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Preliminary estimate of long-term carbon accumulation and loss in 25 boreal peatlands

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Abstract

The rate of carbon accumulation (RCA) was studied stratigraphically in individual vertical cores representing 25 mires in Finland, Estonia and Maine, USA. Carbon 14-datings (325 in total) were used for dating long cores encompassing all or most of the Holocene: **apparent** long-term RCA.

The apparent long-term RCA (g m^{-2} a^{-1}) in Finnish raised bogs and fens ranged from 13 to 41 and from 8 to 25, respectively, and in Maine bogs from 20 to 26 and in a single fen 27. Between and within core variations were great.
In Finnish mires the **true** RCA, as derived from Clymo's peat accumulation model for long cores, was usually about 2/3 of the apparent long-term RCA. A change from intensive decay in the surface layers to very slow decay in deeper peat layers was dated to between some 300-500 years ago.

INTRODUCTION

The rate of carbon accumulation (RCA) at given site of a mire can be studied from dated peat columns with known (dry) bulk density and carbon content. If the profile is encompasing the whole peat stratum, an **apparent** long-term carbon accumulation and carbon loss can be calculated from these parameters (equations 1 and 2). Because the slow, but continuous decay in the anoxic deeper peat has been ignored in this approach, the **true** rate of carbon accumulation is lower (eq. 3, acc. to Clymo, 1984).

(1) long-term (apparent) peat accumulation rate:
$A = r \times \sigma$, where
A = dry mass accumulation (kg m^{-2} a^{-1})
r = net rate of height increment (mm a^{-1})
σ = bulk density of peat, dry (g cm^{-3})

(2) long-term loss of organic matter : $L = 1-M/(TxP)$, where
L = loss (in fraction) of original organic matter produced
M = cumulative mass of organic matter above a given depth (g m^{-2})
T = age of the same level (M) (a)
P = rate of current or estimated production of organic matter (g m^{-2} a^{-1})

(3) net rate of peat carbon accumulation: $A = pe^{-\alpha t}$, where
A = net rate of dry mass accumulation ($g\ m^{-2}\ a^{-1}$)
p = current rate of dry matter addition ($g\ m^{-2}\ a^{-1}$)
α = decay coefficient as a proportion (a^{-1})
t = time (a).

MATERIAL AND METHODS

The material from Finland and Estonia consists of 21 radiocarbon dated long cores (chiefly unpublished peat data by the authors and Dr. Mirjami Tolonen, University of Helsinki). Valuable unpublished data were given by Ms. Liisa Ikonen, Geological Survey of Finland. The material from Maine, USA, includes five radiocarbon dated long cores (Tolonen et al 1988). The total number of 14C datings is 327. The stratigraphical methods have been described in Tolonen et al 1992.

RESULTS AND DISCUSSION

Apparent long-term accumulation and decay

In Finland and Estonia, the long-term accumulation rate of carbon ($g\ m^{-2}\ a^{-1}$, Table 1) was in Finland higher in *Sphagnum* peats (the average of the averages): 20.6, n= 13 (range 12.9 - 40.6) than in sedge peats: 14.1, n= 6 (range 8-24.9). In a drained spruce mire (Nr 20), the average was 24.0 (S.D. 5.8).

The long-term RCA was studied by Tolonen et al.(1992b) in peat layers deposited above a synchronous fire horizon about 100 cm below the present surface. It was followed along a 200 m long transect in Lakkasuo mire. The fire was dated to 1040$\pm$90. As expected, the average apparent RCA was higher in layers in these younger layers than in the older ones (Alm et al. 1992). On the undrained part of this bog area the RCA was 33.6 $\pm$ 0.7 $g\ m^{-2}a^{-1}$ (SE, n=25) and it did not statistically differ from the RCA in the area drained 30 years ago: 35.0 $\pm$0.6 $g\ m^{-2}a^{-1}$ (n=19).

In southern Lapland the long-term height increment of peat usually ranged from 0.1 to 0.4 mm a^{-1}, resulting in very low RCA.
The long-term RCA for bogs and fens in Maine came close to the Southern Finnish ones, being on average 20.5 to 25.8 $g\ m^{-2}\ a^{-1}$ in four ombrotrophic bogs and 26.9 g in one sedge fen (Table 1).

True rate of carbon accumulation and and loss

In *Sphagnum* bogs of Finland and in one aapa fen (numbers 6,14,15,16 and 22 in Table 1), the true accumulation values of carbon (eq 3) were about 2/3 of the long term averages in the same profiles. This factor of 2/3 reflects the approach to a steady state, and may be compared with 4/5 used by Gorham (1991). Applying the factor 2/3 for all long term accumulation values, gives a mean of the true carbon accumulation as follows (S.D. in parentheses):

Sphagnum bogs 14.7 $g\ m^{-2}a^{-1}$, (5.4, range 8.6-27.2)
Sedge mires 9.5 $g\ m^{-2-1}$, (4.2, range 5.4-16.7)

In the raised bog Big Heath, Maine, the true RCA was 10.1 g m^{-2} a^{-1}, which was about 50 % of the long-term RCA for the past 7500 years (Table 1). The calculated decay, 20.9 g m^{-2} a^{-1}, was about 69 % of the carbon input into the catotelm.

A change from intensive decay in the surface layers (cf. Clymo 1984, Damman 1988) to almost constant slow decay in the catotelm was dated to between some 300-500 years (Fig. 3).

CONCLUSIONS

1. Apparent long-term carbon accumulation rates for peat in the catotelm appear to be usually 1.25-1.50 times the true carbon accumulation rates. One way for generalization of the results over the whole boreal area, is to establish useful and practical models that explain the regularities both in the bulk density and height increment of peat. - The lateral expansion of the mires in different time period should be condidered, as well (cf. Elina et al 1984)

2. The impact of the greenhouse effect on the net rate of carbon accumulation in peats can be estimated by means of paleoecology provided that the zonation/climate relationships and the history of mires are known and the controlling factors are understood. The former relationships are reasonably well known by now (Solantie 1986). The current research program SUOSILMU, "The Carbon Balance of Peatlands and Climate Change" in Finland is producing much new information about the less well-known functions of mire ecosystems.

3. Presumably the proposed warming will move the common area of *Sphagnum* bogs (raised bogs) northwards and result in an increase in the total accumulation of carbon, provided precipitation stays similar to the present conditions (that is not known). Neither, we do not know, how much the increase in decay in southern peatlands could compensate for this probable increase in the north.

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	Mire	Locat. N.lat	Site type	(1) m	(2) mm a^{-1}	(3) g $m^{-2}a^{-1}$	(4) g g $m^{-2}a^{-1}$	(5) g $m^{-2}a^{-1}$	(6) g $m^{-2}a^{-1}$
1	Silmäsvuoma	67°33'	RiL	1,7	0,18	9,6 (0,9)	4 - 60	10.7	0,4
2	Ahvenjärvenvuoma	67°34'	RaN	3,7	0,35	16,8 (4,7)	10 - 22	-	-
3	Haukkarimpi	66°21'	RiL	1,9	0,18	10,3 (2,6)	5 - 20	-	-
4	Puohtinsuo	62°45'	RhRiN	4,3	0,43	15,8 (3,3)	8 - 37	-	-
5	Häädetkeidas lagg	62°03'	LkN	1,6	0,19	8,0 (1,4)	6 - 15	-	-
6	Suurisuo	61°00'	RhSN	3,7	0,73	24,9 (7,8)	15 - 30	17,7	14,3
7	Korkianeva	62°45'	RaLkN	3,4	0,57	20,2 (8,9)	13 - 31	9,3	19,8
8	Linnansuo	62°32'	KeR	3,1	0,32	13,9 (4,9)	11 - 16	-	-
9	Ylimysneva	62°08'	RaTR	2,4	0,26	12,9 (3,1)	11 - 44	-	-
10	Häädetkeidas	62°03'	KeR	5,4	0,54	20,8 (5,9)	11 - 40	-	-
11	Kunonniemensuo	62°05'	IR	4,3	0,60	18,1 (11,0)	7 - 24	8,1	9,8
12	Pesänsuo	61°16'	KeR	6,1	0,66	25,0 (11,0)	9 - 118	-	-
13	Lakkasuo	61°47'	RaR	3,3	0,53	14,6 (2,6)	11 - 20	-	-
14	Kaurastensuo	61°01'	KeR	5,2	0,53	18,3 (6,9)	5 - 42	10,9	7,1
15	Laaviosuo	61°01'	RaR	5,4	0,53	20,8 (10,3)	5 - 30	12,8	17,2
16	Varrassuo	61°00'	KeR	4,4	0,66	17,2 (4,7)	6 - 50	11,1	17,5
17	Kurkisuo	60°34'	RaTR	4,7	1,15	40,6 (13,3)	22 - 71	-	-
18	Punassuo	60°14'	KeR	4,9	0,56	19,5 (7,0)	16 - 40	-	-
19	Munasuo	60°05'	RaN	6,4	1,36	35,3 (8,6)	14 - 66	10,3	28,7
20	Pukkilansuo, Salo	60°20	VK, oj.	2,1	0,32	24,0 (5,8)	8 - 56	-	-
21	Torvströmossen	60°11	IR	4,5	0,57	20,1 (4,0)	16.- 60	-	-
22	Nigula Raba	57°40'	KeR	5,3	0,66	29,5 (6,9)	9 - 112	23,0	12,5
23	Crystal Bog	45°18'	"KeR"	6,0	0,66	23,5 (10,4)	15 - 58	-	-
24	Crystal Fen	45°18'	"VL"	4,1	0,44	26,9 (9,8)	13 - 58	-	-
25	Caribou Bog	45°02'	"IR"	6,4	0,64	23,1 (10,8)	12 - 93	-	-
26	Great Heath	45°00'	"RaN"	7,8	0,76	25,8 (11,0)	13 - 33	-	-

Table 1. **Carbon accumulation in 26 peat profiles from Finland, Estonia and Maine. Finnish abbreviations of the site types, cf. Eurola et al. 1984, in: Moore, P.D. (ed), European mires, 11-117. Academic Press, London. Explanation of the columns: Thickness of peat (1); mean height increment (2); mean (S.D. in parentheses) apparent long-term accumulation rate of carbon (3) and its range (4) in the different sections within the core (both according to eq.1); current true rate of carbon accumulation (5) and decay (6) (both accordig to eq.3).**

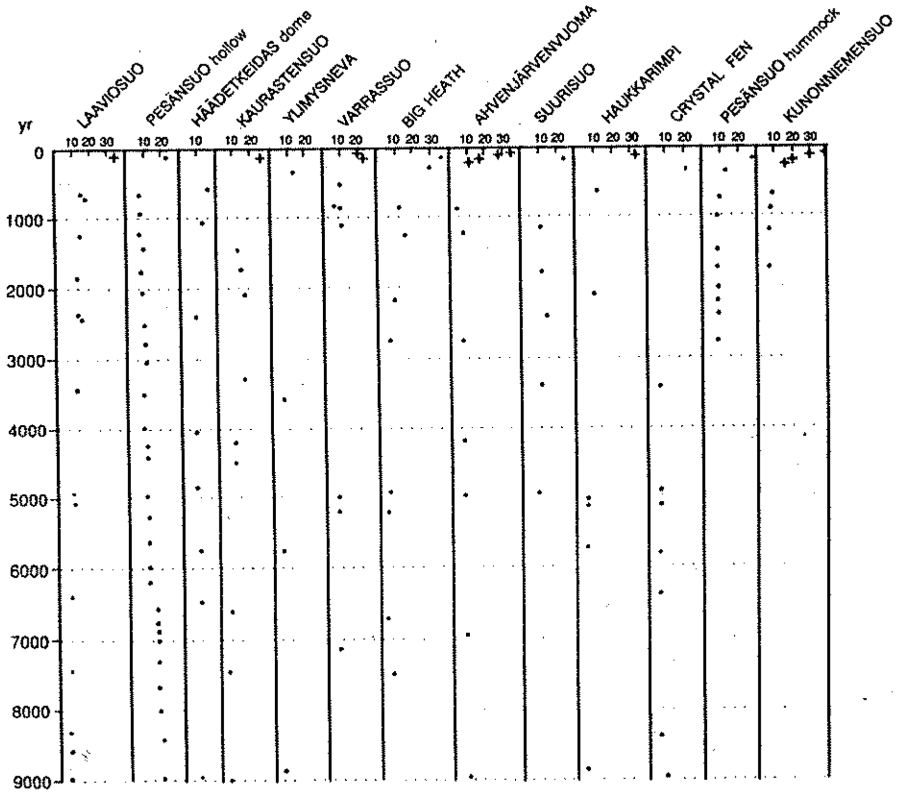

Fig. 3. Dry matter residue (as % of the assumed constant production) versus age according to eq 2 in thirteen long cores. The production values used are 430 g m^{-2} a^{-1} for all cores, but 500 g m^{-2} a^{-1} for Big Heath, Suurisuo, Crystal Fen and Kunonniemensuo