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SURFACE FLUCTUATION IN THREE VIRGIN PINE MIRES IN EASTERN FINLAND

Heikki Kurimo

Seloste

SUON PINNAN KORKEUSVAIHTELU KOLMELLA ITÄ-SUOMEN LUONNONTILAISELLA RÄMEELLÄ

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Altitude fluctuation of the mire surface proportional to that of the groundwater table is presented for three virgin pine mires in eastern Finland during the growing season 1982. The average amplitude of the surface fluctuation ranged from about 18 to 45 millimetres; each of the mires followed a fluctuation scale of its own. The daily rate of the fluctuation was found to be dependent on the period representing a certain type of weather, being limited, however, to a certain maximum.

The daily fluctuation rates were low, generally 0.5–1 millimetres, and only occasionally exceeded 2 millimetres. No sudden fluctuation peaks occurred. Regularities in the mire surface fluctuation, which could be distinguished in all of the mires, were found to be caused by the duration of the period representing a continuous sinking or rise of the groundwater table, and magnitude of it. The daily rate of the surface fluctuation in relation to that of the groundwater table was smaller in the beginning of the period than at the end of the same period. The one-directional rise or sinking of the altitude of the mire surface according to the groundwater table fluctuation is responsible for the autocorrelation of the long-term regression data. The mechanism according to which the mire surface fluctuation is primarily controlled by the fluctuation of the groundwater table leads in most cases to such a situation that a certain altitude position of the groundwater table does not correspond to the same altitude position of the mire surface representing dates separated by a longer period of time. This is of importance in mire hydrology because the water amount capable of being stored in the mire basin without causing any overflow is greater in a basin having a high surface altitude than that of the same basin having a low altitude position.

INTRODUCTION

Surface sinking of peat or gyttja areas after drainage for agriculture, forestry or energy peat production has been a subject of great interest (see e.g. Kokkonen 1931, Lukkala 1949, Kaitera 1954, Eggelsmann 1960b, Agerberg 1961, Kilpiäinen 1976, Nesterenko 1976) because of its practical and hydrological consequences.

Difficulties often arise due to altitude reduction during the construction of roads through peat areas drained for forestry or, especially, for energy peat production. Surface sinking may, in places, exceed half a metre in a few years, for example in the Mekrijärvi energy peat production area, Ilomantsi, eastern Finland. Altitude reduction of the peat or gyttja areas lying along the shores of drained lakes has frequently also been responsible for a reduction in agricultural land use, if not redrained by pumps.

Studies on the theme indicate that sinking takes place rapidly shortly after the ditching treatment has been carried out, but slows down later on. The sinking rate also depends, for example, on the prevailing climatological conditions, depth of the peat layer and that of the ditches, drainage intensity, and characteristics of the peat. The surface of a more intensively drained mire generally sinks faster than that of a mire drained less efficiently.

The natural periodical fluctuation in the peatland surface has been known for decades (see e.g. Weber 1902, Prytz 1932). This phenomenon, however, has been studied much less than the sinking process caused by artifical peatland draining.

Most of the studies concerning virgin peat areas come from Germany (e.g. Uhden 1956, 1960, 1972, Eggelsmann 1960a, Baden and Eggelsmann 1964), many of them including comparisons with drained peatlands. Comparisons of the same type have also been performed by Mustonen and Seuna (1971) in Finland.

Surface fluctuation of a mire has been called "bog respiration" or "oscillation" by Uhden (1956, 1972), and explained as a consequence of the fluctuating groundwater table (see e.g. Baden and Eggelsmann 1964).

The aims of the present study are (1) to compare the surface fluctuation amplitudes of different peat areas, (2) to explain how the altitude of the mire surface depends on that of the groundwater table, (3) to detect regularities according to which the process occurs, and (4) to evaluate the role of the surface altitude fluctuation in the hydrology of the mire.

According to observations made in summer 1981, the surface level of two pine mires in eastern Finland were several centimetres lower than what they were after a long rainy period. Unfortunately, no exact measurements could be carried out. Additional measurement sites were established the following summer and the present study was started in order to verify the theory that vertical movements of the mire surface are proportional to changes in the groundwater table.

The present study was carried out with the co-operation of the local organization of the National Board of Waters (Pohjois-Karjalan Vesipiiri), supported by the Finnish Academy. My thanks are especially due to Mrs. M. Ahtiainen, M.Sc. who arranged the observation net necessary for the study. The field material was collected with the assistance of Mr. A. Latja, Mr. J. Riihelä and Mr. M. Korhonen, M.Sc. Valuable comments on the manuscript were given by Dr. J. Päivänen, Mr. J. Laine, Lic. For. and Mr. P. Seuna, Lic. Tech. The data processing was performed at the University of Joensuu, most of the figures were drawn by Miss T. Toivonen, and the English language was checked by Mr. J. Jerome, M.Sc. The author wishes to thank the above persons as well as all the others who have contributed to the completion of this paper.

METHODS

The following observation system was used to obtain simultaneous altitude records of the groundwater table in relation to the mire surface (Figs. 1–3). The groundwater pipes, three lying close together in each mire, were pushed down hard into the mineral soil underlying the peat layer so they could not move. The initial starting altitude (on June 26, 1982) of the mire surface around each pipe was used as the zero level. This was done by calibrating a millimetre-scaled rod taped to each of the pipes. The altitude of the mire surface surrounding the pipe was indicated by a piece of metal netting with a hole in its centre, lying on the peat surface. The altitude of the mire surface with respect to the zero-level was read from the scaled rod every day, usually at 10.30–11.30 a.m. in the case of two of the mires and at 14.00–16.00 p.m. for the third mire. The observation accuracy was about one millimetre. The corresponding altitude values of the groundwater table were measured simultaneously using an electronic groundwater table wire-recorder (accuracy 0.5 centimetres). Owing to problems with the recorder the accuracy of the groundwater table data was reduced to about two centimetres during the period August 29, — September 10, 1982.

Päivänen (pers. comm.) reports that a similar observation system has been used at Lamminsuo, Zelenogorsk, USSR, in 1973.

The altitude values of the groundwater table and the mire surface were observed relative to the zero level which, in turn, can be converted into absolute units. This was not done, however, because of the lack of levelling points nearby, and because it does not affect the results.

Daily areal precipitation was also determined at the same time using the mean values of 4–5 rain gauges situated 5–20 metres apart from the pipes in each mire area. Wind speed and solar radiation measurements were also carried out, but as they were of the same magnitude in all of the mires this material was not used in the analysis.

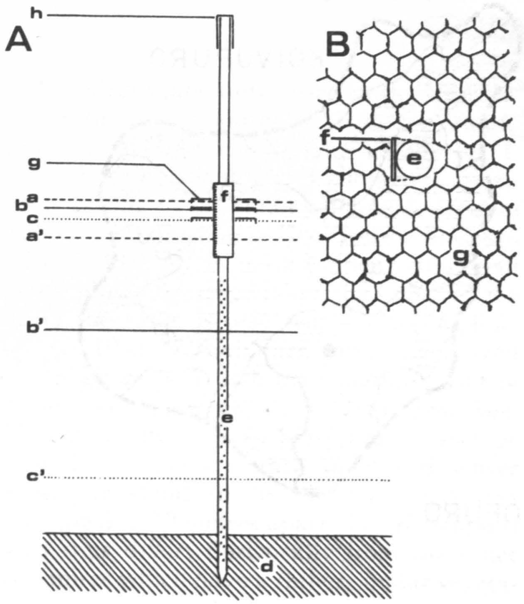

Fig. 1. The observation system for measuring altitude fluctuation in the mire surface with respect to the groundwater table. The metal net, size 40×50 cm, (g) surrounding the groundwater pipe (e) rises and falls according to the surface fluctuation; its altitude position is observed from the scaled rod (f) taped to the pipe (measurement accuracy about one millimetre). The pipe is pushed down firmly into the mineral soil (d) below the peat layer. (a^1, b^1, c^1) altitude positions of the groundwater table, (a, b, c) altitude positions of the mire surface. Altitude of the groundwater table is measured from the top of the pipe (h). The initial altitude of the mire surface (b) was marked 0 on the scaled rod before starting the measurements. (A) from side, (B) from above.

Kuva 1. Havainnointi suon pinnan korkeusvaihtelun mittaamiseksi suhteessa pohjaveden pinnan tasoon. Pohjavesiputken (e) ympärille asetettu katiskalankaverkkopala (n. 40×50 cm) nousee ja laskee suon pinnan korkeusvaihtelun mukaisesti; sen korkeusasema luetaan putkeen teipatusta millimetriasteikolla varustetusta viivottimesta (f). Pohjavesiputki on juntattu tiiviisti turvekerroksen alla olevaan mineraalimaahan (d) siten, ettei se pääse liikkumaan. (a^1, b^1, c^1) pohjaveden pinnan korkeusasemia, (a, b, c) suon pinnan korkeusasemia. Pohjaveden pinnan korkeusasema on mitattu putken päästä (h). Mittausten alkaessa teipattiin viivotin putkeen siten, että suon pintaa (b) osoittava katiskalankaverkko osoitti nollaa. (A) sivulta, (B) päältä.

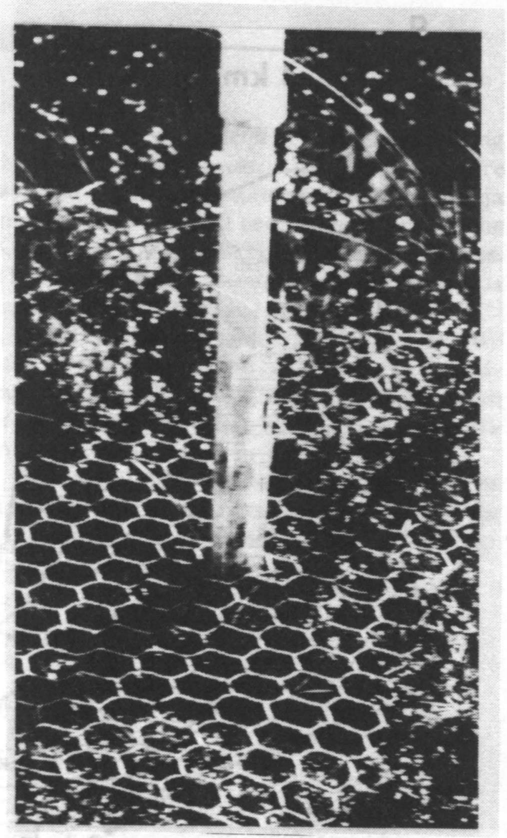

Fig. 2. Pipe site No. 2 in the Koivupuro mire.

Kuva 2. Pohjavesiputki No. 2 Koivupuron rämeellä.

The degree of synchronization between the fluctuating groundwater table and the mire surface altitude, with respect to the zero level, was analysed by comparing diagrams illustrating their progression, and by using correlation techniques. When studying the dependance of the change in the mire surface altitude on the altitude change of the groundwater table, the differences between consecutive paired observations were also used in the regression analysis in order to eliminate autocorrelation.

Correlative day-after-day fluctuation diagrams (co-fluctuation diagrams) were constructed by calculating the daily means of the 3-pipe series representing the same mire. Additional conclusions were drawn by comparing the diagrams representing different mires.

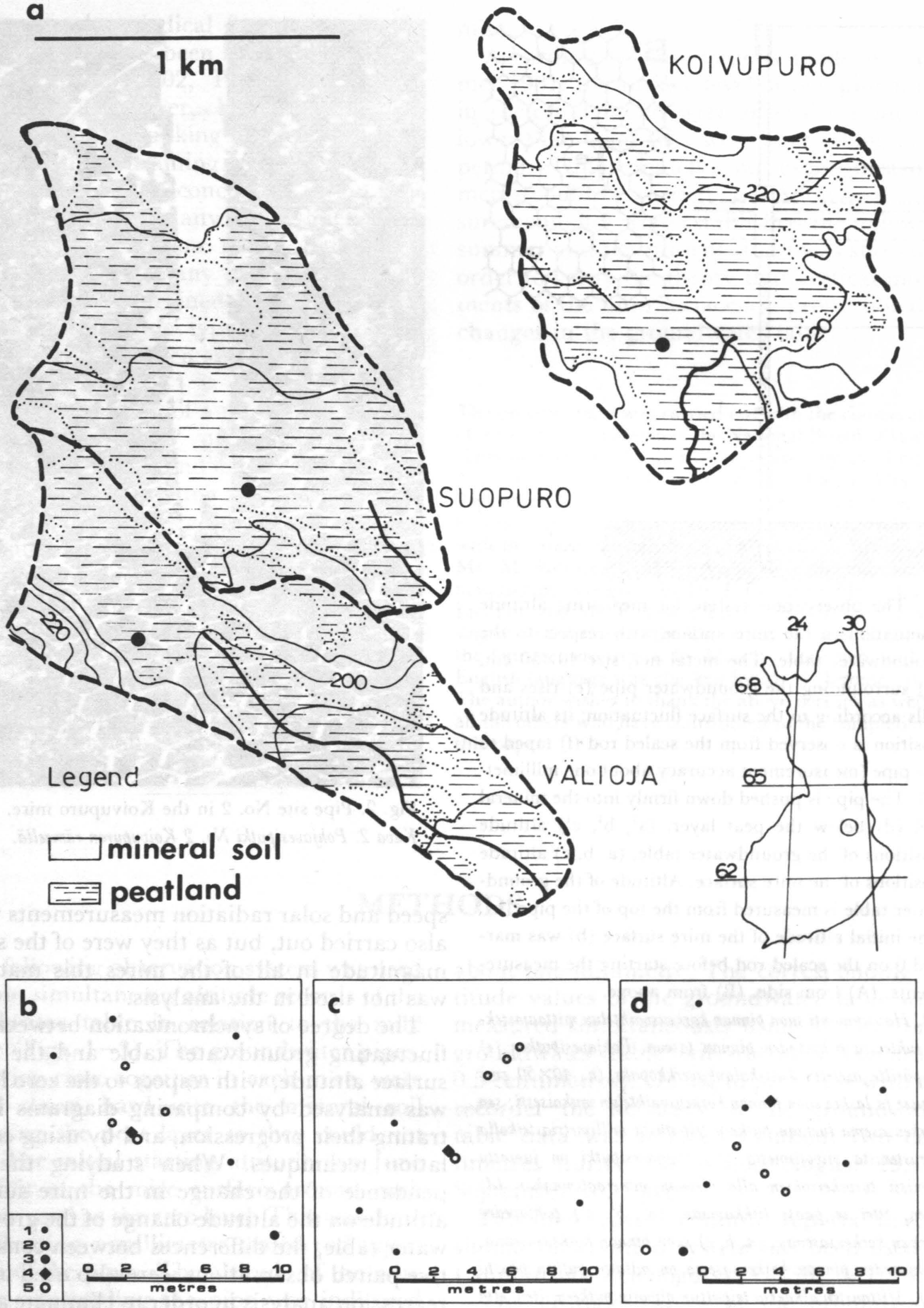

Fig. 3. The study areas (a) and the lay-out of the observation sites in different mires (b = Välioja, c = Suopuro, d = Koivupuro): (1) rain gauge, (2) groundwater pipe, (3) automatic precipitation recorder, (4) anemometre, (5) pyranometre. Fig. 3a by permission of the National Board of Waters (Vesihallitus).

Kuva 3. Tutkimusalueet (a) sekä havaintokohteiden ja -laitteiden sijainti eri soilla (b = Välioja, c = Suopuro, d = Koivupuro): (1) sademittari, (2) pohjavesiputki, (3) piirtävä sademittari, (4) tuulimittari, (5) säteilymittari. Kuva 3a Vesihallituksen luvalla.

STUDY AREAS

The virgin pine mires used in the study lie in the district of southern Sotkamo, eastern Finland (63°52–53' N lat., 28°38–40' E long.; Fig. 3), about 1 to 3 kilometres apart. They belong to the small catchment areas of Suopuro, Välioja and Koivupuro. Suopuro mire (0.48 km^2) is mainly open with small Scots pines growing along the sides of the mire; the same is also true for the Välioja mire (0.19 km^2). Both mires are characterized by *Sphagnum* peat with a vegetation cover of *Eriophorum vaginatum* and *Carex pauciflora.* Koivupuro mire (0.47 km^2) has sedge-type peat. It also has a slightly taller and denser Scots pine stand, the 3–10 -metre high trees growing 5 to 10 metres apart. The Koivupuro area thus differs floristically from the other two mires which have a rather similar vegetation cover.

The thickness of the peat layer surrounding the 3-pipe series varies in the Suopuro mire from 255 to 265 centimetres, in the Välioja mire from 245 to 320 centimetres, and in the Koivupuro mire from 245 to 290 centimetres. Thus there are no essential differences as regards peat thickness.

In all cases the groundwater pipes are situated in the areas where Scots pines are growing, i.e. on the sides of the mires. The lay-out of the pipes and other measurement instruments are illustrated in Fig. 3b,c,d.

The study period lasted from June 26, the day when the metal nets were put around the pipes and the scaled rods calibrated, to September 30, 1982.

RESULTS

Altitude fluctuation of the groundwater table and that of the mire surface

The shape of the fluctuation diagrams (Figs. 4–6) representing different pipe sites (1–3) inside the same mire are quite similar, the disagreements evidently being due to inaccuracies in reading the rod scale, and the wire length of the electronic groundwater table recorder.

Different physical properties related to peat quality, resulting from the mire microtopography, are evidently responsible for the small disagreements depicted in Figs. 4–6 (see e.g. Päivänen 1973, 1983). According to Sjörs (1948), the sinking of the wet microbasin surfaces caused by the sinking of the groundwater table is higher than that of the microhummocks.

In the present study all the pipe sites in Suopuro and Välioja represent even surfaces without any noticeable microrelief. In Koivupuro, pipe site number 1 represents a microhummock of about 7-centimetre relative height, and pipe sites Nos. 2 and 3 represent microbasins or almost even surfaces.

The lowest groundwater table with respect to the initial altitude of the mire surface (zero level) was observed in the Suopuro mire (variation from 22.5 to 25.5 centimetres below the zero level), in the Välioja mire the variation was 18.8 to 19.3 centimetres, and in the Koivupuro mire from 12.5 to 19.0 centimetres.

The maximal fluctuation of the mire surface varied in the Suopuro mire from 1.7 to 2.4 centimetres (mean 2.1 cm), in the Koivupuro mire from 2.7 to 3.9 centimetres (mean 3.0 cm), and in the Välioja mire 1.3 centimetres (mean 1.3 cm). It occurred at approximately the same time (August 6–18) in all the peat areas. Before starting the measurements the mire surface was, in fact, even higher but no precise observations could be made because the metal nets were not in place. According to rough observations made in spring before the study period began, the mire surface was from 0.5 to 1.5 centimetres higher than on June 26, depending on the mire area. Thus the average surface fluctuation during the summer period 1982 can be considered to range from about 1.8 (Välioja)

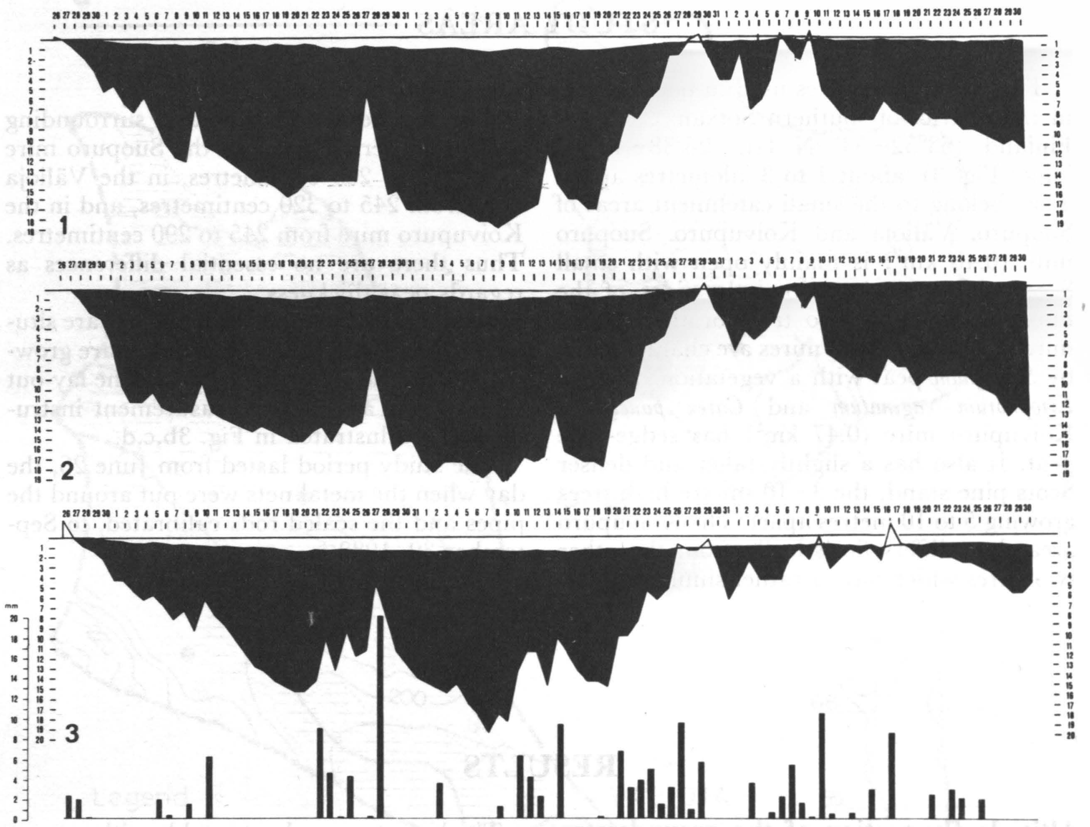

Fig. 4. Altitude fluctuation of the groundwater table (lower limit of the black area) and that of the mire surface (upper limit of the black area) in Välioja represented by pipe site Nos. 1, 2 and 3. The horizontal line represents the initial zero-level of the mire surface in the beginning of the study period. x-axis: dates June 26, – Sept. 30, y-axis: centimetres below 0-level. The block diagram illustrates areal precipitation (mm/day).

Kuva 4. Suon pinnan (mustan alueen yläreuna) ja pohjaveden pinnan (mustan alueen alareuna) korkeusvaihtelu Väliojan rämeellä kolmen pohjavesiputken (1–3) kuvastamana. Vaakatasossa oleva viiva kuvaa tutkimuksen alkaessa vallinnutta suon pinnan 0-tasoa. x-akseli: päivämäärät 26.6.–30.9; y-akseli: senttimetriä 0-tason alapuolella. Pylväsdiagramma kuvaa alueellista sadantaa (mm/vrk).

to about 4.5 (Koivupuro) centimetres (pipe number 2, max. 5.5 cm; see Figs. 4–6).

Table 1 gives a brief summary of the variation in the altitude changes of the groundwater table and the mire surface during different types of meteorological period.

The vertical short-term (daily) fluctuation of the bog surface is extremely small, and is frequently observable only after a lag time lasting many hours (one-day; cf. Figs. 4–6). No sudden oscillations occur. Even the heaviest individual periods of rain responsible for a groundwater table rise of about 8–10 centimetres lead only to a 1–3-millimetre daily rise of the surface. Correspondingly, surface sinking only occasionally exceeds 2 millimetres per day (see Table 1). Therefore, the daily rate of the surface fluctuation is relatively small compared with that of the groundwater table. The daily rate of the vertical surface movement also varies according to the mire area, and is evidently, at least partly, also caused by peat characteristics (cf. e.g. Sjörs 1948, see also Päivänen 1973, 1983).

The altitude of the mire surface does not change essentially as a result of individual periods of rain, if they are not exceptionally heavy and interrupted by rainless days. If, however, a longer rainy period occurs the

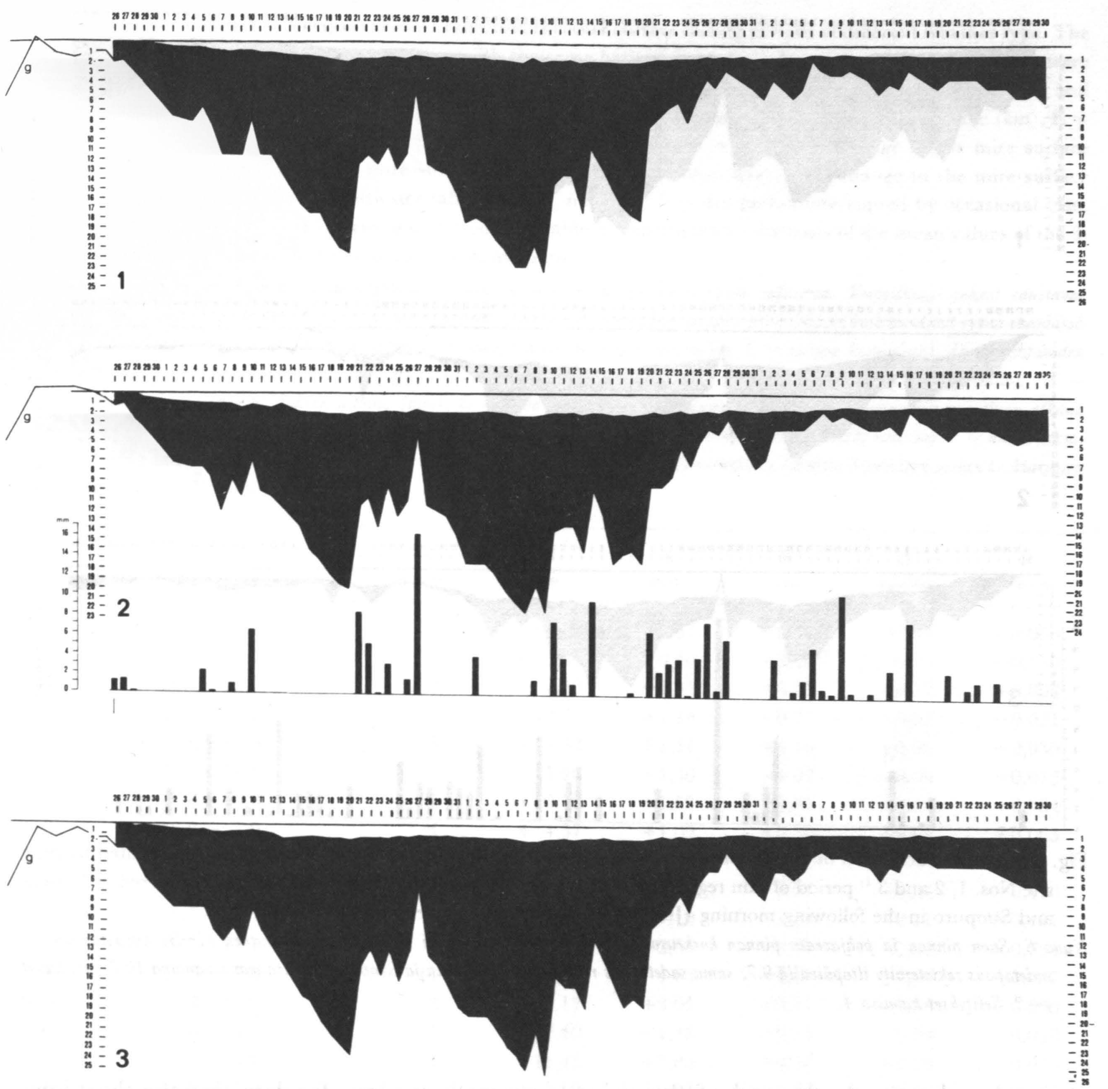

Fig. 5. Altitude fluctuation of the groundwater table and that of the mire surface in Suopuro, represented by pipe site Nos. 1, 2 and 3. (g) groundwater table, measured before June 26, 1982. For explanations, see Fig. 4.

Kuva 5. Suon pinnan ja pohjaveden pinnan korkeusvaihtelu Suopuron rämeellä kolmen pohjavesiputken (1–3) kuvastamana. (g) pohjaveden pinta ennen kesäkuun 26 päivää. Selitykset kuvassa 4.

change process, now cumulative, leads in one direction only and the rise of the mire surface can be clearly noticed.

On a scale of a period lasting for many days, corresponding to a continuously sinking groundwater table, the subsidence of the mire surface seems to take place slightly faster in the beginning part of the period that at the end of it. The same is true for the simultaneous sinking of the groundwater table which also generally slows down at the end of the period, due to the decrease in the hydraulic conductivity of the peat with increasing depth (see e.g. Päivänen 1973, 1983), associated with the reduced runoff.

The rise in the mire surface also follows the same principle: it is faster in the beginning part of the period but slows down towards the end of the period. The corresponding speed of the rise in the groundwater table altitude is

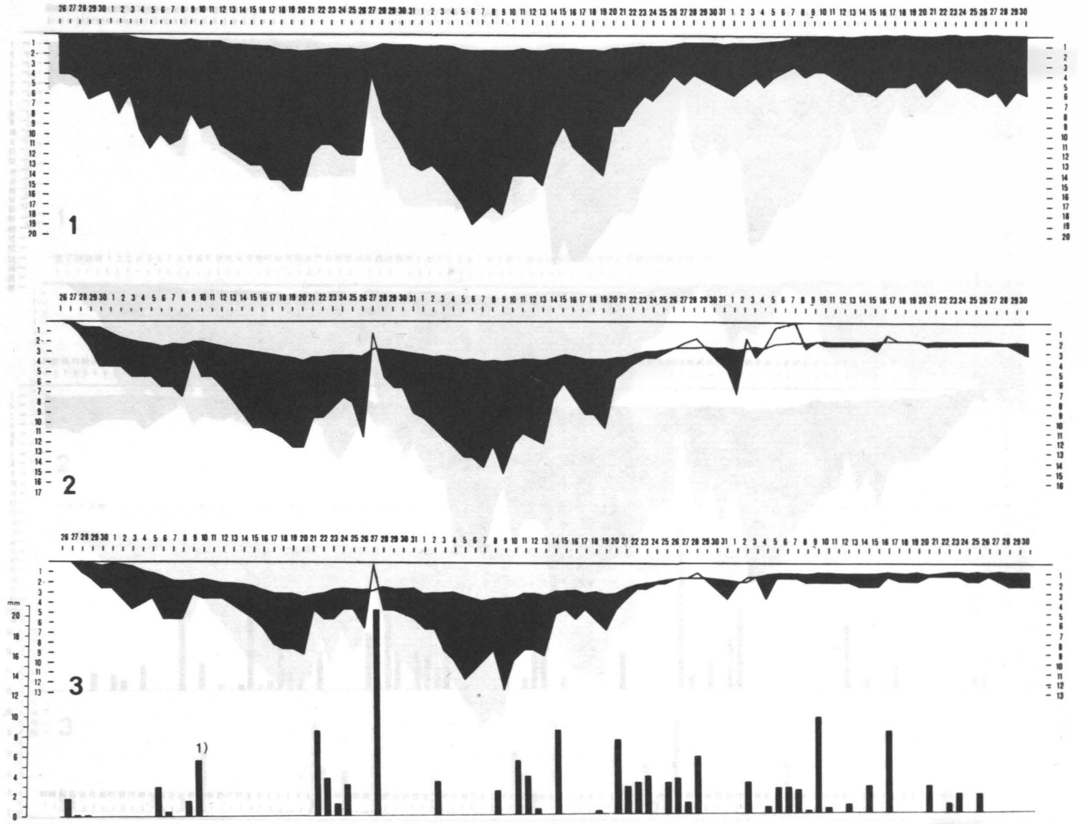

Fig. 6. Altitude fluctuation of the groundwater table and that of the mire surface in Koivupuro, represented by pipe site Nos. 1, 2 and 3.$^{1)}$ period of rain registered at afternoon (July 9,); the same period of rain registered in Välioja and Suopuro in the following morning (July 10, cf. Figs. 4–5). For explanations, see Fig. 4.

Kuva 6. Suon pinnan ja pohjaveden pinnan korkeusvaihtelu Koivupuron rämeellä kolmen pohjavesiputken (1–3) kuvastamana. $^{1)}$ *sadetapaus rekisteröity iltapäivällä 9.7; sama sadetapaus rekisteröity Väliojalla ja Suopurolla seuraavana aamuna 10.7, vrt. kuvat 4–5. Selitykset kuvassa 4.*

also reduced towards the end of the rising period, again for the same reason, but in the opposite direction (increase in the hydraulic conductivity of the peat with increasing depth, which permits an increase in runoff) assuming that the rate of precipitation per day is constant during the period. In principle, the speed of the subsidence/rise of the groundwater table, as well as that of the mire surface altitude obviously follows the hysteresis-curve: fluctuation takes place slowly in the very beginning of the period, grows fast rapidly and is reduced slowly again towards the end of the period (cf. Figs. 7–9; dotted lines representing the change between the periods leading to the opposite direction). The observation interval (day) is, however, generally too long for detecting the short low-speed part including the periodical fluctuation curve.

Although the fluctuation of the surface altitude follows that of the groundwater table it takes place on an extremely reduced altitude scale. Due to this the dependence of the surface altitude on time is practically roughly linear as regards periods of both sinking and rising, but that of the groundwater table depth on time for the same periods is more or less curvilinear, as illustrated in Figs. 4–6.

The diagrams representing surface altitude fluctuation should be, in theory, curvilinear following the shape of the corresponding groundwater table diagrams, even though on an extremely reduced altitude scale. The slight curvilinearity is less clearly apparent in the present data, however, obviously because it is shadowed by the irregularities and/or hidden by the inaccuracies.

Table 1. Altitude changes in the groundwater table and the mire surface during periods of different weather type. The periods compared represent weather types with the same hydrometeorological nature. Areal shover rains were mainly responsible for the different duration of the periods compared. A = number of period, B = beginning and end of the period, C = duration of the period (days), D = periodical change in the groundwater table (cm), E = daily change in the groundwater table, periodical mean (cm/day), F = periodical change in the mire surface (mm), G = daily change in the mire surface, mean of the period (mm/day), H = change in the mire surface altitude per change in the groundwater table (= F/D; mm/cm). $^{1)}$ = dry period interrupted by occasional rain. (–) = sinking direction, (+) = rising direction. The table is constructed on the basis of the mean values of the 3-pipe series. a = Välioja, b = Suopuro, c = Koivupuro.

Taulukko 1. Pohjaveden pinnan ja suon pinnan korkeusvaihtelut erilaisten säätyyppien vallitessa. Vertailtavat jaksot edustavat säätyyppejä, jotka hydrometeorologisesti ovat osapuilleen samanlaisia. Vertailtavien jaksojen erilaiseen kestoon olivat syynä etupäässä paikalliset kuurosateet. A = jakson numero, B = jakson alku- ja loppupäivämäärä, C = jakson kesto (vrk), D = pohjaveden pinnan muutos jakson aikana (cm), E = pohjaveden pinnan keskimääräinen vuorokautinen muutos jakson aikana (cm/vrk), F = suon pinnan korkeusmuutos jakson aikana (mm), G = suon pinnan keskimääräinen vuorokautinen korkeusmuutos jakson aikana (mm/vrk), H = suon pinnan korkeusaseman muutos/pohjaveden pinnan korkeusaseman muutos (= F/D; mm/cm). $^{1)}$ *= kuiva jakso, jossa esiintyy ajoittaisia sateita. (–) = laskeva suunta, (+) = nouseva suunta. Taulukko on laadittu 3-putkisen sarjan keskiarvojen perusteella. a = Välioja, b = Suopuro, c = Koivupuro.*

A No.	B period	C days	D cm	E cm/day	F mm	G mm/day	H mm/cm
1.	27.6.– 9.7.$^{1)}$	12	–10,53	–0,87	–0,53	–0,04	–0,050
2.	10.7.–20.7.	9	– 3,60	–0,40	–0,47	–0,05	–0,130
3.	20.7.–22.7.	2	+ 2,70	+1,35	+0,25	+0,12	+0,098
4.	27.7.– 7.8.	11	–12,73	–1,15	–0,27	–0,02	–0,021
a 5.	9.8.–12.8.	3	+ 3,33	+1,11	+0,16	+0,06	+0,050
6.	14.8.–18.8.	4	– 5,20	–1,30	–0,07	–0,02	–0,013
7.	18.8.–25.8.	7	+10,73	+1,53	+0,37	+0,05	+0,034
8.	3.9.– 7.9.	4	+ 4,37	+1,09	+0,30	+0,08	+0,063
1.	27.6.– 9.7.$^{1)}$	12	– 8,77	–0,73	–0,97	–0,08	–0,110
2.	10.7.–20.7.	9	– 9,87	–1,10	–1,10	–0,11	–0,111
3.	20.7.–24.7.	4	+10,63	+2,65	+0,37	+0,09	+0,034
4.	27.7.– 7.8.	11	–18,00	–1,63	–0,67	–0,06	–0,037
b 5.	9.8.–12.8.	3	+ 9,17	+3,05	+0,17	+0,06	+0,018
6.	14.8.–19.8.	5	– 7,40	–1,48	–0,13	–0,03	–0,018
7.	19.8.–23.8.	4	+11,43	+2,85	+0,40	+0,10	+0,035
8.	4.9.– 7.9.	3	+ 2,50	+0,83	+0,20	+0,07	+0,080
1.	26.6.– 8.7.$^{1)}$	12	– 4,87	–0,40	–1,63	–0,05	–0,335
2.	9.7.–20.7.	10	– 6,07	–0,60	–1,47	–0,14	–0,241
3.	20.7.–24.7.	4	+ 3,80	+0,95	+0,53	+0,13	+0,140
4.	27.7.– 7.8.	11	–11,50	–1,05	–1,03	–0,09	–0,090
c 5.	9.8.–11.8.	2	+ 3,70	+1,85	–0,30	–0,15	–0,081
6.	15.8.–19.8.	4	– 3,53	–0,88	–0,30	–0,08	–0,085
7.	19.8.–23.8.	4	+ 5,53	+1,38	+0,80	+0,10	+0,145
8.	4.9.– 7.9.	3	+ 1,80	+0,60	+0,37	+0,12	+0,203

Most of the small-scale irregularities in the period graphs of the surface fluctuation diagrams can be explained as being counterparts of the corresponding irregularities in the fluc-

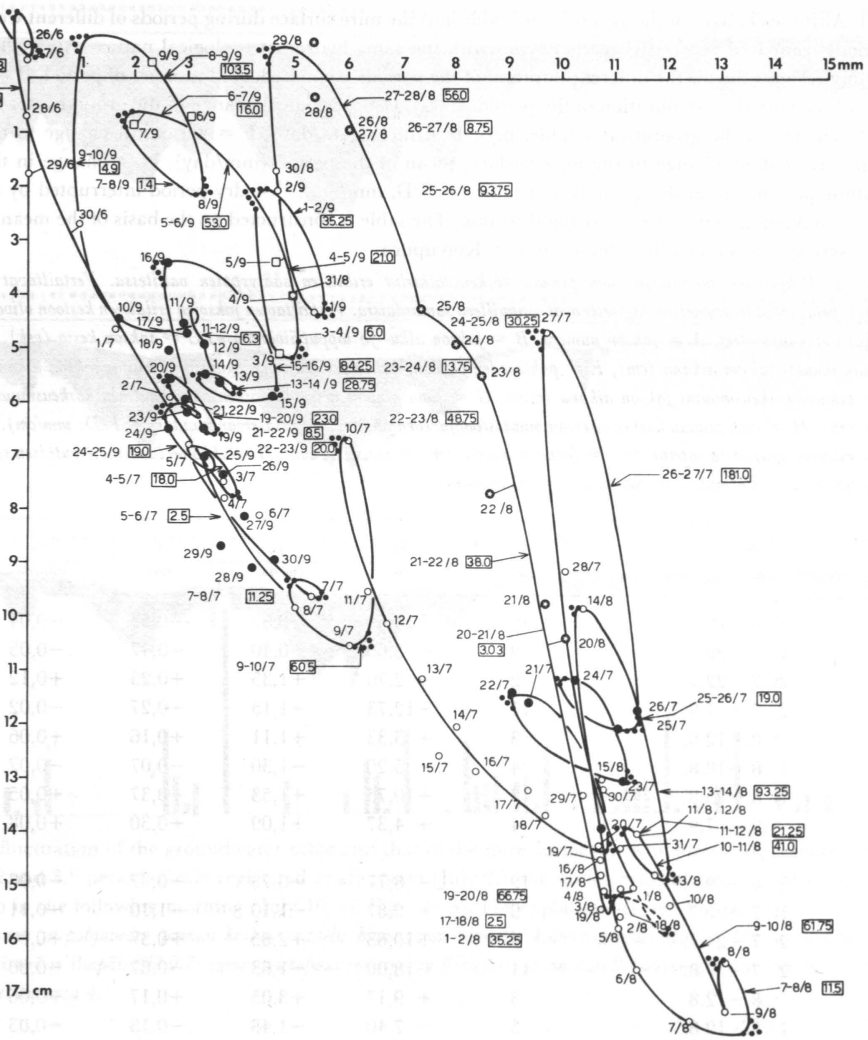

Fig. 7. Co-fluctuation of the groundwater table depth (distance between the mire surface and the altitude of the groundwater table; y-axis) versus the surface altitude (x-axis) in the Välioja mire. The different point symbols are used for making clearer the main hydrometeorological periods. The diagram is constructed by using mean values of the 3-pipe series. Areal precipitation values corresponding to the subsequent observations are given in 0.1-millimetres.

Kuva 7. Yhteisvaihteludiagramma Väliojan rämeeltä pohjaveden syvyyden (suon pinnan ja pohjaveden pinnan korkeusasemien erotus; y-akseli) ja suon pinnan korkeusaseman (x-akseli) suhteen. Erilaisia pistesymboleja on käytetty selventämään hydrometeorologisia pääjaksoja. Diagramma on laadittu käyttäen 3-putkisen sarjan keskiarvoja. Paikallinen vuorokausisadanta on ilmoitettu kymmenesosamillimetreinä.

tuation diagrams representing the depth of the groundwater table. Part of these small-scale irregularities originates from small rain showers, different periodical evapotranspiration etc., part of them due to factors not precisely analyzed here (e.g. the physical properties of the peat), and the rest to inaccuracies in the material. As only three series of observations are available, and the observation values show great variance the material does not permit precise conclusions to be made concerning small-scale fluctuation.

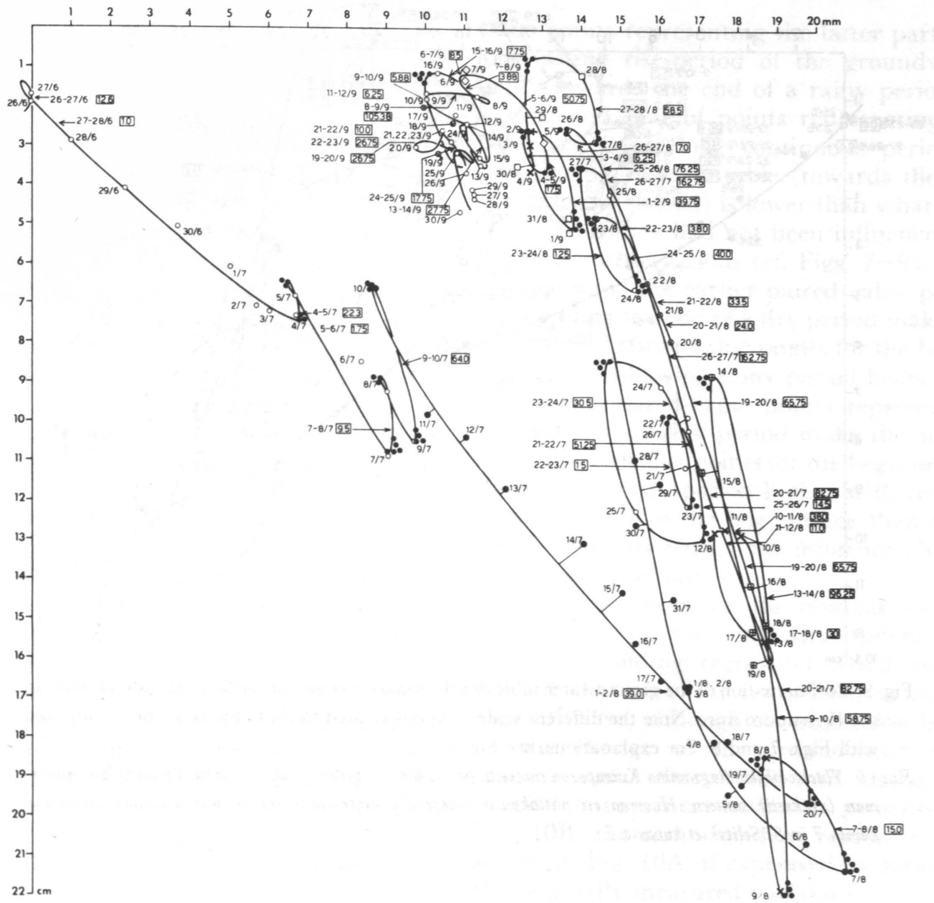

Fig. 8. Co-fluctuation of the groundwater table depth (y-axis) versus the surface altitude (x-axis) in the Suopuro mire. For explanations, see Fig. 7.

Kuva 8. Yhteisvaihteludiagramma Suopuron rämeeltä pohjaveden syvyyden (y-akseli) ja suon pinnan korkeusaseman (x-akseli) suhteen. Selitykset kuvassa 7.

Co-fluctuation in the groundwater table depth and surface altitude

Figures 7−9 illustrate the relationship between the depth of the groundwater table (y-axis) and the simultaneous altitude of the mire surface (x-axis), connected with lines for subsequent days. The complex curve is divided into descending and ascending limbs, each representing a certain period of the same hydrometeorological type. All the diagrams (Figs. 7−9; cf. Figs. 4−6) show that during periods of continued drought (groundwater table continuously sinking) the mire surface also sinks. Correspondingly, a rising groundwater table, especially if continuous, leads to a rise in the mire surface.

The individual limbs of the co-fluctuation curves seem to be more or less curvilinear (see Figs. 7−9) – the rate of the surface fluctuation with respect to that of the groundwater table (mm/cm) is smaller in the beginning of a certain hydrometeorological period than at the end of the same period. The reason for the curvilinearity of the limbs, as well as for their opposite trends has already been discussed above. Both sinking of the groundwater table caused by continuous drought, and rise of it due to continuous periods of rain or melting of snow follow the

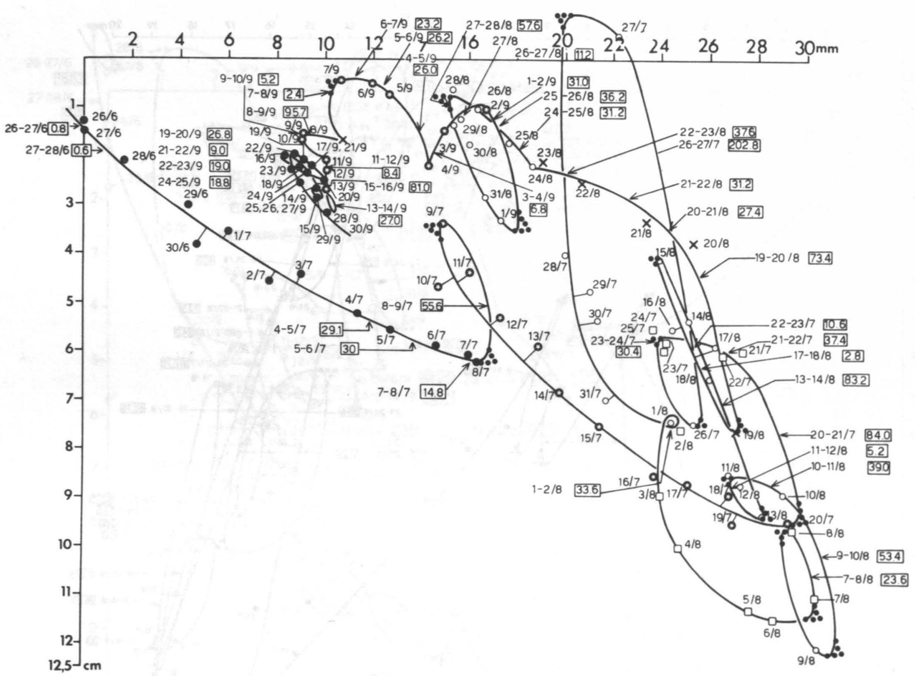

Fig. 9. Co-fluctuation of the groundwater table depth (y-axis) versus the surface altitude (x-axis) in the Koivupuro mire. Note the different scale in x-axis related to that of y-axis when compared with Figs. 7 and 8. For explanations, see Fig. 7.

Kuva 9. Yhteisvaihteludiagramma Koivupuron rämeeltä pohjaveden syvyyden (y-akseli) ja suon pinnan korkeusaseman (x-akseli) suhteen. Huomaa eri mittakaava x-akselilla suhteessa y-akselin mittakaavaan verrattuna kuviin 7 ja 8. Selitykset kuvassa 7.

same principle but lead to vertical surface movement in opposite directions.

The shape of the limb curves (Figs. 7–9) is dependent at least on the duration of the dry of wet period, and the magnitude of the fluctuation in the groundwater table.

The rate of the periodical surface fluctuation related to that of the groundwater table (mm/cm) was clearly always the highest in the Koivupuro area (Table 1). Nevertheless, the pine mires behave in the same way even though they follow an oscillation scale of their own. Evidently factors such as peat type and quality (different physical properties), basin characteristics, microtopography, etc., which are different in each area are responsible for the different oscillation amplitude and oscillation rates characteristic of each mire.

Limbs equivalent to each other can be distinguished in all of the diagrams representing different mires. There is some disagreement, however. Most of this is due to different areal precipitation (note the daily precipitation rates; see Figs. 4–6 and 7–9, and evidently also to different areal evaporation (not measured) which give rise to different areal fluctuations in the groundwater table. Only a small fraction of the variation can be explained by other means, e.g. inaccuracy of the data.

Quite often the rise in the mire surface seems to continue after heavy rain in spite of the fact that the groundwater table starts to sink again (short-term lag). Correspondingly, the mire surface sometimes continues to sink after small rain showers, especially when the groundwater table is at a low level.

As a whole, the mechanism of the altitude fluctuation in the mire surface can be well explained by the combined influence of the groundwater table fluctuation and the water-absorbing/releasing characteristics of the peat (see e.g. Päivänen 1973, 1983, Ahti 1978), as seen from the diagrams.

General regressions

(1) Depth of the groundwater table versus mire surface altitude

As indicated by Figs. 7–9, illustrating the relationship (1) between the depth of the groundwater table and surface altitude (Fig. 10A) includes numerous limbs representing rising and sinking curves of corresponding hydrometeorological periods. Therefore the graph (Fig. 10A), based on the total data cannot principally be considered as a coherent unit. The regression equations for the different mires are calculated, however, in order to determine the line which depicts the linear regression between the variables in question (1).

Observations gathered after subsequent short time intervals are generally affected by autocorrelation, i.e. the subsequent observations are not independent but influenced by observations measured shortly before. It is the mire surface oscillation which, if cumulative in one direction, leads to the autocorrelation that gives rise here to dispersion of the paired-value points for the total graph (see Fig. 10A; cf. Figs. 7–9). The higher the amplitude of the mire surface fluctuation with respect to that of the groundwater table fluctuation, the stronger the autocorrelation.

(2) Change in the altitude of the groundwater table versus that of the mire surface

As the corresponding change values (differences between the same subsequent observations) of the paired observations cannot be affected by the earlier changes they can be used as independent observations, and the corresponding graph is not influenced by autocorrelation. Graph (2), based on the change values, is therefore ”purified”.

In order to avoid autocorrelation, a similar regression analysis has been performed using paired change-values, calculated from the subsequent observations (Fig. 10B).

Comparison of graphs (1) and (2)

The autocorrelation is clearly seen when Figures 10A and 10B are compared. Autocorrelation is apparent from the fact that the coordinational position (with respect to the altitude of the mire surface) of the paired-value points representing the latter part of a long-lasting rise-period of the groundwater table (towards the end of a rainy period) is higher, and that of points representing the latter part of a long continuous period of sinking groundwater table (towards the end of a long dry period) is lower than what they would be if they had not been influenced by the earlier observations (cf. Figs. 7–9). Correspondingly, the earlier paired-value points representing the end of a dry period make the subsequent paired-value points for the beginning of the following rainy period lower, and the earlier paired-value points representing the end of the rainy period make the subsequent paired-value points for the beginning of the following dry period higher with respect to the altitude of the bog surface than what they would have been, if not influenced by the preceding situation.

Regression based on the original altitude observations (1; Fig. 10A) thus differs from the corresponding regression based on the altitude changes of the same observations (2; Fig. 10B). So, although the regression based on the change in the groundwater table (cause) versus that of the mire surface altitude (consequence) occurs as presented in Fig. 10B, the same incident results as presented in Fig. 10A, if expressed by means of the originally measured variables.

The regression coefficients of the lines based on the original altitude data (Fig. 10A) have a higher value than those of lines calculated by means of the altitude changes (Fig. 10B).

The explanation for the difference between regression coefficients is simply the fact that the surface is capable of rising (or sinking) at a limited (maximum) rate per day only (cf. Päivänen 1983; fig. 10). Therefore it is natural that the regression coefficients as well as the constant terms differ from each other.

The coefficient of determination (R^2) is quite high for the correlations based on the altitude data. The coefficient of determination of the correlations based on the altitude changes is low, compared with that of the correlations representing the altitude data, due to the extraordinary low value of the corresponding regression coefficient. As can be seen the cluster of paired-value points is much more concentrated around the lines illustrated in Fig. 10B than around those

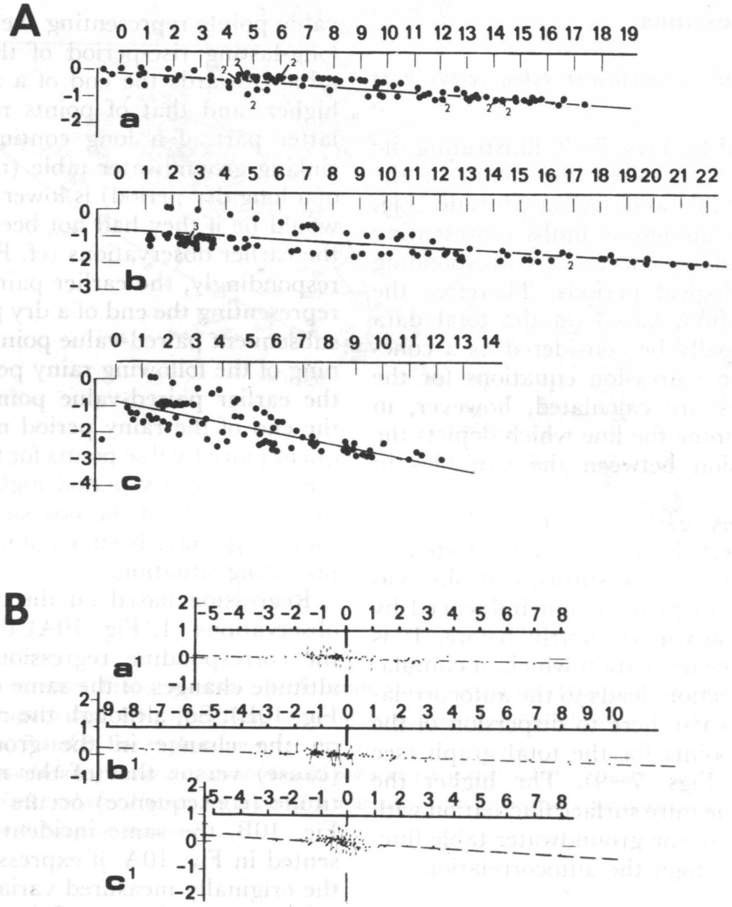

Fig. 10. Relationship between (A) depth of the groundwater table (x-axis) and the mire surface, altitude (y-axis), (B) change in the altitude of the groundwater table (x-axis) and that of the mire surface (y-axis) in Välioja (a, a^1), Suopuro (b, b^1) and Koivupuro (c, c^1). Scale in centimetres. The linear regression equations, and the other statistical signs are for A: $(n = \frac{3 \times 97}{3})$

(a) $y = -0{,}062x - 0{,}144$, $R^2 = 0{,}714$, $r = 0{,}84^{***}$, $F = 237{,}142$, $S(Y/X) = 0{,}196$
(b) $y = -0{,}051x - 0{,}868$, $R^2 = 0{,}459$, $r = 0{,}68^{***}$, $F = 80{,}750$, $S(Y/X) = 0{,}332$
(c) $y = -0{,}194x - 0{,}846$, $R^2 = 0{,}568$, $r = 0{,}75^{***}$, $F = 124{,}869$, $S(Y/X) = 0{,}514$

for B: $(n = \frac{3 \times 96}{3})$
(a^1) $dy = -0{,}024dx - 0{,}010$, $R^2 = 0{,}334$, $r = 0{,}58^{***}$, $F = 47{,}268$, $S(Y/X) = 0{,}181$
(b^1) $dy = -0{,}026dx - 0{,}036$, $R^2 = 0{,}462$, $r = 0{,}67^{***}$, $F = 80{,}612$, $S(Y/X) = 0{,}216$
(c^1) $dy = -0{,}042dx - 0{,}012$, $R^2 = 0{,}212$, $r = 0{,}46^{***}$, $F = 25{,}314$, $S(Y/X) = 0{,}355$

Observations in Fig. A are autocorrelated, those in Fig. B not. According to t-test the regression coefficients of the lines do not differ significantly from each other concerning neither Fig. 10A (a/b, a/c, b/c) nor Fig. 10B (a^1/b^1, a^1/c^1, b^1/c^1); the same result was reached for a/a^1, b/b^1 and c/c^1.

Kuva 10. Pohjaveden pinnan syvyyden (x-akseli) ja suon pinnan korkeusaseman (y-akseli) välinen vuorosuhde (A) sekä pohjaveden pinnan muutoksen (x-akseli) ja suon pinnan korkeusaseman muutoksen (y-akseli) välinen vuorosuhde (B) Väliojalla (a, a^1), Suopurolla b, b^1) ja Koivupurolla (c, c^1). Mittakaava senttimetrejä. Suoraviivaiset regressioyhtälöt ja muut tilastolliset tunnukset on esitetty asetelmassa. Kuvan A havaintopisteiden välillä esiintyy autokorrelaatiota, kuvan B pisteiden suhteen sitä ei esiinny. Eri soita edustavien kuvaajien regressiokerrointen t-testin perusteella suot eivät eroa tilastollisesti toisistaan, ei myöskään kuvien A ja B samoja soita edustavat kertoimet.

shown in Fig. 10A. All of the correlation coefficients are statistically highly significant, however, and the "purified" lines do not differ essentially from those based on data possessing autocorrelation. According to the t-test carried out on the regression coefficients, the mires do not differ significantly from each other.

Comparisons

Baden and Eggelsmann (1964) found that the yearly oscillation of the bog surface ranged from 1,5 to 3 centimetres in a raised undrained bog (Königsmoor) in north-western Germany, while the yearly fluctuation amplitude in a drained raised bog at the same time was higher (variation from 3,7 to 4,2 centimetres). In later years, the yearly amplitude of the bog surface fluctuation varied from 2,1 (minimum year characterized by high groundwater table) to 5,8 centimetres (maximum year characterized by low groundwater table) for the same drained bog. The oscillation amplitude of another drained German bog (Ostenholzer Moor), presented earlier by Uhden (1956, 1960), was in agreement with the results reached by Eggelsmann (1960a) and Baden and Eggelsmann (1964) as well as the surface fluctuation amplitude measured in another undrained German bog (Grosser Moosbruch; Weber 1902; cit. Baden and Eggelsmann 1964). Amplitudes for the undrained German bogs mentioned are only 25–33 % of the amplitude of a more intensively drained Danish mire (Prytz 1932).

In an open bog in south-eastern Finland (the Huhtisuo bog), the maximum difference of 15 cm in the undrained bog surface was measured during 1961–1969 (Mustonen and Seuna 1971). In these measurements the altitude of the bog surface in the virgin bog followed rather closely the variation in the groundwater table. The regression coefficient was 0,98 and the correlation coefficient 0,84, which was statistically significant (risk < 1 per cent).

In the drained part of the Huhtisuo bog the maximum variation was about 15 centimetres during the same period, but the fact that the mean altitude of the bog surface sank 12 centimetres simultaneously as a result of drainage must be taken into account. The regression coefficient between the bog surface and groundwater table was in this case 0,27, but the relationship was not statistically significant.

Owing to the small number of measuring times and observation points the results can not be generalized or extrapolated beyond the range of observations (Seuna pers. comm.).

The evaluated yearly fluctuation amplitude of the mire surface in the study area (only year 1982), corresponds approximately to the values given for the drained and undrained German bogs, but is significantly lower than the values reported from the Huhtisuo bog area.

The yearly fluctuation of the mire surface seems to vary within wide limits both in virgin and drained mires. The variation takes place not only from year to year but also from mire to mire. According to the results of the present study, differences of the same magnitude as those reported from Germany also occur between distinct peat areas.

The comparisons made above emphasize the wide variation of the surface oscillation caused by different hydrometeorological conditions (yearly amplitude variation) but also areal basin and peat characteristics here not studied are evidently responsible for variations of the same magnitude.

Regression coefficient

According to Eggelsmann (1960a) and Baden and Eggelsmann (1964), the regression coefficient (b) of a drained raised German bog was low (b= 0,034) when using the altitude values, and that of an undrained bog even smaller. Mustonen and Seuna (1971), on the other hand, report the regression coefficient of the virgin part of the Huhtisuo bog to be nearly 1 (b = 0,98), and that of the drained part of the same bog considerably less (b = 0,27). The values of the regression coefficients reached in this study vary from 0,051 (Suopuro) to 0,194 (Koivupuro), all the values being relatively small and resembling

As no data has yet been gathered concerning drained mires in Sotkamo, no comparison with coefficients representing drained mires can be made.

Correlation coefficient

The values of the coefficient of determination (R^2), and those of the correlation coefficient (r) of the regression equations vary considerably in the study area (Fig. 10). According to Baden and Eggelsmann (1964), the correlation coefficient for a drained raised German bog, calculated from the regression equation based on the altitude data, was very high (r = 0,953; statistically significant; risk level 1 %?), but that calculated for the undrained bog quite low (r = 0,346). On the other hand, Mustonen and Seuna (1971) re- the virgin part of the Huhtisuo bog to be high (r = 0,84; risk level 1 %) while that for the drained part ow (r = 0,50; risk level 5 %). The values of the correlation coefficients calculated on the basis of the altitude data are quite high in the studied virgin mires (ranging from 0,68 in Suopuro to 0,84 in Välioja), resembling that for the virgin part of the Huhtisuo bog.

Disagreement concerning the results of the studies compared here may partly arise from the short period covered by of the present study. Differences in peat and mire basin characteristics may also be responsible for the wide variation (cf. Päivänen 1983).

DISCUSSION

Shrinkage/swelling of the peat due to drying/watering, especially if continuous, is responsible both for the cracking, and the vertical fluctuation of the mire surface altitude.

The results of drying undisturbed peat samples in the laboratory have shown that the shrinkage of the samples depends largely on the main type of the peat and its physical properties (Päivänen 1983). The multiple regression model including bulk density and sampling depth (Päivänen 1983) together explained 56 and 32 per cent of the variation in shrinkage in S and C peats, respectively. In the peat types mentioned the degree of determination (100 × R^2) of the multiple regression model, including the water content at sampling (per cent of fresh weight) and sampling depth, was almost as good as in the former model.

The structural water loss phase, and the *shrinkage phase of the drying process have* been demonstrated in the laboratory (e.g. Päivänen 1983), the latter phase characterized by the linear dependence of the volume loss on the water loss. Whether the residual water loss phase would be operating in the wet conditions prevailing in the virgin mires is less evident (cf. Paavilainen 1963).

Results concerning the shrinkage based on laboratory experiments do not totally agree with those reached in the field. The graph illustrating the relationship between drying time and shrinkage (vol. per cent of fresh volume) obtained in laboratory tests by drying water-saturated peat samples in an oven (see Päivänen 1983: fig. 10), is almost linear at the beginning of the drying period but becomes curvilinear later on (after drying time of 13 h). The field graph representing the dependence of the mire surface altitude (mm) on time (day) is, on the contrary, practically almost linear (cf. figs. 4–6), assuming that the period it represents was regular as regards the weather type (e.g. rainless, sunny days).

The disagreement in the shape of the graphs mentioned here is, however, not fundamental as discussed and it is explained as originating from the different conditions prevailing in the laboratory and in the field.

In the laboratory a small piece of peat is dried quickly, and the water loss is not re*placed. As the water content decreases the* shrinkage speed will also be reduced (cf. Päivänen 1983: fig. 10), i.e. wet peat shrinks faster than dry peat.

Conditions in the field differ from those in the laboratory. The drying surface peat layer continuously receives capillary water from below so that the water content of the peat remains relatively high, and only seldom sinks below the level corresponding to the "reduced shrinkage", i.e. the beginning of the curvilinear part in the laboratory shrinkage-time graph. It must be kept in mind, however, that various peat types having different physical properties shrink in different ways (Päivänen 1983).

Naturally, the drying-shrinkage process of the peat layer lying *in situ* in the field takes place at a much slower rate than that of a sample in the drying oven of the laboratory.

Corresponding to the shrinkage also the watering-swelling process leading to the rise of the mire surface, can be explained as operating in the same way, although in the opposite direction.

The amount of the sinking/rise of the mire surface (corresponding to the shrinkage/swelling rate of the peat sample) per time unit (day, hour) is limited to a certain maximum rate, however (cf. Päivänen 1983: fig. 10). This maximum rate (sinking/rise of the mire surface) per day cannot be practically exceeded even though the change in the altitude of the groundwater table would be enormous (see Fig. 10B). This rule, according to which the peat is able to shrink or swell only a limited rate per time unit, is responsible for the absence of the sudden small-scale peaks in the mire surface fluctuation diagram. The mechanism described in this paper efficiently smoothens out the peaks corresponding to the simultaneous large changes present in the groundwater table fluctuation. On the other hand it leads to extremely smooth, long-term fluctuations representing periods of "high-altitude" and "low-altitude" surfaces, assuming that continuous long dry and wet periods occur.

An additional review is included in the paper on the basis of the results obtained here, in order to examine the relationship between the surface altitude fluctuation and the mire basin overflow response, in connection with the general peatland hydrology.

Surface altitude fluctuation related to the mire basin overflow response

The water-storing capacity of soil (peat) is inversely proportional to the altitude position of the groundwater table (see e.g. Baden and Eggelsmann 1964, Mustonen and Seuna 1971).

Before beginning to overflow, soil (peat) receives as much water as the porous, air-filled surface layer above the groundwater table is capable of holding. The water-storing capacity of the peat layer above the groundwater table is therefore dependent, in addition to the thickness and water content of the peat layer, also on the physical properties of the peat (porousity, bulk density, humifivation degree etc., most of them intercorrelated; see e.g. Päivänen 1973, 1983). The drier (water content low), more porous (bulk density low) and thicker the layer above the groundwater table the more surplus water (rain, meltwater) it can receive, and the higher the water-storing capacity of the peat (cf. e.g. Baden & Eggelsmann 1964).

When the groundwater table sinks as a result of runoff activity and/or evapotranspiration the less wet surface peat layer above the groundwater table becomes drier and thicker, and the water-storing capacity of the peat increases. With the increasing depth of the groundwater table, and reduction in the hydraulic conductivity of the deeper layer also subsurface water flow and runoff is reduced.

Increase of the water-storing capacity is not, however, equivalent to the sinking of the groundwater table, but that value minus the simultaneous sinking of the mire surface. Although this latter amount is not very much in absolute terms, as can be seen from the diagrams, the cumulative subsidence during a longer period can in some places reach several centimetres, even during a single growing season. The difference is not compensated until after a long period's lag time with a preceding period representing "high" groundwater table values (see Figs. 7–9).

According to the mechanism described earlier, the altitude of the mire surface equivalent to the critical point at which the water-storing capacity of the peat layer is exceeded, is not constant but changes with time. The *maximum volume of water capable of being* stored in the mire basin (retained by the peat) corresponds to the critical point of the water-storing capacity to be exceeded, and is equivalent to the altitude value of the mire surface at that very instant. Naturally, the increased hydraulic conductivity of the surface peat results in some stronger subsurface water flow and runoff taking place along with the decrease of the groundwater table depth, even though the water-storing capacity is not exceeded.

When the altitude of the mire surface has sunk (= is at an absulute low) as a result of a long dry period, the mire basin is no longer capable of storing as much water (retained by the peat) as it did immediately before the dry period without beginning to overflow. After the mire surface has been slowly rising again, due to a long rainy (snowmelt) period, the amount of water capable of being stored in the mire basin is increased. From this it follows that the same (high) altitude position of the groundwater table, which in spring (when the altitude of the mire surface is high due to snowmelt) does not cause any noteworthy overflow, may, in summer (when the altitude of the mire surface is low due to long dry and warm periods), be responsible for the water-storing capacity being exceeded, and give rise to a remarkable sudden overflow peak.

In spring the amount of surplus water necessary to cause the storing capacity to be exceeded is, of course, much smaller than in summer when the groundwater table lies at a low level in relation to the surface due to long dry periods.

Normally the yearly maximum of the mire surface altitude is reached twice in Finland, in spring after the snowmelt period, and in late autumn after the fall rains (cf. e.g. Mustonen and Seuna 1971). Of course, the altitude fluctuation in the mire surface not only occurs in accordance with the yearly periodicity but the periods are of different order ranging from a few days' duration to periods lasting several years (cf. e.g. Baden and Eggelsmann 1964, Mustonen and Seuna 1971).

That proportion of hydrological buffering which is dependent on the water-storing capacity of the peat layer lying above the groundwater table, is changing all the time due to the simultaneous fluctuation in the groundwater table and that of the mire surface. It is equivalent to the storing capacity corresponding to that of the peat layer above the groundwater table. The thickness of this peat layer is, in turn, independent of the absolute altitude of the fluctuating variables, i.e. the peat layer above the groundwater table can lie 1, 10 or 20 centimetres higher or lower without the water-storing capacity of the peat layer being changed. In this sense the mire surface fluctuation does not have any influence upon the buffering.

On the other hand, the maximum volume of water capable of being stored in the mire basin (retained by the peat) varies according to whether the absolute surface altitude lies high or low. It is this fluctuation amplitude equivalent to the water volume capable of being stored which in a sense, too, can be considered as a buffering effect. For example, if the amplitude of the mire surface fluctuation of a virgin (undrained) mire is higher or lower compared with that of a drained mire, the maximum volume of water capable of being stored by the peat is proportional to the fluctuation amplitudes, respectively.

A virgin mire reacts the extraordinary heavy rain in beginning to overflow but the flow of the superficial surplus water is reduced by the natural mire surface microtopography (cf. Päivänen 1968, Hyvärinen and Vehviläinen 1978, 1980), the influence of which is eliminated in drained areas by the ditches. The water feed from the virgin mires in cases of extraordinary heavy rain is therefore less compared with that from drained peat areas. As the influence of the mire surface fluctuation on the microtopography is not well known, the problem of how fluctuation affects the superficial water flow is still open.

SUMMARY

In the present paper, the surface altitude fluctuation, and the process responsible for it is examined. In addition, the relationship between the surface fluctuation and the mire basin overflow response is discussed.

The material was collected from three virgin pine mires during the growing season 1982, and is composed of simultaneous observations representing the altitude of the groundwater table and that of the surface; three series per each mire.

The main results were the following:

- the average amplitude of the surface fluctuation ranged from 18 to 45 mm,
- each of the mires followed a fluctuation scale of their own,
- the daily rate of the surface fluctuation was dependent on the period representing a certain type of weather,
- the daily sinking or rising rate of the mire surface was generally higher in the beginning part of the period representing a continuously sinking or rising groundwater table than at the end of it; both rates were absolutely low, however,
- the daily fluctuation rates were generally low (0,5–1 mm/day),
- no sudden surface fluctuation peaks occurred,
- regularities in the surface fluctuation were caused by the duration of the period representing a continuous sinking or rise of the groundwater table, and magnitude of it,
- the short-term surface altitude fluctuation followed the corresponding fluctuation of the groundwater table on an extremely reduced altitude scale,
- the long-term surface fluctuation followed the corresponding fluctuation of the groundwater table on the same reduced scale, too, but being left behind due to long continuous rising or sinking periods (lag),
- the same altitude position of the groundwater table was at different times responsible for different altitude positions of the mire surface,
- the overflow treshold for the same mire lied in different altitudes at different times.

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SELOSTE

SUON PINNAN KORKEUSVAIHTELU KOLMELLA ITÄ-SUOMEN LUONNONTILAISELLA RÄMEELLÄ

Kolmelta Itä-Suomen luonnontilaiselta rämeeltä tutkittiin suon pinnan korkeusvaihteluita suhteessa pohjaveden pinnan samanaikaisiin vaihteluihin kasvukautena 1982. Korkeusvaihtelu oli erilaista eri soilla amplitudin vaihdellessa keskimäärin rajoissa 18–45 mm. Korkeusvaihtelu oli samantapaista kaikilla soilla joskin se tapahtui kullakin suolla omassa mittakaavassa.

Päivittäisen korkeusvaihtelun määrä riippui vallitsevasta säätyypistä sillä rajoituksella, että se ei ylittänyt tiettyä maksimiarvoa. Päivittäinen suon pinnan korkeusvaihtelu oli vähäistä, yleensä 0,5–1 mm ja vain harvoin se ylitti 2 mm. Äkillisiä suuria suon pinnan korkeusvaihteluita ei esiintynyt. Kaikilla rämeillä havaittiin samanaikaisia ja -suuntaisia suon pinnan korkeusvaihteluita, jotka säännönmukaisuudet aiheutuivat ensisijaisesti jatkuvasti nousevan tai laskevan pohjaveden pinnan muutoksen kestosta ja suuruudesta. Päivittäinen suon pinnan korkeusmuutos vastaavaa pohjaveden pinnan muutosta kohti oli pientä tällaisen jakson alussa mutta suureni jakson loppua kohti. Pohjaveden pinnan pitempiaikaisesta kohoamisesta tai alenemisesta johtuva vastaavaan suuntaan tapahtuva suon pinnan vertikaalinen liikunto aiheuttaa sen, että pitempiaikaista kokonaisvuorosuhdetta kuvaavassa pistejoukossa esiintyy autokorrelaatiota.

Mekanismi, jossa pohjaveden pinnan korkeusvaihtelut primäärisesti säätelevät suon pinnan korkeusvaihtelua, johtaa useimmiten siihen, että tiettyä pohjaveden pinnan korkeusasemaa ei pitkän aikajakson lopussa enää vastaakaan sama jakson alussa vallinnut suonpinnan korkeusasema. Tällä on merkitystä suon hydrologiassa sikäli, että suoaltaaseen, jonka turvepinta on korkealla tasolla voi altaan tulvimatta sitoutua suurempi kokonaisvesimäärä kuin samaan suoaltaaseen, jonka pinta on alemmalla tasolla.