ACTA FORESTALIA FENNICA

191

EFFECT OF DRAINING AND FERTILIZATION ON SOIL RESPIRATION AT THREE AMELIORATED PEATLAND SITES

OJITUKSEN JA LANNOITUKSEN VAIKUTUS MAAHENGITYKSEEN KOLMELLA SUOMUUTTUMALLA

Jouko Silvola, Jukka Välijoki & Heikki Aaltonen

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Seloste

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HELSINKI 1985

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Soil respiration readings are reported for three ameliorated peatland sites of different types, covering a period of four years, during which the sites were drained and treated with various fertilizers. Respiration is shown to increase exponentially with temperature, varying mostly in the range 100–500 mg CO$_2$ m^{-2}h^{-1}. The changes in soil respiration followed those in surface temperature with a time-lag of approx. 3–3.5 hours. At one site, where the groundwater table dropped by about 0.5 m after ditching, soil respiration increased 2.5-fold within a few weeks, whereas at the other two sites both the fall in the groundwater table and the resultant changes in soil respiration were small.

The fertilizers tested were slow-dissolving PK, fast-dissolving PK, wood ash, slow-dissolving PK + urea, slow-dissolving PK + Nitroform (ureaformaldehyde) and slow-dissolving PK + urea + a micro-element mixture. Application of fast-dissolving PK or urea led to a rapid increase in soil respiration at the site poorest in nutrients, and slow-dissolving PK to a slow increase in respiration. The greatest, steady increase of all was achieved by treatment with ash. At the sites with a higher natural nutrient content the application of fertilizers usually led to a decline in soil respiration lasting 1–2 years, after which the initial level was normally regained. Treatment with micro-elements caused an initial fall in soil respiration values in all three biotopes, followed by a pronounced increase.

Maahengitystä mitattiin neljän vuoden ajan kolmen erilaisen suomuuttuman koealoilta, jotka tutkimuksen aikana ojitettiin ja lannoitettiin eri tavoin. Maahengitys lisääntyi eksponentiaalisesti lämpötilan noustessa vaihdellen koealoilla yleensä välillä 100–500 mg CO$_2$ m^{-2} t^{-1}. Vaihtelut maahengityksessä seurasivat muutoksia maanpinnan ilman lämpötilassa n. 3–3.5 tunnin viiveellä. Yhdellä koealalla vesipinta laski ojituksen jälkeen n. 0.5 m, minkä seurauksena maahengitys lisääntyi muutamassa viikossa n. 2.5 kertaiseksi. Kahdella muulla alueella vedenpinnan lasku oli vähäinen ja vastaavasti muutokset maahengityksessä olivat pieniä.

Käytetyt lannoitteet olivat hidasliukoinen PK, nopealiukoinen PK, puun tuhka, hidasliukoinen PK + urea, hidasliukoinen PK + Nitroform, ja hidasliukoinen PK + urea + hivenaineseos. Tutkituista niukkaravinteisimmalla suotyypillä nopealiukoinen PK- ja urealannoitus aiheuttivat nopean ja hidasliukoinen PK hitaan kasvun maahengityksessä. Suurimman pysyvän kasvun aiheutti tuhkalannoitus. Ravinteikkaammilla suotyypeillä lannoitus aiheutti yleensä 1–2 vuotta kestäneen alenemisen maahengitykseen, mikä tavallisesti palautui. Hivenainekäsittely aiheutti kaikille suotyypeille ensin maahengityksen alenemisen ja lopuksi huomattavan lisäyksen.

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1. INTRODUCTION

It is typical of peatlands in a natural state that their annual primary production usually exceeds the depreciation in organic matter. Thus an annual growth of some 0.2–1.5 mm is normally observed in boreal peatlands (see Aaby and Tauber 1975), corresponding to a mean accumulation of 40–50 g of organic matter per m^2 per year. Annual production figures of 200–500 g m^{-2} have been recorded on continuous *Sphagnum* moss surfaces, varying according to the site and species involved (Pakarinen 1978), while the field, shrub and tree layer production can naturally vary very greatly, figures of around 100 g m^{-2} having been calculated for certain poor pine bogs in Southern Finland (Silvola 1980, Vasander 1982).

The above figures would lead us to conclude that the majority of the organic matter produced on peatland, perhaps just under 90 %, is lost, and only a small proportion remains to contribute to peat growth (cf. Tolonen 1977). It also implies that only a small increase in the depreciation value on a mire is required (about 10 %) for growth to cease altogether. This depreciation takes place above all trough decomposition, which is generally limited by the low availability of oxygen and nutrients in mires and the low pH and temperatures (Latter et al. 1967, Karsisto 1979a). It may be assumed that even quite small alterations in these limiting factors, e.g. a warming of the climate, could suffice to reverse the carbon balance in peatlands (Silvola and Hanski 1979, Billings et al. 1982).

One very extensive change in the factors limiting decomposition in many mires has been brought about in practice by draining, which increases the depth of the aeriated horizon. A further considerable stimulation of decomposition can then be achieved by the spreading of fertilizers, and perhaps also lime. Although peatlands are frequently very poor in nutrients, considerable amounts can be found to have accumulated in peat horizons, and thus one of the critical questions as far as the use of peatlands for agriculture and forestry is concerned is whether the nutrients bound in the peat can be made to circulate by stimulating decomposition.

The term 'soil respiration' is used to refer to the carbon dioxide produced by the various respiration processes in the soil and released into the surrounding air, this carbon dioxide being derived from the aerobic respiration of various microbes, soil animals and plant roots. The relative importance of these decomposing agents is not necessarily proportional to the amounts of carbon dioxide they produce. The soil animals, for example, have been calculated to produce only about 5 % of the total CO_2 (Markkula 1982, Huhta and Setälä 1984), but they adapt the material into a form which makes it more readily decomposable by other agents, and this indirect effect is estimated to be very much greater than the energy consumption involved would suggest. Thus soil respiration measurements cannot be said to give by any means a comprehensive picture of the decomposition activity taking place in soil, since it does not tell us what agents are at work and of what importance each is in relation to the process as a whole (cf. Witkamp 1966, Lähde 1969). Estimates of the proportion of this respiration attributable to the plant roots have often had to be based on indirect calculations (see Svensson and Rosswall 1980). In spite of these drawbacks, soil respiration is justifiably in widespread use as a general measure of biological activity in soils. If one knows the concentrations of various substances in the material to be decomposed, it is then possible with some degree of accuracy to calculate the rate of mineralization of the nutrients and the amount of carbon dioxide returning into the air.

The present paper examines the effects of draining and the application of various fertilizers upon soil respiration at three peatland sites. The work forms part of a larger project to assess the ecological effects of draining and fertilization (Pasanen 1980). The authors wish to thank all those who were involved in the work for their cooperation, and particularly the members of the Ahvensalo group.

Thanks are due to Enso-Gutzeit OY for allowing the experimental plots to be set up on their land, and to Kemira OY for looking after the application of fertilizers. Financial help is acknowledged from the Maj and Tor Nessling Foundation and the Academy of Finland.

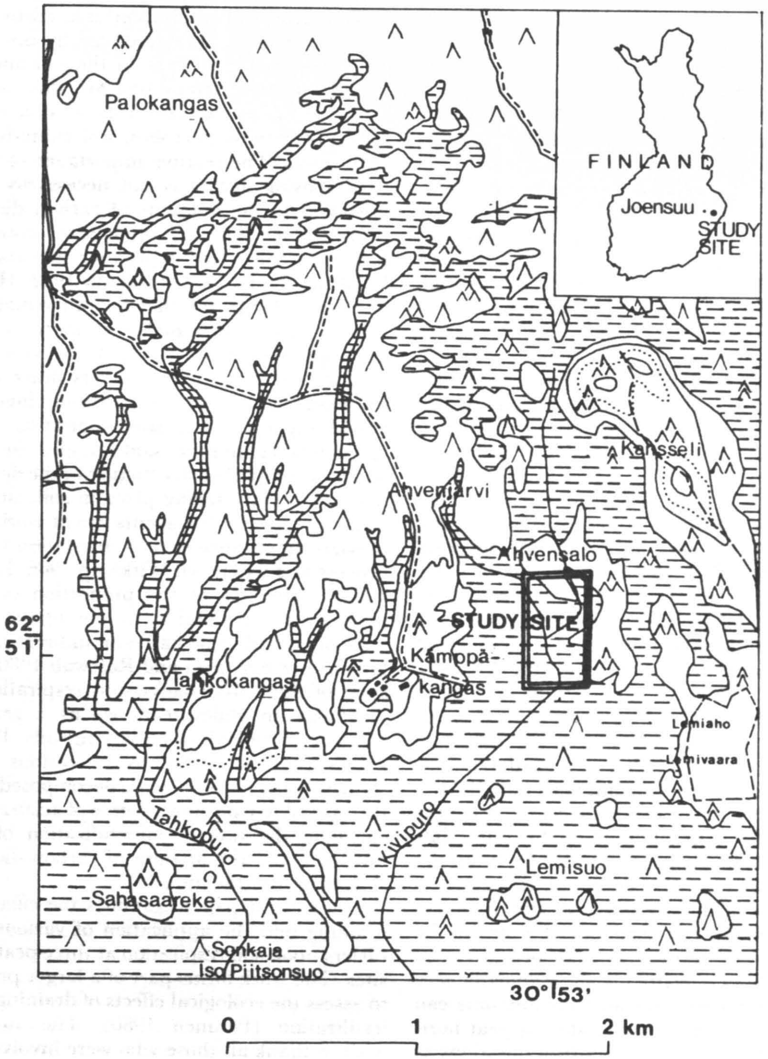


Fig. 1. Location of the study area.

2. MATERIAL AND METHODS

21. The area studied

The research took place in the Ahvensalo area, south of Palokangas in the commune of Ilomantsi (62°51′ N, 30°53′ E), an area characterized geomorphologically by deltas, sandurs and ravines (Fig. 1). The sites studied are located in low-lying terrain beside the stream of Kivipuro as it flows away from Palokangas, and at the same time form the northern edge of the large peatland area of Piitsonsuo. The area was partially drained some 40–50 years ago, and some additional draining has taken place since. Old ditches had virtually grown over, however, by the time this work was commenced, especially in the south of the area. This earlier draining had led to a considerable increase in tree growth and had altered the species composition of the vegetation to the extent that the original mire type could no longer be accurately discerned from the surface vegetation.

Sites were chosen which were representative of three distinct biotopes (Fig. 2 and Table 1). Site 1 had evidently originally been an oligotrophic sedge pine mire, the proportion of *Eriophorum vaginatum* in the surface vegetation having incresed greatly as a consequence of draining. The dominant mosses were *Sphagnum fuscum* and *S. magellanicum*. The tree cover was almost entirely pine in the southern part of the site, but featured both pine and birch in the northern part.

At site 2 the original mesotrophic sedge pine mire had been altered by the vegetation succession which had followed upon drainage. Here the tree cover comprised approximately equal amounts of pine and birch, the field layer was dominated by *Vaccinium vitis-idaea* and *V. myrtillus* and the moss layer contained mainly *Polytrichum commune*.

Site 3 was *Vaccinium myrtillus* spruce swamp on which the tree layer was dominated by large spruces, the field layer by *Vaccinium vitis-idaea* and *V. myrtillus* and the ground layer by *Pleurozium schreberi* and *Hylocomium splendens*. The thickness of the peat layer was about 0.5 m in the northern part of the spruce swamp, increasing southwards to about 2 m where it bordered onto site 1.

22. Establishment of the sample plots

A forest road was constructed across the area in the early spring of 1979 and the forest was thinned, the resulting timber and felling waste being removed. Statistics on the growing stock after completion of these procedures are giving in Table 1. Sample plots of 900–1200 m^2 in area and amounting to 13–26 in number were then defined for each biotope, the ditches being dug along the boundaries between these in August 1979. Groundwater wells were sunk for monitoring purposes along transects running through plots 8, 15 and 23 (12 wells altogether) at site 1, plots 2 and 9 (12 wells) at site 2 and plots 3 and 9 (10 wells) at site 3. In addition, a small meteorological screen was set up at each site to measure air temperature and relative humidity at heights of 2 m and 0.2 m and soil temperature at depths of 5 cm and 20 cm. Precipitation was measured at an open place in the middle of the area. Discharge in the stream, Kivipuro, was monitored at dams constructed above and below the area occupied by the sites. Some of the measurements concerned were carried out for use in connection with the project in general and are of no immediate relevance to the present topic.

23. Application of fertilizers

Fertilizer was spread on the plots in October–November 1979, or spring 1980 in the case of the plots receiving ash. Various types of PK and NPK fertilizers were used as well as ash (Table 2 and Fig. 2). The PK fertilizers comprised a slow-dissolving type (SL, Siilinjärvi apatite and biotite) and a fast-dissolving type (FA, superphosphate +

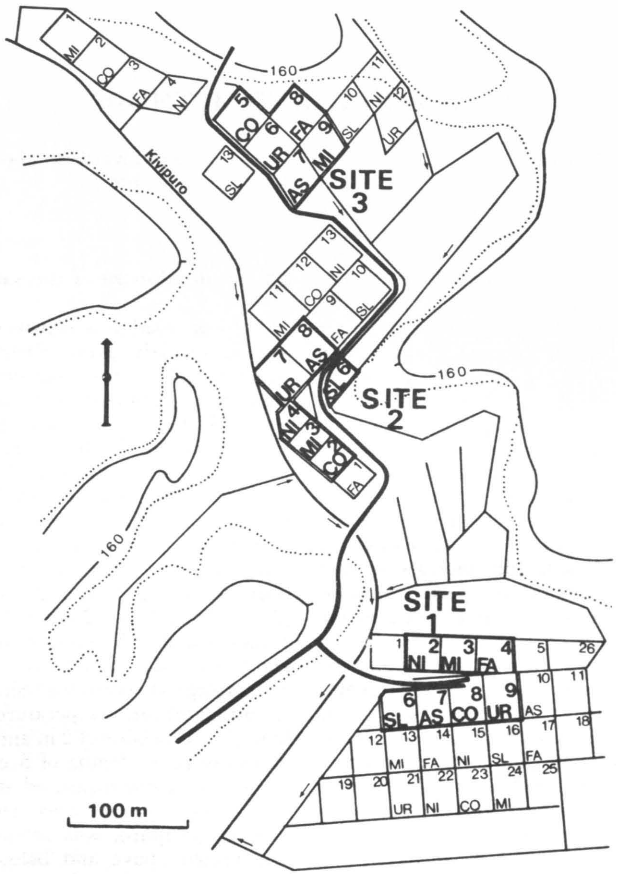


Fig 2. The experimental plots, separated one from another by the drainage ditches. The plots in which soil respiration was measured are indicated by large letters. The abbreviations denote the various fertilizers used: CO = non-fertilized control plot, SL = Siilinjärvi apatite + biotite, FA = superphosphate + potassium salt, UR = urea + Siilinjärvi apatite + biotite, NI = Nitroform + Siilinjärvi apatite + biotite, MI = micro-element mixture + urea + Siilinjärvi apatite + biotite, AS = wood ash.

potassium salt). The basic NPK fertilizer used was of a slow PK type with an addition of either urea (UR) or slow-dissolwing Nitroform (NI, ureaformaldehyde) as the nitrogen source. The micro-element fertilizer (MI) was a NPK fertilizer in which the PK was slow-dissolving, to which a micro-element mixture was added, together with urea as the nitrogen source. The wood ash used (AS) contained less phosphorus and potassium than the above, variable amounts of trace elements and a high concentration of calcium.

Table 1. General features of the sites.

	Site I	Site II	Site III
Trees			
Betula pendula and B. pubescens			
Stems/ha	184	524	113
Average diameter (1.5 m) cm	11.1	11.2	16.7
Average height m	10.6	12.5	15.6
Volume m^3/ha	11.1	36.2	20.5
Pinus sylvestris			
Stems/ha	954	547	67
Average diameter (1.5 m) cm	11.1	14.6	21.6
Average height m	9.3	13.9	17.9
Volume m^3/ha	58.2	64.8	22.5
Picea abies			
Stems/ha	–	44	519
Average diameter (1.5 m) cm	–	10.9	17.9
Average height m	–	11.8	16.1
Volume m^3/ha	–	4.0	120.1
Dominant field layer species	*Eriophorum vaginatum*	*Vaccinium vitis-idaea* *Vaccinium myrtillus*	*Vaccinium myrtillus* *Vaccinium vitis-idaea*
Dominant ground layer species	*Sphagnum magellanicum* *Sphagnum fuscum*	*Polytrichum commune*	*Pleurozium schreberi* *Hylocomium splendens*
Thickness of peat m	1.5–2	1	0.5–1
Depth of water table cm			
before draining	0–10	20–30	10–30
after draining	40–60	40–50	30–50

Table 2. Various fertilizers, abbreviations and amounts of elements (kg ha^{-1}) used.

Non-fertilized	CO	–
PK : Siilinjärvi apatite + biotite	SL	43.6 P + 83.0 K
PK : superphosphate + potassium salt	FA	43.6 P + 83.0 K
NPK : urea + Siilinjärvi apatite + biotite	UR	43.6 P + 83.0 K + 100.0 N
NPK : Nitroform (urea-formaldehyde) + Siilinjärvi apatite + biotite	NI	43.6 P + 83.0 K + 100.0 N
NPK + micro-element mixture : urea + Siilinjärvi apatite + biotite + micro-element mixture	MI	43.6 P + 83.0 K + 100.0 N + 12.8 Cu + 9.8 Fe + 5.5 Zn + 5.5 Mn + 1.4 Mo + 1.1 B + 0.7 Na
Wood ash (3000 kg/ha)	AS	19.9 P + 56.5 K + 602.6 Ca + 0.3 Cu + 0.8 Zn + 24.5 Mn + 0.3 B

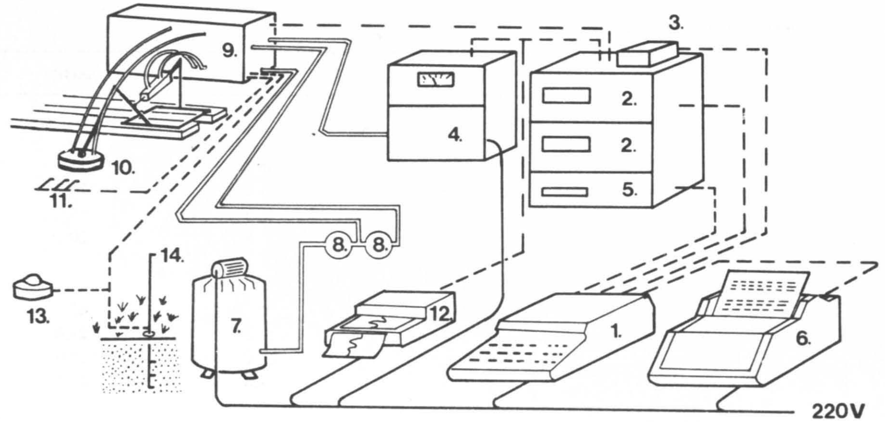


Fig. 3. Scheme of the equipment used for measuring carbon dioxide and environmental parameters. 1 calculator, 2 scanner, 3 clock, 4 IRGA, 5 voltmeter, 6 printer, 7 compressor and pressure tank, 8 pressure regulator, 9 magnetic valves, 10 CO_2 exchange chamber, 11 temperature sensors, 12 recorder, 13 irradiation sensor, 14 temperature sensors.

24. Measurements

The carbon dioxide measurements were performed using an infra red gas analyser (IRGA, URAS 2 T, Hartmann & Braun) coupled to a data acquisition system (Hewlett-Packard 3052A) (Fig. 3). The equipment was set up in a caravan, enabling it to be transported easily from one site to another. An open method was employed for measuring CO_2 exchange, in addition to which the chamber was closed over the site to be measured only for the actual time of measured. Using an air flow rate of 90 l h^{-1} the chamber had to be closed for about 6 mins to ensure representative results. The operation of the chamber was controlled by a system involving compressed air, magnetic valves and pneumatic cylinders, and the air flow was also regulated with magnetic valves. The green parts of the plants were removed from the place where measurements were to be carried out and a plastic tube of diameter 19 cm was carefully inserted into the ground to accept the chamber, whic was pressed down onto a horizontal sealing ring mounted on the upper edge of this tube (Fig. 4). Preliminary experiments were carried out to ascertain the most suitable pressure and flow values for use with the chamber. It also proved essential to arrange a compensatory air flow into the chamber so that air with a high concentration of CO_2 should not be sucked up from the ground, since even a small drop in the compensatory air flow relative to the sample flow caused a steep rise in the CO_2 values recorded. Correspondingly, an increase in compensatory air flow beyond the point of equilibrium caused the CO_2 readings to fall very slowly. It was thus decided to operate with a slight excess of compensatory in order to prevent fluctuations in flow conditions from causing any suction effect in the chamber. The compensatory air was taken in from the surrounding atmosphere via a small pressure tank so that its CO_2 content would follow that prevailing otherwise with just a small time-lag. The measurements of CO_2 exchange were accompanied by temperature readings for each location over the chamber taken at the ground surface, at a depth of 2 cm and at 5, 10 or 20 cm depending on the channel.

Nine measurement channels were normally in use simultaneously, located in three groups, in which the sample points were about 1 m apart. The lengths of the tubes and cable effectively prevented measurements from being made in all the plots, so that this aspect of the work was restricted to the plots indicated in Fig. 2. These data were collected from the beginning of June to the end of September in 1979–1982, each site being studied twice during each summer, the two measurements for 1979 being timed one before and one after the ditching of the area. Measurements were normally carried out over a period of 2–3 weeks at a time, each plot being measured for 5–6 days, involving some 6–9 points within the plot, each of which was studied for 1–2 days. One measurement cycle lasted about 1.5 hours, provided there were no interruptions or technical difficulties, which meant that about 15 such readings could be carried out in a day. Altogether more than a thousand points of size 283 cm^2 were measured, implying a total of about 25 000 individual respiration readings.

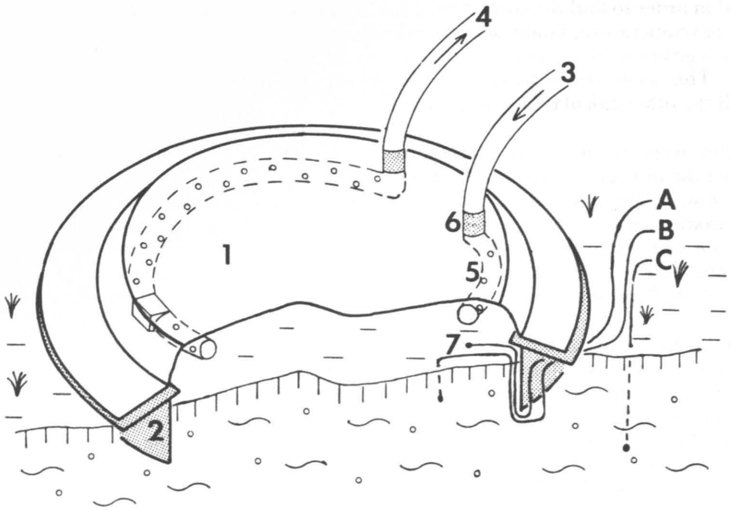


Fig. 4. The CO_2 exchange chamber in closed position. 1 chamber, 2 matching cylinder in soil, 3 tube for incoming air, 4 tube for measuring air, 5 air fractionation tube, 6 junction piece, 7 temperature sensors: A air at ground surface, B peat −2 cm, C peat −5 cm.

Some respiration measurements were also carried out in the laboratory, using virtually the same equipment as in the field. The samples in this case were pieces of peat about 20 cm thick and 15 cm in diameter taken from the surface of the sampling sites using a cylinder cutter and stored in plastic pots. The measurements were made in a climatic chamber in which the ambient temperature could be regulated.

The litter production of trees and shrubs was evaluated by collecting the litter in inverted cones of surface area 1 m^2 located c. 1 m above the ground. Each site had 13 of these cones, which were emptied 2–4 times a year and the contents dried and weighed.

Water levels in the groundwater wells were measured daily during the summer of 1979 and approximately weekly in the subsequent years. More frequent readings were taken during rainy spells.

25. Calculations

Comparison of the soil respiration values and ground surface temperatures showed a clear similarity in rhythm between the two, with a certain delay factor. Since the results of the laboratory experiments had suggested the use of a regression model of the form $y=a\cdot e^{bx}$ to represent the dependence of CO_2 production upon temperature, this equation was tested in order to find the correct delay in the effect of temperature, finally selecting the value which gave the best coefficient of determination. This same delay factor was then used in all the other calculations (tests, simulations).

Estimates were made of the carbon released from the peat of the non-fertilized control plots during the summer by simulating the CO_2 production by reference to temperature and the above regression equation, and these results were then compared to the actual biological production and litter production data.

The trends in soil respiration in the same plot in the various years and the differences between the plots in the same area treated with different fertilizers were compared using an analysis of covariance with temperature as the independent variable and soil respiration as the dependent variable. This test was performed on the readings taken before and after draining of the area in 1979, while for the other years a measurement period for comparison purposes was selected from the data representing the middle or late summer. The basic unit in the tests was a plot in which soil respiration readings had been taken under varying conditions, all the results from each plot being of equal status in the analysis in this respect. The test employed the temperature dependency equation to determine a soil respiration value for each plot to correspond to the mean temperature for the group being tested, thus making it possible to compare the results of measurements carried out under different conditions. Following the analysis of covariance the plots were grouped by reference to the Student-Newman-Keuls mean value test (at the 5 % risk level). The tests were performed using a library program on Hewlett-Packard 9845B desktop computer. The fully intercomparable soil respiration values obtained using this test enabled the respiration trends in the various plots to be compared both in relation to their initial values (before draining) and in relation to the non-fertilized control plots belonging to the same site.

3. RESULTS

31. Groundwater table

The thickness of the aerobic layer in peat is determined to a great extent by the groundwater table, which thus becomes an important factor governing the level within which decomposition can fluctuate. The variations in the groundwater table at the various sites studied here are indicated in Fig. 5, which also contains information on the times at which respiration measurements were performed at each site. Three out of the 10–12 groundwater wells dug at each site, selected so as to be representative of the fluctuations encountered at that site, are marked on Fig. 5.

Well no. 1 at site 1 represents best the trend in the groundwater table in those plots where soil respiration was measured. During the first time of respiration measurement in July 1979 the groundwater was very close to the surface, whereas during the second time the water table was in process of sinking as a result of ditching, being at the depth of 30–50 cm. Later the values tended to vary in the range 40–60 cm.

Wells nos. 3 and 6 at site 2 lie on the northern edge of the site and well no. 11 on the southern edge, so that the water table fluctuations shown in the figure are evidently fairly representative of those occurring at the site as a whole. During the first measuring period 1979 the water table was at the depth of 20–40 cm and during the second one 30–50 cm. The groundwater table then remained at depths of between 30 and 60 cm throughout the following three years with only very minor exceptions.

The wells chosen to represent site 3 were similarly located in different parts of the site and serve adequately to cover the fluctuations occurring at that site in general. The groundwater table is seen here to have been at a depth of 20–30 cm at the time of the first respiration measurements in 1979, but to have persisted at around 10–30 cm even during the second measurement period in September 1979. Considerable fluctuations were then seen in subsequent years, typically within the depth range 10–50 cm.

32. Dependence of soil respiration upon temperature

Samples were taken from each site before the application of fertilizer in September 1979 and used for the measurement of respiration at various temperatures under laboratory conditions. The samples were kept at each temperature sufficiently long for them to reach the same temperature throughout and for CO_2 production to become stabilized. The absolute values obtained are not entirely comparable with those measured under natural conditions, where the temperature in the soil is seldom constant throughout. Similarly the thickness of the soil sample, 20 cm is perhaps insufficient to represent natural respiration under all conditions. As may be seen from Fig. 6, the values were between 100 and 200 mg CO_2 m^{-2} h^{-1} at 5 °C, increasing to about 800 mg at site 1, 1000 mg at site 2 and 1300 mg at site 3 at a temperature of 30 °C. For the sake of comparison, respiration curves are also indicated in the figure for a number of mires in a natural state, measured using the same method.

The measurements performed in the field similarly showed soil respiration to be dependent upon temperature. A series of typical recordings is shown in Fig. 7. The scatter in the figures is quite large, but examination of the trends for individual measurement points shows their fluctuations to follow those in air temperature with an apparent delay of a few hours. The use of regression analysis to determine the extent of this delay factor more precisely (Fig. 8) gave different distributions of data points with different delay values, the best coefficient of determination being obtained with a delay of two cycles, amounting in practice to about 3–3.5 hours.

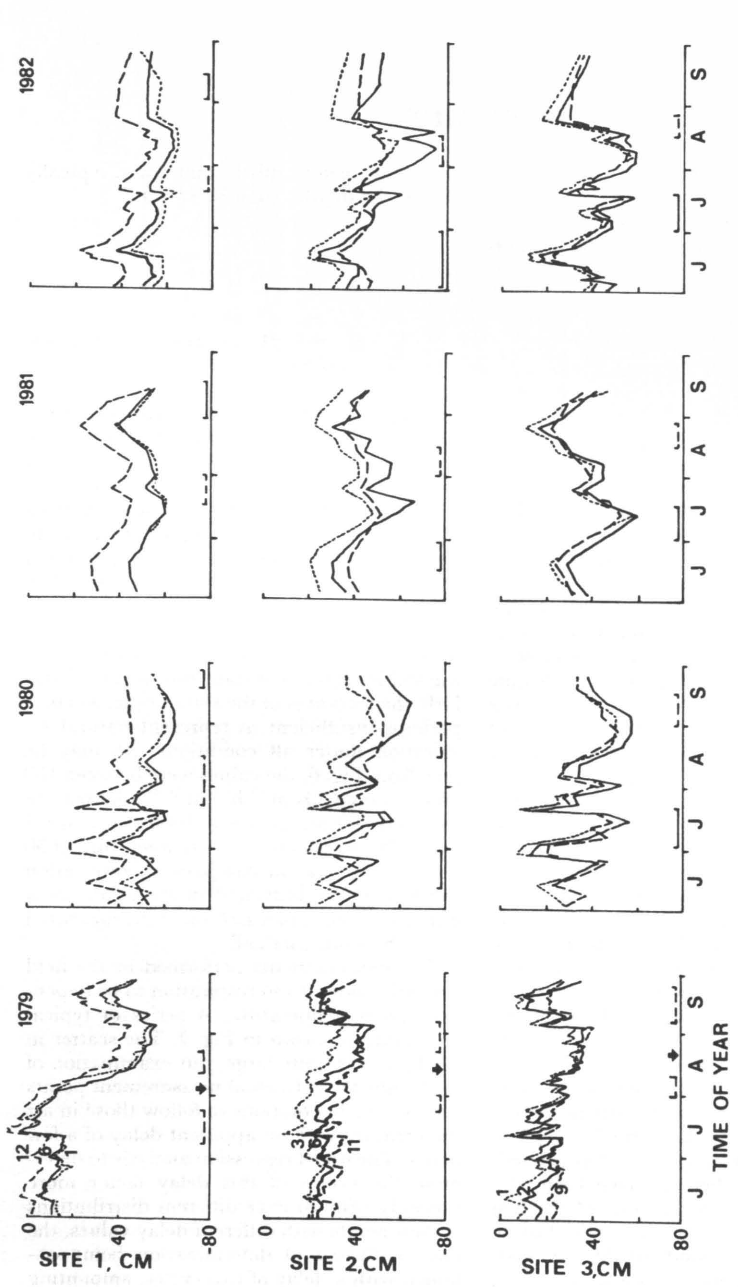


Fig. 5. Groundwater table at the three sites during the four years of the experiment. Each site is represented by three example wells selected from different parts of the area to be representative of the full range of variation. The arrows show the times of draining at different sites. The short lines denote the times at which soil respiration measurements were carried out (the broken lines show the sequences of readings used in tests to evaluate the effects of the fertilizers).

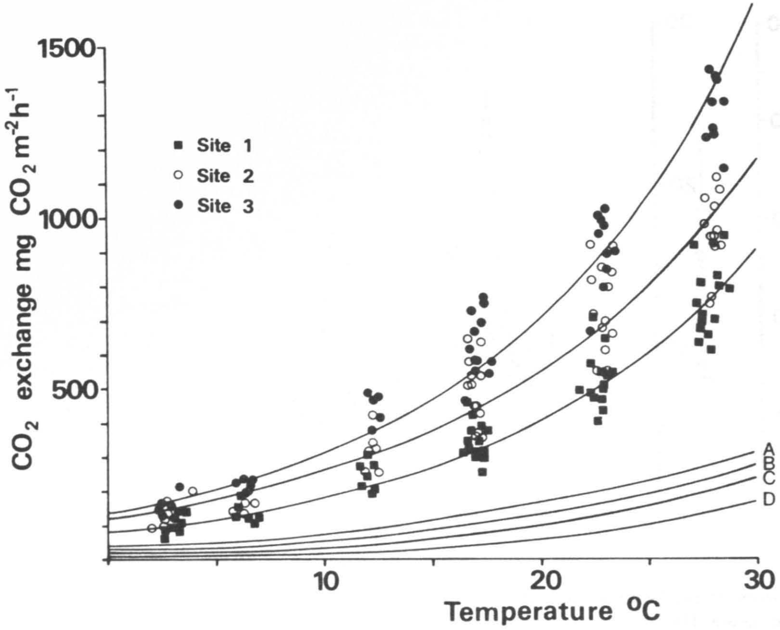


Fig. 6. Soil respiration as measured in the laboratory at various temperatures using samples from different study sites in September 1979. Regression curves for samples from a few mires in a natural state are included for comparison. A Kaurastensuo in Lammi, a *Sphagnum fuscum* pine bog (Silvola and Heikkinen 1979), B a *Sphagnum fuscum* hummock on a *S. papillosum* fen, Salmisuo in Ilomantsi, C *S. fuscum* surface of a *S. fuscum* pine bog, Ahvensalo in Ilomantsi, D *S. papillosum* surface on a *S. papillosum* fen, Salmisuo in Ilomantsi (authors' own measurements).

33. Respiration in the non-fertilized plots

The non-fertilized control plots were compared one with another by calculating from their regression equations values corresponding to +15 °C. As may be seen in Fig. 9, respiration increased by a factor of 2.5 within a few weeks at site 1 after ditching, after which it declined slightly from year to year, being about twice the initial value by 1982.

The initial value recorded at site 2 was about 1.5 times that at site 1, but the changes caused by draining were less pronounced, a very slight increase taking place to reach a peak in 1980, after which a slightly more marked fall took place.

The mean respiration values at site 3 were of the same order as at site 2, but the variations were somewhat greater, evidently due to the greater fluctuations in the groundwater table (Fig. 5). In spite of certain deviations in different directions, the level remained in practice virtually constant throughout the period studied, at around 300 mg CO$_2$ m^{-2} h^{-1}. The general trend would thus seem to have been for respiration at site 1 to approach the same level at which it already was at sites 2 and 3.

The decomposition of organic material was simulated using a model in which respiration values were calculated on an hourly basis from the temperature dependence relation-

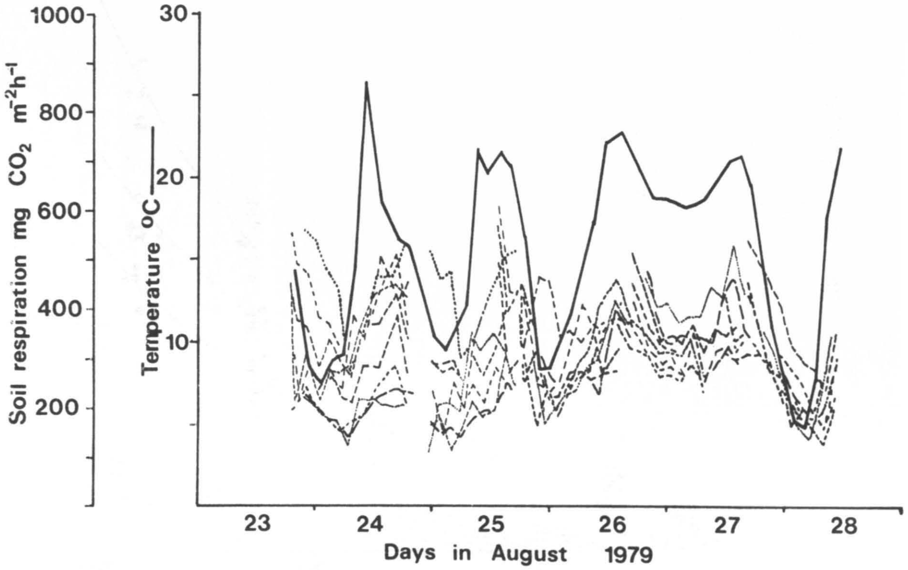


Fig. 7. A series of typical soil respiration readings taken on 9 channels (site 2, in 1979), and air temperatures at the ground surface. The interruptions represent pauses in the measurements or changes of experimental plot.

ships obtained here. Fig. 10 shows one example of the relationship between the simulated respiration and the real values measured in the plot concerned at the same time. The daily and cumulative respiration values for four months in 1979, transformed into organic material by reference to the mean figures for carbon content, are depicted in Fig. 11. Thus the daily respiration rate at site 1 before draining is estimated to correspond to 2–3 g of organic material per m^2, and that recorded after draining to 6–7 g m^{-2}. The figures for sites 2 and 3 are generally in the range 2.5–5 g m^{-2}. Similarly the cumulative values for the four-month period are approx. 450 g m^{-2} at site 1 and 400 g m^{-2} at sites 2 and 3.

The effect of draining on the balance of organic matter in the peat was evaluated by calculating the respiration in 1979 using the regression equation of the first measuring period to represent the whole summer and comparing this with the simulated respiration for the summer after ditching. Both of these results were then compared with the available data on surface vegetation and litter production. As may be seen in Fig. 12, the depreciation in organic matter during the four summer months before draining corresponds approximately to the sum of the surface vegetation and litter production, whereas the respiration value for the year after ditching, approx. 650 g m^{-2}, exceeds this sum many times over.

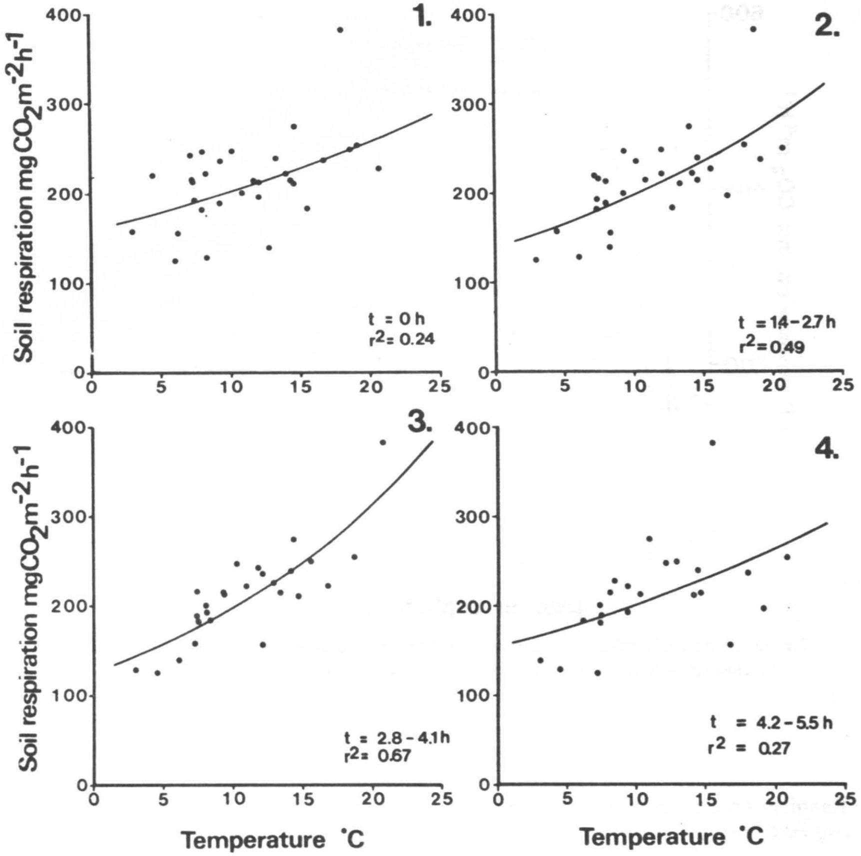
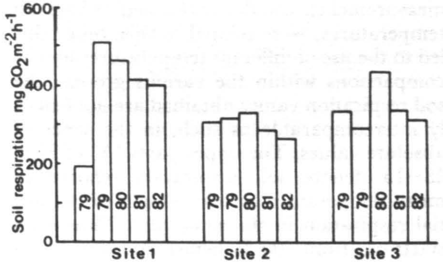


Fig. 8. Dependence of soil respiration on temperature when the latter has been measured in terms of air temperature at the surface of the ground simultaneously (1) or with a time-lag of one (2), two (3) or three (4) measurement cycles. r^2 = coefficient of determination, t = accepted time-lag. The results used here were recorded on 3.–5. 7. 1980 at one point in plot 6 at site 3.

Fig. 9. Mean soil respiration at +15 °C in the control plots at the three sites. The results were obtained from regression curves (y = a·e^{bx}) fitted to the measured values with a temperature time-lag of 2.8–4.1 hours. The measurement sequences are the same as used to test the effects of the fertilizers (see Fig. 5).



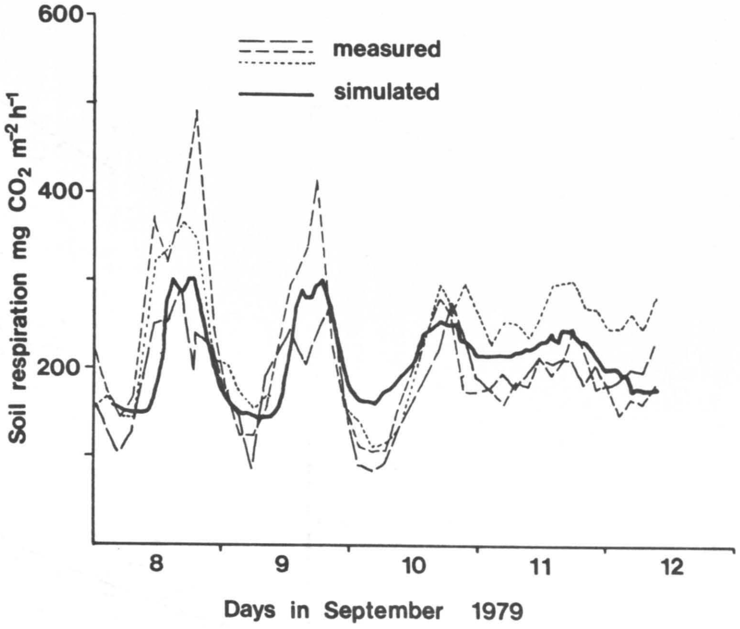


Fig. 10. Example of respiration values calculated by simulation techniques and measured values obtained on three channels for the same plot at the same time.

34. Respiration trends in the plots receiving fertilizer

In comparing the soil respiration figures recorded for the same plot over four years and in comparing the trends in the various fertilized plots with the appropriate control plot use was made of an analysis of covariance in which a mean temperature was calculated for each group to be tested and the individual measurements, usually performed at varying temperatures, were related to this. Since this led to the use of different temperatures for the comparisons within the various groups, the soil respiration values obtained are not usually intercomparable as such, in the sence of absolute values. The upper parts (A) of Figs. 13—15 denote soil respiration relative to mean temperature as percentages of the initial respiration in the same plot. Thus each starts out from 100 % before draining.

A second series of tests was performed in which the independent population consisted of the results for all the plots at one site in a given year and these were then related to the mean temperature during the period over which measurements were carried out. After this the value for each plot was calculated as a proportion of the control plot value for the same round of measurements (Figs. 13—15:B). The aim of this procedure was to isolate the effects of differing fertilizers from the changes caused by other reasons, particularly by draining. The mean temperature and the respiration values related to that obtained from each series of tests are given in Tables 3—5. The grouping achieved in the mean value test serves to indicate which plots have soil respiration values which differ at the 5 % risk level.

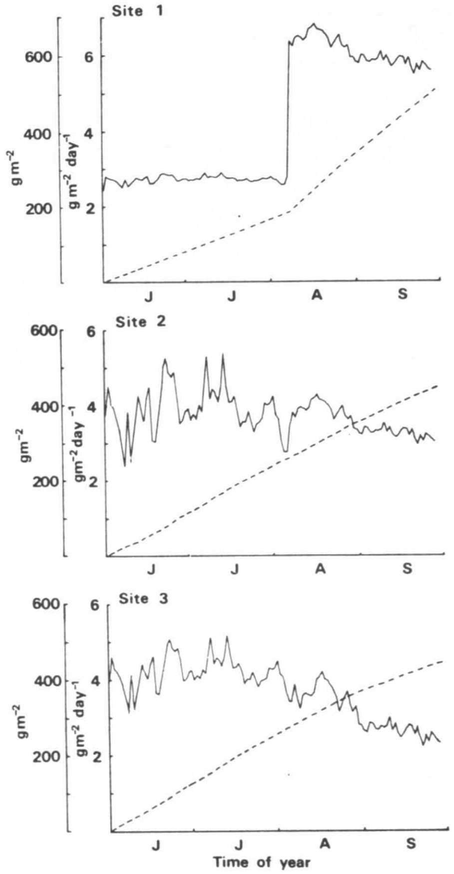


Fig. 11. Depreciation of organic matter (dry weight) in the peat in the non-fertilized plots at the three sites in 1979, calculated as daily and cumulative values from the simulated respiration data. August 10th was chosen as the date of transition from the first to the second set of readings and resulting regression lines.

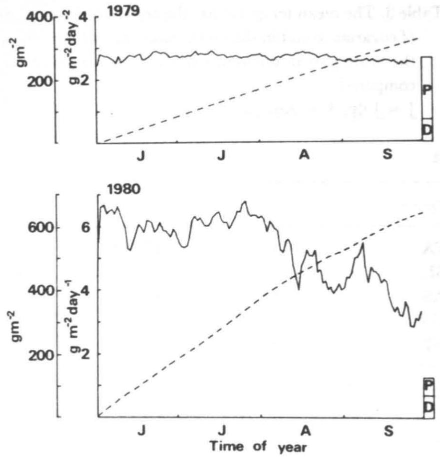


Fig. 12. Above: simulated depreciation of organic matter in the peat based on use of the regression curve for the period prior to ditching to represent a whole summer (values from plot 8, site 1, for 1979). Below: similar simulation based on regression lines for 1980. The mean production of the surface vegetation (P) at site 1 (Vuorinen et al. 1981, Kuusipalo 1983, pers. comm.) and the mean production of litter (D) from the trees are also indicated.

341. Site 1

Soil respiration in the control plot (CO) of site 1 increased 2.5-fold after ditching and was still twice the initial value in the fourth year. As may be seen in Fig. 13:B, this plot happened to have the highest level of respiration of all at site after ditching.

The FA plot, which received fast-dissolving PK fertilizer, showed an increase in soil respiration by a third over the value recorded after ditching when measured during the following summer, but the values then fell sharply in subsequent years. In comparison to the control plot the pattern is similar, but with a less pronounced drop between the second and fourth years, because the control values also fell during that interval.

Table 3. The mean temperature, the respiration values related to that and the grouping (a-f) obtained in the analysis of covariance and in the mean value test (at the 5 % risk level) at site 1. In the first series of tests (A) the results of the same plot in different years and in the second series (B) the results of different plots in the same year are compared.
J = July, A = August

A

Fertilizer	T°C	1979 J	1979 A	1980	1981	1982
FA	14.7	145.5/a	271.9/b	444.8/d	345.4/c	301.1/b
SL	14.9	–	428.1/b	448.3/b	362.3/a	402.8/ab
AS	14.6	130.6/a	317.4/b	344.1/b	384.1/c	447.9/d
UR	14.4	161.5/a	482.9/d	558.5/e	391.1/c	320.0/b
NI	15.2	175.3/a	–	397.7/d	312.2/b	358.5/c
MI	15.3	213.6/a	378.6/d	312.2/c	251.4/b	462.8/e
CO	16.2	231.2/a	538.0/d	497.9/c	438.4/b	414.8/b

B

Year	T°C	FA	SL	AS	UR	NI	MI	CO
1979 J	16.8	161.3/ab	–	139.9/a	175.8/bc	197.1/c	228.7/d	234.4/d
1979 A	12.7	254.4/a	408.5/d	311.4/b	469.3/e	–	361.2/c	513.3/f
1980	15.9	455.1/cd	449.3/bc	349.8/a	569.7/e	405.5/b	316.3/a	494.2/d
1981	15.5	353.7/c	367.2/cd	392.7/de	399.5/e	313.8/b	251.2/a	423.3/f
1982	13.3	288.8/a	391.6/c	442.5/d	312.9/ab	340.2/b	449.3/d	395.5/c

Table 4. The mean temperature, the respiration values related to that and the grouping (a-d) obtained in the analysis of covariance and the mean value test (at the 5 % risk level) at site 2. In the first series of tests (A) the results of the same plot in different years and in the second series (B) the results of different plots in the same year are compared.
J = July, A = August

A

Fertilizer	T°C	1979 J	1979 A	1980	1981	1982
SL	11.8	335.1/bc	319.4/bc	353.2/c	203.5/a	298.1/b
AS	11.4	326.5/b	299.9/a	282.1/a	279.1/a	328.6/b
UR	12.7	358.3/c	375.9/c	260.3/ab	274.8/b	239.7/a
NI	10.9	295.6/ab	330.7/b	308.5/b	264.3/a	331.7/b
MI	11.4	–	219.0/a	200.3/a	254.3/b	286.0/c
CO	12.6	286.6/a	314.9/b	331.8/b	280.4/a	270.6/a

B

Year	T°C	SL	AS	UR	NI	MI	CO
1979 J	12.9	344.3/cd	337.2/cd	360.1/d	316.6/bc	232.8/a	288.7/b
1979 A	11.6	315.5/ab	300.4/a	365.1/c	336.9/b	–	305.8/ab
1980	7.4	321.0/d	253.0/b	210.5/a	263.8/b	183.9/a	297.1/c
1981	13.4	217.3/a	293.2/b	281.5/b	292.5/b	274.3/b	285.8/b
1982	13.6	312.8/c	343.5/d	247.5/a	360.1/d	303.3/bc	277.9/ab

Table 5. The mean temperature, the respiration values related to that and the grouping (a-d) obtained in the analysis of covariance and the mean value test (at the 5 % riske level) at site 3. In the first series of tests (A) the results of the same plot in different years and in the second series (B) the results of different plots in the same year are compared.
A = August, S = September

A

Fertilizer	T°C	1979 A	1979 S	1980	1981	1982
FA	9.5	–	253.4/b	252.6/b	187.7/a	277.1/c
AS	10.6	278.6/b	259.5/b	329.8/c	205.6/a	264.3/b
UR	10.5	315.1/b	316.7/b	292.5/ab	261.0/a	282.4/a
MI	9.0	–	255.9/a	329.5/b	250.3/a	339.6/b
CO	9.7	302.0/b	264.9/a	362.3/c	290.8/ab	273.4/ab

B

Year	T°C	FA	AS	UR	MI	CO
1979 A	12.8	–	301.3/a	338.3/a	–	337.4/a
1979 S	7.0	227.3/a	223.6/a	279.6/b	237.0/a	234.8/a
1980	9.8	254.9/a	322.0/c	284.6/b	337.4/c	363.2/d
1981	11.3	204.7/a	212.6/a	266.2/b	276.2/b	310.3/c
1982	11.2	292.3/a	270.7/a	291.0/a	362.6/b	289.3/a

Since no values representing the situation before ditching are available for plot SL (slow-dissolving PK), no comparisons can be made, but a gradual rise in respiration can be observed after the application of fertilizer compared with the control plot, continuing up to the fourth year.

The ash plot (AS) showed a pronounced increase in soil respiration, both in relative and in absolute terms, up to the fourth year, when the figure was almost 3.5 times the pre-drainage reading. Where the value for this plot was 60 % of that for the control plot immediately after ditching, it had risen to 120 % of the control value by the fourth year.

The UR plot, receiving urea + slow-dissolving PK, showed the greatest increase in soil respiration as a result of ditching, reaching its peak in the year after application of the fertilizer. This was followed by a steep decline in respiration values. As may be seen in Fig. 13:B, this decline was far more pronounced than in the control plot (approx. 120 % of the control value in 1980 and 80 % in 1982).

No readings are available for the NI plot (Nitroform + slow-dissolving PK) for the time immediately after ditching, but it is highly probable that the trend was similar to that seen elsewhere at site 1. By summer 1980 soil respiration in this plot was 2.3 times the initial value, after which the trend was very similar to that noted in the SL plot, implying a slight decline in absolute terms but a very slight increase in comparison to the control values.

The MI plot (slow-dissolving PK + urea + micro-elements) was the only one at site 1 in which soil respiration diminished after the application of fertilizer. As seen in Fig. 13:B, the falling trend was more pronounced than in the control plot. In 1982 the figure had nearly doubled, however, when this plot, together with plot AS had the highest soil respiration figures of all.

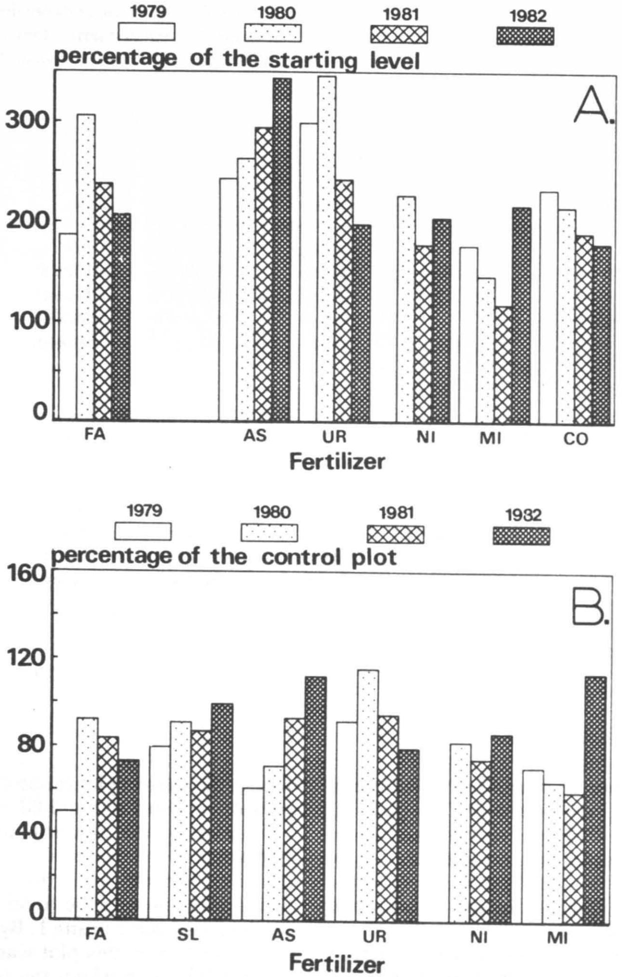


Fig. 13. Trends in soil respiration in plots receiving different fertilizers at site 1 evaluated in relation to the initial situation (A) and the non-fertilized plot (B). The percentages are based on respiration values obtained from analysis of covariance in which the readings for each test group are adjusted in accordance with the mean temperature for that group as a whole. The abbreviations of the different fertilizers are the same as in Fig. 2.

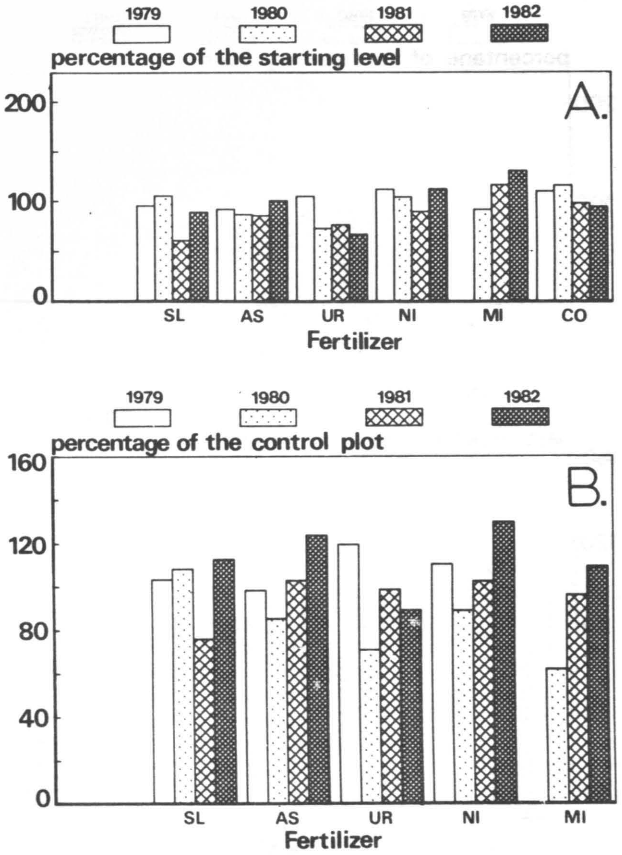


Fig. 14 Trends in soil respiration in plots receiving different fertilizers at site 2 evaluated in relation to the initial situation (A) and the non-fertilized plot (B). For further explanation, see Fig. 13.

342. Site 2

As a general feature of the soil respiration values at site 2, it may be said that the changes were very much less marked than at site 1. The value for the control plot (CO) increased a little after ditching, after which a gentle fall set in (Fig. 14:A).

The figures recorded in plot SL remained virtually at the same level as in the period preceding ditching both after this operation and following application of the fertilizer. A considerable reduction in soil respiration took place in 1981, however, and a conciderable rise the next year, which exceeded all the previous results relative to the control value.

In absolute terms, an extremely gradual fall in respiration values took place in plot AS following ditching and fertilization, with a slight rise in 1982. The situation is rather

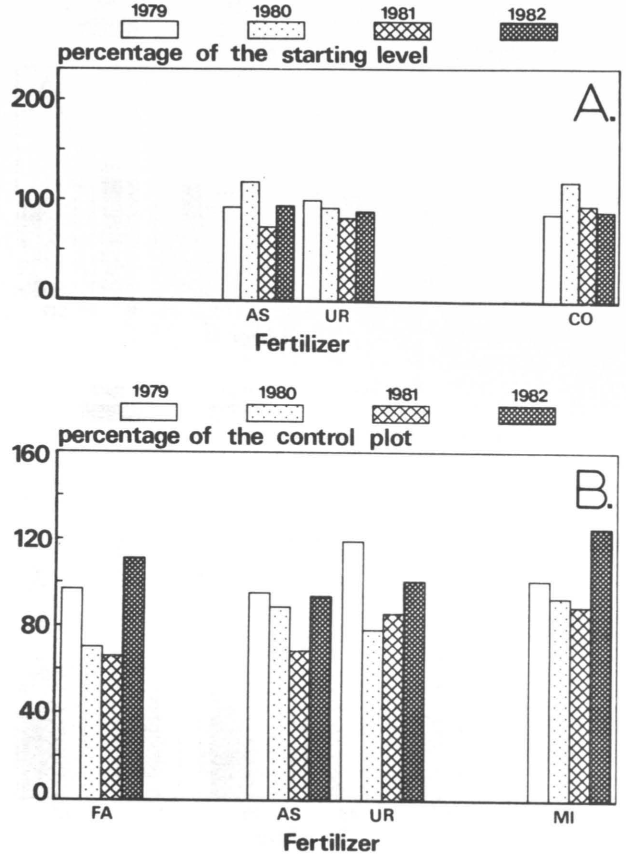


Fig. 15. Trends in soil respiration in plots receiving different fertilizers at site 3 evaluated in relation to the initial situation (A) and the non-fertilized plot (B). For further explanation, see Fig. 13.

different in appearance when compared with the control values, however, since now practically no change can be discerned after ditching, whereas the application of fertilizer was followed by a drop to the minimum value for soil respiration and then a distinct rise.

The respiration values for the UR plot after fertilization remain consistently below those recorded prior to this treatment, while in relation to the control plot a considerable fall in respiration is seen the year after fertilization, followed by a recovery and then a further fall.

The NI plot featured a two-year decline in soil respiration values in absolute terms after application of the fertilizer, followed by a return to the initial level. Viewed in relation to the control levels, the trend here was just the same as for the AS plot, with a fall in values after fertilization and a subsequent rise in each of the remaining years.

No data are available for the MI plot in the

year after draining, but the changes were presumably small, as in the other plots at site 2 (Fig. 14:A). After fertilization some reduction in respiration presumably took place in relation to the control plot, as elsewhere (Fig. 14:B), but the trend in the remaining two years was a rising one.

343. Site 3

The changes in soil respiration in absolute terms after ditching and fertilization were again fairly small. The readings for the control plot (CO) were a little lower after ditching, but increased slightly the following year, only to diminish again over the last two years (Fig. 15:A).

A considerable decline compared with the control values took place in the FA plot after application of the fertilizer, 60–70 % of the control level, but a return to a point a little above the initial value was seen in the fourth year.

A decline relative to the control value took place in the AS plot during the first two years, with a return to close the initial level in the third year after fertilization.

Soil respiration declined slightly in the UR plot throughout the period studied, implying a considerable drop relative to the control level immediately after fertilization and a partial recovery in the next two years.

Respiration in the MI plot fell in the two years following application of the fertilizer, but rose markedly in the third year to exceed the initial value.

4.DISCUSSION

41. Soil respiration in non-fertilized plots

Soil respiration usually varied in the range 100–500 mg CO_2 m^{-2} h^{-1} in the plots examined. The scatter was extremely great, and values covered practically the whole of this range in almost all the plots every time measurements were taken. This means that a small number of samples is scarcely sufficient to reveal the true differences in soil respiration brought about by the various treatments. CO_2 production increased exponentially with rising temperature, with a delay of 3–3.5 hours with respect to air temperatures at the surface of the ground. It has been presented that in practice the dependence of soil respiration on temperature is not due entirely to biological factors, but that the soil always contains high concentrations of CO_2, which passes faster into the air through diffusion when temperatures rise (Schlesinger 1977).

It may be concluded from Figs. 9, 13, 14 and 15 that CO_2 production in autumn 1979 must have averaged approx. 400 mg m^{-2} h^{-1} at site 1, about 300 mg at site 2 and something less than 300 mg at site 3. The values obtained for the samples studied in the laboratory differed markedly from those measured in the field. Soil temperatures in September were mostly in the range 10–15 °C, with a fairly even distribution through the soil, and yet the laboratory figures for an ambient temperature of 12 °C were approx. 330 mg CO_2 m^{-2} h^{-1} in the samples from site 3, approx. 250 mg in those from site 2 and approx. 200 mg in those from site 1 (Fig. 6). These discrepancies can probably be attributed to the lowering in the groundwater table and the peat properties particular to the individual sites. The peat at site 1 had low bulk density and was poorly decomposed and since the groundwater table had been high, some readily decomposable material had evidently remained in the peat, whereas at site 3 the peat had higher bulk density and was well decomposed and at site 2 the extent of decomposition lay between these two extremes. It would seem that in the case of a compact, decomposed peat of the kind encountered here at site 3 laboratory measurements performed on a sample 20 cm thick are representative of soil respiration as a whole, whereas given the poorly humified nature of the peat at site 1 and the drop in the groundwater table, it would seem that about a half of the total soil respiration takes place below the 20 cm level (cf. Lähde 1966, 1969). Site 2 seems to lie between the other two in this respect, too.

Total decomposition after draining during the four summer months in the non-fertilized plot at site 1, as simulated by reference to the measured temperatures and calculated respiration functions, was approx. 650 g m^{-2}, whereas the calculated value for the conditions prevailing before draining was approx. 300 g m^{-2}. Annual production in the surface vegetation was calculated at 197 g m^{-2} in 1979 and 56 g in 1980, while litter production of trees was 70 g m^{-2} (means for site 1). A further factor on the production side is of course production in the tree roots, but there is unfortunately no means of estimating this from the tree cover data available here. At any event, it is highly probable that at site 1 the rate of peat decomposition after ditching is considerably in excess of the rate of production of new organic material in the peat, since the above-mentioned decomposition rates for the summer months still have to be increased by an amount corresponding to decomposition during the remainder of the year (cf. Havas and Mäenpää 1972). At sites 2 and 3 actual peat accumulation would seem to have come to an end with the previous attempt at draining, since litter production was of the same order as at site 1 and production in the surface vegetation lower (Vuorinen et al. 1981).

Similar respiration values to those obtained here for site 1 before draining have been reported elsewhere on peatlands in a natural state (Fig. 6), whereas the other readings taken here exceed most of the values reported in comparable experiments. Kosonen (1968) obtained soil respiration values of 65–220 mg CO_2 m^{-2} h^{-1} in a meadow with a soil composed of fine sand with a thin humus layer, while daily figures for carbon release in peat soils during the summer are reported to be of the order of 1–2.2 g C m^{-2} where there is a vegetation cover present and 0.37–0.94 g C m^{-2} in the absence of a vegetation cover (Belkovskiy and Reshetnik 1981). Corresponding values for carbon release per day are quated as being 0.11–0.68 g C m^{-2} in the ombrotrophic parts of a Subarctic mire in summer (Svensson 1980), 1.6–2.5 g C m^{-2} in a pine forest around midsummer (Repnevskaja 1967) and 0.55–0.95 g C m^{-2} in mixed oak forest (Froment 1972). Spring and summer carbon release figures in fresh forest soils in the temperate zone are said to vary in the range 0.76–7.2 g m^{-2} per day (Edwards and Sollins 1973).

42. Effect of treatment with fertilizers on soil respiration

The three sites differed in their initial conditions and trends during the early part of the experiment. Site 1 underwent a pronounced drop in the groundwater table, whereas the other two sites did not experience this in the first year after ditching. Differences also appeared in the structure and decomposition of the peat, again with site 1 standing out most clearly from the others. Ditching and fertilization can bring about changes in the acidity of peat (Table 6, Sepponen and Haapala 1979), and a reduction in soil acidity is usually regarded as stimulating an increase in soil respiration (Martin and Holding 1978, Tate 1980). Thus the features particular to each area should be bore in mind when evaluating the effects of the different fertilizers on conditions at the sites.

421. PK fertilizers

The fast-dissolving PK fertilizer (FA plots) had an effect which operated in opposite directions at sites 1 and 3, soil respiration showing an increase in the year following applications of the fertilizer at site 1, with a subsequent decline trend which still left the rate of respiration higher than at the outset, whereas a two-year decline in respiration values set in at site 3, after which values returned to the initial level. At site 1 the acidity increased as much as in the control plot, but at site 3 the increase was greater (Table 6).

Soil respiration increased gradually in the slow-dissolving (SL) plots at sites 1 and 2, with the exception of a decrease in the summer of 1981.

The stimulation of soil respiration achieved with the PK fertilizers at site 1 suggest that the soil microbes were suffering from a deficiency of these nutrients. The effects of the fast-dissolving fertilizer were evident at once, the rapid rise in soil respiration being attributable to the immediate utilization of easily metabolized organic compounds contained in the surface peat. At site 2 the microbes were not experiencing any appreciable lack of phosphorus or potassium, as may be seen from the results of the addition of slow-dissolving PK fertilizer. At site 3 treatment with fast-dissolving phosphorus and potassium fertilizer had the effect of reducing soil respiration for a two-year period.

Martin and Holding (1978) did not observe an addition of phosphorus alone to have any effect on soil respiration, while Waksman and Purvis (1932), measuring CO_2 release from non-fertilized peat samples and samples treated with phosphate and nitrogen fertilizers, concluded that microbial activity was not limited by any shortage of nitrogen or phosphorus but by the availability of oxidizable carbon. Soil respiration increased once the peat had been treated chemically to transform the carbon chains into a more soluble form. Also Salonius (1972) concluded, that in the acid organic soil the microbial activity may be limited by shortage of decomposable matter and acid conditions rather than by shortage of nutrients. Bååth et al. (1978) have similarly shown, that microbial activity may in certain situations be restricted by the supply of energy. This energy restriction is particularly evident in the case of the spruce swamp biotope, where the sudden increase in nutrients served only to disturb the decompositional system.

422. Ash

Fertilization with ash brought about a marked decrease in acidity at all three sites

Table 6. PH values in the surface layer of peat at the study sites. J=July, A=August, S=September. Pasanen et al. 1983, Vuorinen and Grönlund 1984, pers. comm.

Site 1

Fertilizer	1979 J	1979 A	1980 A	1981 J	1982 J
SL	4.2	4.2	4.8	4.8	4.3
FA	4.1	4.0	3.2	4.5	4.4
AS	4.1	4.1	6.3	7.2	5.8
UR	4.2	4.2	4.9	4.5	4.2
NI	4.5	–	4.0	–	5.0
MI	4.1	4.0	4.1	4.7	4.3
CO	4.2	4.2	3.3	4.2	4.0

Site 2

Fertilizer	1979 J	1979 A	1980 A	1981 A	1982 A
SL	–	–	–	–	5.0
AS	4.6	4.8	4.7	5.8	5.5
UR	4.6	4.3	4.8	4.7	4.5
NI	–	–	3.6	–	4.7
MI	–	–	4.2	–	4.7
CO	–	–	3.4	–	4.3

Site 3

Fertilizer	1979 A	1979 S	1980 S	1981 A	1982 A
FA	4.0	4.1	3.3	4.2	4.3
AS	4.2	4.0	5.2	4.5	6.0
UR	4.2	4.1	4.4	5.0	4.6
MI	4.5	4.2	5.1	5.3	4.7
CO	4.2	4.2	4.6	4.3	4.2

(Table 6), leading to a very pronounced stimulation of soil respiration at site 1 and a slight stimulation at site 2. At site 3 the respiration first decreased and returned later close to the initial level.

The amounts of soil bacteria present in the surface peat horizons of a dwarf shrub pine bog have been shown to have increased markedly upon draining and dressing with ash, while fertilization with ash is reported to have increased the amounts of aerobic microbes considerably in the 10 cm thick surface horizon of a ditched wet poor fen (Huikari 1953). Karsisto (1979b) similarly reports an acceleration in the decomposition of cellulose and an increase in total bacteria, particularly in the surface peat, upon treatment with ash.

423. NPK fertilizers

The use of urea (UR) and Nitroform (NI) as sources of nitrogen led to quite distinct trends. The more rapid dissolving of urea became evident at site 1, where its effect

resembled that brought about by the fast-dissolving PK fertilizer, while at sites 2 and 3 this urea nitrogen had a pronounced detrimental effect on soil respiration in summer 1980. Respiration in the urea plot was at a lower level by the end of the experiment than initially at all three sites.

The use of Nitroform meant that the fertilizer had virtually no effect at site 1. Some lowering of the level of soil respiration was caused at site 2 in summer 1980, but this was not as pronounced as in the urea plot.

NPK fertilizers are reported to have achieved a slight increase in microbial activity in the litter horizons of birch and alder forests, but this activity declined markedly in the lower soil horizons (Van Cleve 1974).

Kovalenko et al. (1978) have shown nitrogen fertilizers to reduce soil respiration, largely by lowering the pH of the soil. The acidity did not increase here in NPK plots more than in control plots, rather the contrary (Table 6).

Karsisto (1979b) observed increases in numbers of bacteria in a pine bog upon the application of NPK fertilizers, while in a spruce swamp the same treatment reduced the numbers of bacteria in those plots in which the groundwater table had been regulated to a depth of 70 cm. The bacteria in the pine bog had presumably been suffering from a greater shortage of nutrients than those in the spruce swamp, which must have been naturally richer in nutrients.

The present results obtained with NPK fertilizers employing these two sources of nitrogen can also be explained well in terms of differences in nutrient requirements.

424. NPK + micro-elements

NPK fertilizer with additional micro-elements (MI plots) had similar effects at sites 1 and 3, in that soil respiration diminished steadily at first but returned over the initial level in the last year of the experiment. At site 2 the values for the MI plot increased already during the third year, having reached their minimum in 1980.

This fertilizer contained large amounts of copper, administered at a rate of 12.8 kg ha^{-1}. The concentrations of total copper ($\mu g\ g^{-1}$ dry weight) in the surface peat were 5–10 before the fertilization, 35–67 in 1980, 13–200 in 1981 and 38–122 in 1982 (Pasanen et al. 1983). It has been shown in many studies, that copper decreases soil respiration rate, although large variations seem to be in the concentration values, in which the toxic effects have appeared (cf. Tyler 1974, Ebregt and Boldewijn 1977, Mathur and Rayment 1977, Mathur et al. 1980, Shinner et al. 1980, Lucas 1982).

It would seem that the micro-element mixture had also here a toxic effect on microorganisms, for unusually, a reduction in soil respiration was also noted at site 1 in this case. Evidently a better nutrient balance had been achieved by the end of the experiment, and trace elements in the right concentrations can thus be said to improve microbial activity.

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SELOSTE

OJITUKSEN JA LANNOITUKSEN VAIKUTUS MAAHENGITYKSEEN KOLMELLA SUOMUUTTUMALLA

Luonnontilaisilla soilla perustuotanto on yleensä suurempi kuin hajotus, ja näin orgaanista ainetta kasautuu turpeeksi. Boreaalisilla soilla turpeen muodostus on yleensä 0.2–1.5 mm vuodessa vastaten keskimäärin 40–50 g kuiva-ainetta neliömetrille. Vaikka suot ovat usein karuja kasvupaikkoja, on paksuihin turvekerrostumiin kerääntynyt runsaasti ravinteita. Kun soita käytetään maa- ja metsätaloudessa, on yksi luonnollinen kysymys, millaisella nopeudella turpeen sisältämät ravinteet vapautuvat hajotustoiminnan tuloksena kasvien käyttöön.

Tässä työssä tutkittiin ojituksen ja erilaisten lannoituskäsittelyiden vaikutusta hajotustoimintaan kolmella suokoealalla. Koealueilla oli jo aikaisemmin, 40–50 vuotta sitten tehty ojituksia ja sen jälkeen joitakin perkauksia, joten ne eivät olleet kokeen alkaessakaan luonnontilaisia. Tosin, erityisesti alueen eteläosassa ojat olivat pitkälti umpeen kasvaneet. Koeala 1 lienee alunperin ollut sararämettä, joskin aikaisemmat ojitukset olivat tehneet pintakasvillisuudesta monin paikoin tupasvillavaltaisen. Alue 2 lienee alunperin ollut ruohoinen sararäme, jossa kuitenkin kokeen aikana pintakasvillisuudessa vallitsevina olivat mm. puolukka, mustikka ja korvenkarhunsammal. Alue 3 edusti mustikkatyypin korpea. Alueella 1 puuston muodosti pääsasiassa mänty (n. 1100 kpl ha^{-1}, korkeus n. 10 m, tilavuus n. 70 m^3 ha^{-1}), alueella 2 suunnilleen puoliksi mänty ja koivu (n. 1100 kpl ha^{-1}, korkeus n. 13 m, tilavuus n. 100 m^3 ha^{-1}) ja alueella 3 pääasiassa kuusi (n. 700 kpl ha^{-1}, korkeus n. 17 m, tilavuus n. 160 m^3 ha^{-1}). Turpeen paksuus vaihteli korven n. 0.5 metristä sararämeen 2 metriin. Tutkimuksen alussa alueella 1 vesipinta oli 0–10 cm, alueella 2 20–30 cm ja alueella 3 10–30 cm maanpinnasta. Ensimmäisen tutkimusvuoden elokuussa koealueet ojitettiin, mistä lähtien pohjaveden syvyys oli alueella 1 40–60 cm, alueella 2 40–50 cm ja alueella 3 30–50 cm.

Hajotusaktiivisuuden tutkimisessa käytettiin CO_2:n tuoton eli maahengityksen mittaamista. Maahengitystä on yleisesti käytetty maaperän biologisen aktiivisuuden mittarina, ja vaikka se ei sellaisenaan anna täydellistä kuvaa hajotustoiminnasta, sillä on katsottu olevan selvät korrelaatiot hajotusaktiivisuuteen ja ravinteiden mineralisaatioon. Käytetyssä menetelmässä kammio painautui mittausajaksi maata vasten, ja imetyn näyteilman hiilidioksidipitoisuus mitattiin infrapunakaasuanalysaattorilla (IRGA, URAS). Ensimmäisen mittauskierroksen jälkeen koealat ojitettiin ja toisen kierroksen jälkeen lannoitettiin. Käytetyt lannoitteet olivat hidasliukoinen ja nopealiukoinen PK, kaksi NPK-lannoitetta, joissa toisessa oli typen lähteenä urea ja toisessa Nitroform, puuntuhka sekä NPK-lannoite, johon oli lisätty hivenseos.

Mittaustulosten testauksessa käytettiin kovarianssianalyysiä, jossa mittaustulokset suhteutettiin testijoukon yhteiseen keskilämpötilaan, ja näin saatiin eri lämpötiloissa suoritetut mittaukset keskenään vertailukelpoisiksi. Testien avulla tutkittiin toisaalta maahengityksen kehitystä yksittäisillä ruuduilla neljän vuoden aikana, sekä toisaalta verrattiin eri lannoitekäsittelyjen vaikutusta suhteessa kehitykseen lannoittamattomalla kontrolliruudulla. Student–Newman–Keuls-keskiarvotestin avulla testattiin, mitkä ruudut testiryhmässä eroavat toisistan 5 % riskillä.

Maahengitys vaihteli koealueilla yleensä välillä 100–500 mg CO_2 m^{-2} t^{-1} ja vaihtelut seurasivat lämpötilan vaihteluita noin 3 tunnin viiveellä. Kun alueella 1 vesipinta laski ojituksen jälkeen noin puolella metrillä, maahengitys lisääntyi muutamassa viikossa 2.5 kertaiseksi. Alueilla 2 ja 3 ojituksen aiheuttama vesipinnan lasku oli vähäinen ja samoin muutokset maahengityksessä olivat pienempiä. Ennen ojitusta alueella 1 maahengityksen pohjalta laskettu orgaanisen aineen poistuma turpeesta arvioitiin olevan vain vähän suurempi kuin turpeeseen tuleva orgaaninen aines (pintakasvillisuuden tuotos ja kariketuotanto). Sen sijaan ojituksen jälkeisenä vuonna turpeen orgaanisen aineen poistuman laskettiin olevan moninkertainen turpeeseen tulevaan orgaaniseen aineeseen verrattuna.

Lannoituskäsittelyillä oli erilainen vaikutus eri suotyypeillä johtuen ilmeisesti eroista luontaisessa ravinteisuudessa ja vedenpinnan muutoksissa. Nopealiukoiset PK- ja NPK -lannoitteet aiheuttivat alueella 1 (sararäme) huomattavan nousun ja myöhemmin laskun maahengityksessä. Alueilla 2 ja 3 (ruohoinen sararäme ja korpi) nopealiukoiset lannoitteet aiheuttivat vähenemisen maahengityksessä, mikä myöhemmin ainakin osittain palautui. Hidasliukoiset PK- ja NPK- lannoitteet aiheuttivat alueilla 1 ja 2 lievää maahengityksen kasvua (alueella 2 taantumavaiheen jälkeen). Tuhkalannoitus aiheutti alueella 1 huomattavan ja koko tutkimusjakson kestävän maahengityksen kasvun, alueella 2 lievän kasvun lyhyen taantumavaiheen jälkeen, ja alueella 3 kaksi vuotta kestävän taantumavaiheen, ja tämän jälkeen palautumisen alkuperäiselle tasolle. NPK + hivenseos aiheutti kaikilla koealoilla mahdollisesti kuparin myrkkyvaikutuksesta johtuvan laskun maahengityksessä, mikä kuitenkin viimeistään neljäntenä vuotena palautui ylittäen aikaisemmat tasot.

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SILVOLA, J., VÄLIJOKI, J. & AALTONEN, H. 1985. Effect of draining and fertilization on soil respiration at three ameliorated peatland sites. Seloste: Ojituksen ja lannoituksen vaikutus maahengitykseen kolmella suomuuttumalla. Acta For. Fenn. 191: 1–32.

The respiration rate at three ameliorated peatland sites varied mostly in the range 100–500 mg CO_2 m^{-2} h^{-1}, and the changes followed those in the surface temperature with a time-lag of c. 3 hrs. After dropping the groundwater table by c. 0.5 m soil respiration increased 2.5-fold, which means, that the rate of peat decomposition is considerably in excess of the rate of production of new organic material in the peat. Application of fast-dissolving PK or urea led to a rapid increase in soil respiration at the site poorest in nutrients. The greatest, steady increase was achieved by treatment with ash. At the sites with a higher natural nutrient content the application of fertilizers usually led to a decline in soil respiration lasting 1–2 years. Treatment with micro-elements caused an initial fall in respiration, followed by a pronaunced increase.

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