Suo 43(4–5): 277–280, 1992(1993)

Kimmo Tolonen, Harri Vasander, Antoni W.H. Damman and R.S. Clymo

PRELIMINARY ESTIMATE OF LONG-TERM CARBON ACCUMULATION AND LOSS IN 25 BOREAL PEATLANDS

Tolonen, K., Vasander, H., Damman, A.W.H. & Clymo, R.S. 1992: Preliminary estimate of long-term carbon accumulation and loss in 25 boreal peatlands. — Suo 43:277–280. Helsinki. ISSN 0039-5471

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. 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.

Key words: Climatic change, organic matter, stratigraphy

K. Tolonen, Department of Biology, University of Joensuu, P.O. Box 111, FIN-80101, Finland
H. Vasander, Department of Forest Ecology, University of Helsinki, Finland
A.W.H. Damman, Department of Ecology and Evolutionary Biology, University of Connecticut, USA
R.S. Clymo, School of Biological Sciences, Queen Mary and Westfield College, London, UK

INTRODUCTION

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

(1) long-term (apparent) peat accumulation rate:

$A = r\ \rho$, where

A = rate of dry mass accumulation (kg $m^{-2}a^{-1}$)
r = net rate of height increment (mm a^{-1})
ρ = dry bulk density of peat (g cm^{-3})

(2) long-term loss of organic matter:

$L = 1 - M/(T\ P)$, where

L = loss (as proportion) of original organic matter produced
M = cumulative mass of organic matter above a given depth (g m^{-2})
T = age of this depth (a)
P = rate of 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 = 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 radiocarbon datings is 327. The stratigraphical methods have been described in Tolonen et al. 1992b.

RESULTS AND DISCUSSION

Apparent long-term accumulation and decay

In Finland and Estonia, the long-term apparent accumulation rate of carbon (g $m^{-2}a^{-1}$, Table 1) was 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). 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 was studied by Tolonen et al. (1992a) 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 ± 90. As expected, the average apparent RCA was higher 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 ± 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 ± 0.6 g $m^{-2}a^{-1}$ (n = 19).

Table 1. Carbon accumulation in peat profiles from Finland, Estonia and Maine, USA. Finnish abbreviations of the site types, cf. Eurola et al. 1984. 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); true rate of carbon accumulation (5) and decay (6) (both according to eq. 3).

Mire	Location N. lat	Site type	(1) m	(2) mm a^{-1}	(3) g $m^{-2}a^{-1}$	(4) 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 Puohtiinsuo	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	–	–
27 Big Heath	44°06′	"TR"	4.9	0.63	20.5 (9.1)	14–67	10.1	20.9

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 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 $m^{-2}a^{-1}$, (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 7 500 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 and 500 years (Fig. 1).

CONCLUSIONS

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 to generalise 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 mires in different time periods should be considered, as well (cf. Elina et al. 1984, Korhola 1992).

It may be possible to estimate the impact of the greenhouse effect on the net rate of carbon accumulation in peats by 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

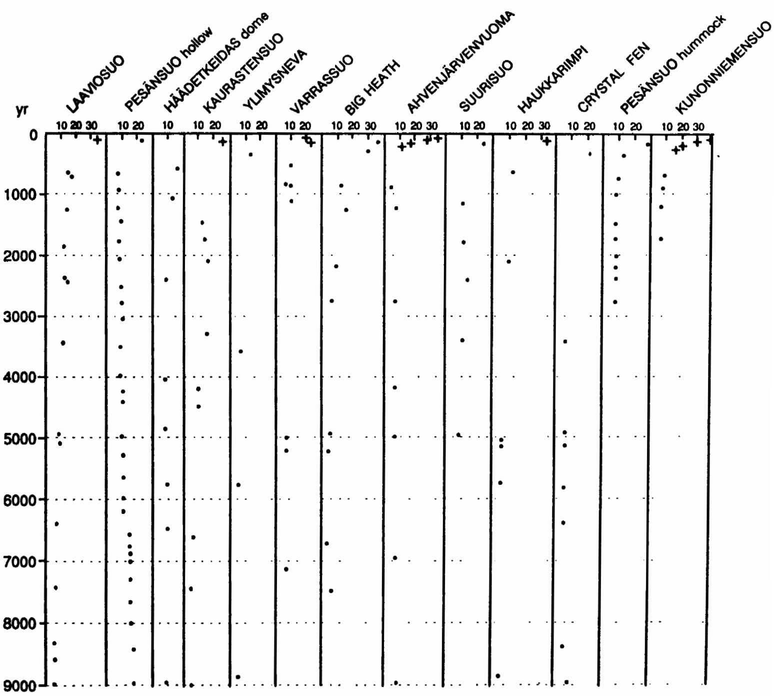

Fig. 1. Dry matter residue (as % of the assumed constant production) *versus* age according to eq. 2 in thirteen long cores. The production values used are 430 g $m^{-2}a^{-1}$ for most cores, but 500 g $m^{-2}a^{-1}$ for Big Heath, Suurisuo, Crystal Fen and Kunonniemensuo (cf. Table 1). Dating was by dendrocalibrated radiocarbon dating (dots) and by moss increment dating (crosses).

information about the less well-known functions of mire ecosystems.

Presumably the postulated warming will, if precipitation patterns remain the same, move the area of *Sphagnum* raised bogs northwards. It may then result in an increase in the total accumulation of carbon, and increase the rate of decay in southern peatlands. To what extent these effects will compensate we cannot tell.

ACKNOWLEDGEMENTS

We thank Dr. Mati Ilomets (Tallinn, Estonia) for contributing data for the Estonian mires and logistic support.

REFERENCES

Alm, J., Tolonen, K. & Vasander, H. 1992: Determination of recent apparent carbon accumulation in peat using dated fire horizons. — Suo 43:191–194.

Clymo, R.S. 1984: The limits to peat bog growth. — Phil. Trans. R. Soc. London B 303:605–654.

Damman, A.W.H 1988: Regulation of nitrogen removal and retention in Sphagnum bogs and other peatlands. — Oikos 51:291–305.

Elina, G.A., Kuznecov, O.L. & Maksimov, A.I. 1984: Strukturno-funktsional'naja organizatsija i dinamika bolotnyh ekosistem Karelii. — Nauka. Leningrad. 128 pp.

Eurola, S., Hicks, S. & Kaakinen, E. 1984: Key to Finnish mire types. — In: Moore, P.D. (ed.), European mires: 11–117. Academic Press. London.

Gorham, E. 1991: Northern peatlands: role in the carbon cycle and probable responses to climatic warming. — Ecol. Appl. 1:182–195.

Korhola, A. 1992: Mire induction, ecosystem dynamics and lateral extension on raised bogs in the southern coastal area of Finland. — Fennia 170:25–94.

Solantie, R. 1986: Suoyhdistymätyypeistä suhteessa ilmastollisiin ja hydrologisiin vyöhykkeisiin. (Summary: The zonation of peatland complex types in relation to climatic and hydrological zones.) — Suo 37:73–85

Tolonen, K., Davis, R.B. & Widoff, L. 1988: Peat accumulation rates in selected Maine peat deposits. — Maine Geol. Survey, Dept of Conservation. Bull. 33:1–99.

Tolonen, K., Possnert, J., Jungner, H., Sonninen, E. & Alm, J. 1992a: High resolution ^{14}C dating of surface peat using the AMS technique. — Suo 43:271–275.

Tolonen, K., Vasander, H., Damman, A.W.H. & Clymo, R.S. 1992b: Rate of apparent and true carbon accumulation in Boreal peatlands. — Proc. 9th Int. Peat Congress, Uppsala, Sweden, 22–26 June 1992, Vol. 1:319–333.