung einer Methode zur Beschreibung flächenrepräsentativer Leitböden der Moore. unpublished. (in German)

Zeitz J, Velty S (2002) Soil properties of drained and rewetted fen soils. J Plant Nutr Soil Sc 165(5):618–626

Zeitz J, Zauft M, Roßkopf N (2008) Use of stratigraphic and pedogenetic information for the evaluation of carbon turnover in peatlands. In: Farrell C, Feehan J (Eds.) Proceedings of 13th International Peat Congress, Vol. 1, Tullamore, pp. 653-655