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CHANGES IN THE CARBON BALANCE OF FORESTED MIRES IN KARELIA DUE TO DRAINAGE

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The carbon balance of undrained and drained parts of a herb-rich pine fen mire ecosystem were calculated. The drainage had been carried out twenty years earlier. Drainage resulted in an increase of 1.23 t C $ha^{-1} a^{-1}$ within the ecosystem. The increase was due to increased stand production, which exceeded a loss of carbon from the peat (–0.32 t $ha^{-1} a^{-1}$).

Keywords: Peat, peatland forestry, phytomass, Russia

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INTRODUCTION

The increase in atmospheric CO_2 concentrations due to human activity and the ensuing possible implications for global climate are cause for international concern. Research into the influence of human activity on biospheric factors and processes affecting the carbon balance of ecosystems is therefore needed. The drainage of peatlands for forestry in the boreal zone represents such a case. It is important to determine whether drainage promotes the emission or fixation and accumulation of carbon in mire ecosystems.

On the basis of soil respiration studies, Silvola (1986) reported that drainage for forestry can increase CO_2 emissions from peatlands tenfold. Investigations in the St. Petersburg region by Kobak (1988) also showed that drained forested mire ecosystems emitted 2.5–3 times more CO_2 than undrained ones. In contrast, the results of Laine et al. (1992), indicated that drainage may also promote the accumulation of carbon in peatlands. As noted by Päivänen (1990) and Vompersky (1991), it is necessary to carry out thorough carbon balance studies in order to determine the extent to which drained forested mire ecosystems bind or emit CO_2.

The aim of our study was to determine the change in the carbon balance of one of the most common types of forested mire ecosystems in Karelia after twenty years of drainage. The carbon stores of the main components of the mire ecosystem were determined: the standing phytomass, annual phytomass production and litterfall, surface and saturated peat layers, drainage water and soil atmosphere.

MATERIALS AND METHODS

The study was carried out near the Kindasovo Field Station, 60 km west from Petrozovodsk, south Karelia (61°51´N 33°28´E). A research plot was laid out in a mesotrophic herb-rich pine fen (*Pinetum herboso–sphagnosum*) and an analogous drained site on the same mire. The drainage had been carried out in 1971 using a ditch spacing of 120 m.

The phytomass of various vegetation layers (tree, field and bottom layers) and litterfall were determined from sample trees using the methods of the International Biological Programme (Utkin 1975). Data were collected at the time of drainage, i.e. 1971, and twenty years later, i.e. 1991.

The organic matter content of the litter layer that had accumulated on the drained site was determined from ten 0.25 m^2 sample plots.

The carbon store of the peat deposits was determined in 1991 by taking volumetric samples at 10-cm intervals down to a depth of 1 m and thereafter, as a single sample to the base of the deposit (drained = 156 cm; undrained = 178 cm). The thickness of the peat layer was measured in 1971 and again in 1991. Bulk density values for the drained site before drainage are assumed to be the same as present day values of the undrained site. The calculated loss of organic matter at the drained site has been compared to a value estimated using mineralization rates determined by Kozlovskaja et al. (1978).

The carbon concentrations of the phytomass, litter and peat samples were determined using the Tyurin wet digestion method (Irinushkina 1970).

Water samples from piezometers installed in the drained and undrained sites at 0.5 and 1 m depths and from the main ditches and natural watercourses were taken monthly. Concentrations of organic matter were determined using the dichromate oxidation method (Rukovodstvo po ... 1977) and of organic carbon by a photochemical method (Martynova & Lozovik 1985).

To calculate the organic matter and carbon contents of the peat water, the stores of water in the peat had to be estimated. For the saturated zone, the water store was calculated using Nesterenko's (1979) regression equation adapted for south Karelian conditions:

$$W = 95.62 - 33.7\gamma$$

where W = saturated water capacity and γ = bulk density.

The water content of the unsaturated zone was calculated by taking samples and determining moisture content.

RESULTS AND DISCUSSION

At the time of drainage, the stands were similar but after twenty years of drainage, productivity had considerably increased (Table 1). The 1991 total phytomass of the undrained site was 78.0 t ha^{-1} while that of the drained site, 135.6 t ha^{-1} (Table 2). Most of the increase is due to the tree compartment. The proportion of field and bottom layer phytomass, particularly *Sphagnum* species, decreases after drainage (also Reinikainen et al. 1984).

The annual phytomass productivity at the undrained site represents 11% of the total phytomass; the corresponding value for the drained site is 8.6% (see Table 2). Annual litterfall for the undrained site represents 92% of the annual phytomass production; the corresponding value for drained site is 69%. Litterfall from the tree layer accounted for <50% of total litterfall at the undrained site; for the drained site, the tree layer accounted for 88%. Although conditions for mineralization are improved by drainage, litterfall accumulated at the drained site as a forest litter layer (3.5 t ha^{-1}). This is because tree litterfall is less easily decomposed. Net phytomass production (the difference between the annual phytomass increase and litterfall) was 0.8 t ha^{-1} at the undrained site, but 3.4 t ha^{-1} at the drained site, i.e. net phytomass productivity was over four times greater at the drained site.

The upper 10 cm of peat is meso–eutrophic and composed of transitional *Sphagnum* peat. Deeper, the peat consists of more decomposed (20–25%) sedge–*Sphagnum* residues. The ash

Table 1. Characteristics of the stands in 1971 (before drainage) and 1991.

Year	Species composition[1)]	Height m	Diameter cm	Density m^2/ha	Volume, m^3/ha Alive(Dead)	Increment during last 5 years, m^3/ha
Undrained site						
1971	40 P	9.9	13.9	4.2	18(0)	–
	60 B	9.2	8.5	6.3	26(0)	–
1991	40 P	10.3	15.5	5.5	28(1.2)	0.34
	60 B	10.4	9.7	9.2	43(2.5)	1.00
Drained site						
1971	38 P	10.3	12.1	4.8	18(0)	–
	62 B	9.0	9.2	8.0	30(0)	–
1991	48 P	15.8	18.7	11.3	68(7)	2.62
	50 B	13.8	12.9	15.9	91(3)	3.06
	1 S	7.1	7.4	0.2	1(0)	0.05

[1)] per cent, P = Scots pine, B = birch, S = Norway spruce

Table 2. Phytomass, phytomass production and litterfall production in undrained and drained sites.

	Undrained	Drained
Phytomass, t ha^{-1}	78.0(38.9)[1]	135.6(67.6)
Tree layer, %	86.1	98.3
Field layer, %	7.3	0.5
Bottom layer, %	6.6	1.1
Phytomass production, t $ha^{-1}a^{-1}$	8.2(4.2)	11.0(5.7)
Tree layer, %	43.9	91.5
Field layer, %	29.6	4.5
Bottom layer, %	26.5	4.0
Litterfall production, t $ha^{-1}a^{-1}$	7.4(3.9)	7.6(4.0)
Tree layer, %	42.9	88.0
Field layer, %	39.7	6.5
Bottom layer, %	17.4	5.5

[1] Carbon

content of the upper 10-cm layer is 7–9% and that of the deeper peat, 3.5–5%. Subsidence up to 30 m from the ditch averaged 28 cm and in the middle of the ditch, 20 cm (Fig. 1). The bulk density of the surface peat had increased after drainage. The average value for the 0–50-cm peat layer in the undrained site was 0.089 g cm^{-3} and for the drained site 0.123 g cm^{-3}. The peat reserve at the undrained site was 1 496 t ha^{-1} and at the drained site, 1 471 t ha^{-1} (Table 3).

The organic matter and carbon concentrations of the peat water collected in 1991 from the piezometers were greater for the drained site. For the 0–50-cm layer, the organic matter concentrations from the undrained site averaged 86.6 mg/l and from the drained site, 162.4 mg/l. For carbon, the corresponding values were 32 and 80 mg/l. For the 50–100-cm layer, organic matter concentrations from the undrained site averaged 60.3 mg/l and from the drained site, 152.8 mg/l. Corresponding carbon values were 20 and 69 mg/l. The total organic matter store of the soil water for the undrained site was 1.1 t ha^{-1} and 2.1 t ha^{-1} for the drained site. The corresponding carbon stores were 0.4 and 1.0 t ha^{-1} (Table 3).

CONCLUSIONS

The results indicate that carbon accumulation in this herb-rich pine fen mire ecosystem has been increased by 1.23 t $ha^{-1}a^{-1}$ due to drainage. The increased accumulation is accounted for by increased phytomass production (+1.43 t $ha^{-1}a^{-1}$). Because of increased decomposition, the carbon store of the peat is actually reduced (–0.32 t $ha^{-1}a^{-1}$).

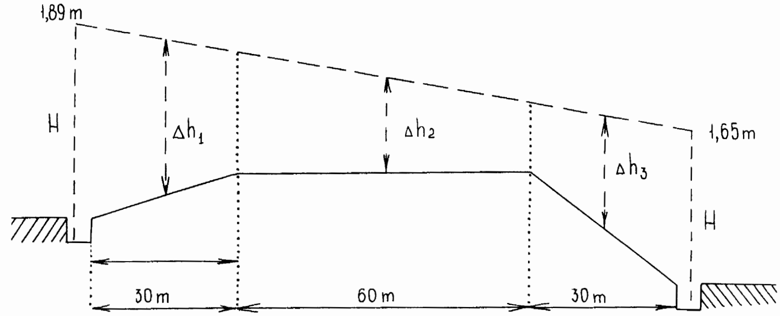

Fig. 1. Peat subsidence and its determination after drainage. H = peat thickness, - - - - = peat surface before drainage, ———— = peat surface after drainage, ... = border of the near ditch area, Δh_1–Δh_3 = peat subsidence.

Table 3. The amount of phytomass and peat (mass) and carbon (t ha^{-1}) in undrained and drained sites. The annual change is calculated as the difference between drained and undrained values and dividing by 20, i.e. years since drainage.

Component	Undrained			Drained			Annual change	
	Mass	C	%	Mass	C	%	Mass	C
Vegetation								
Tree layer	67.2	33.5	4.6	133.4	66.5	8.8	+3.30	+1.65
Field + bottom layer	10.8	5.4	0.5	2.2	1.1	0.1	−0.43	−0.22
Total	78.0	38.9	5.1	135.6	67.6	8.9	+2.87	+1.43
Soil								
Litter	–	–	–	3.5	1.8	0.1	+0.17	+0.09
Peat	1496.0	693.6	94.6	1474.5	687.1	90.9	−1.01	−0.32
Soil water	1.1	0.4	0.1	2.1	1.0	0.1	+0.05	+0.03
Total	1497.1	694.0	94.7	1480.1	689.9	91.1	−0.78	−0.20
Overall total	1575.1	732.9	100	1615.7	757.5	100	+2.09	+1.23

REFERENCES

Agrokhimicheskie metody issledovanija pochv 1975: Moskva. 656 pp.

Irinushkina, E.V. 1970: Rukovodstvo po khimicheskomu analizu pochv. — Moskva. 478 pp.

Kobak, K.I. 1988: Biologicheskie komponenty uglerodnogo tsikla. — Leningrad. 248 pp.

Kozlovskaja, L.S., Medvedeva, V.M. & P'javchenko, N.I. 1978: Dinamika organicheskogo vetchestva v protsesse torfoobrazovanija. — Nauka. Leningrad. 172 pp.

Laine, J., Vasander, H. & Puhalainen, A. 1992: Effect of forest drainage on the carbon balance of mire ecosystems. — Proc. 9th Int. Peat Congress, Uppsala, Sweden, June 22–26, 1992. Vol. 1: 170–181.

Martynova, N.N. & Lozovik, P.A. 1985: Opredelenie organicheskogo ugleroda v prirodnykh vodakh s ispol'zovaniem sistemy nepreryvnogo gazovogo potoka. — In: Organicheskoe vetshestvo i biogennye elementy v vodakh Karelii: 191–203. Petrozavodsk.

Nesterenko, I.M. 1979: Melioratsija zemel' Evropejskogo Severa SSSR. — 356 pp.

Päivänen, J. 1990: Suometsät ja niiden hoito. — Kirjayhtymä. Helsinki. 231 pp.

Reinikainen, A., Vasander, H. & Lindholm, T. 1984: Plant biomass and production of southern boreal mire ecosystems in Finland. — Proc. 7th Int. Peat Congress, 18–23 June 1984, Dublin. Vol. 4: 1–20.

Rukovodstvo po khimicheskomu analizu poverkhnostnykh vod sushy 1977: Leningrad. 541 pp.

Silvola, J. 1986: Carbon dioxide dynamics in mires reclaimed for forestry in eastern Finland. — Ann. Bot. Fennici 23:59–67.

Utkin, A.I. 1975: Biologicheskaja produktivnost' lesov. Metody izuchenija i resul'taty. — Lesovedenie i lesovodstvo 1975/1: 9–189.

Vompersky, S.E. 1991: Les i bolota: osobennosti krugovorota vetchestv i projavlenija biosfernoj roli. — Lesovedenie 1991/6: 54–64.