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THE ENVIRONMENTAL EFFECTS OF FOREST DRAINAGE

METSÄOJITUKSEN YMPÄRISTÖVAIKUTUKSET

INTRODUCTION

Over the years 1972-76 the Department of Peatland Forestry, University of Helsinki, were involved in carrying out investigations concerning the environmental effects of forest drainage. The work was financed by the Finnish Academy of Science and Letters. After 1976, the means obtained mainly from the Ministry of Agriculture and Forestry have rendered it possible to continue the study, although on a smaller scale. Assistance in setting up the experimental fields and maintaining these has been received from the National Board of Forestry, the Finnish Forest Research Institute and from the timber companys Rosenlew Oy and Yhtyneet Paperitehtaat Oy. The National Board of Waters have participated in the investigations mainly by carrying out the analyses of water quality. The investigations were concerned both with the immediate and long-term hydrological effects of forest drainage, the effect of forest drainage on the quality of waters, and with the effect of forest drainage on stand growth on mineral soil sites bordering drained peatlands.

The main part of the study was carried out on two hydrological fields, one, called Lyly, being located in northern Tavastia, in the parish of Juupajoki (61°55'N, 24°20'E), near the Forest Station of the University of Helsinki, and the other, called Muhos and located in Ostrobothnia in the parish of Muhos (64°55'N, 26°05'E), in the experimental area of the Finnish Forest Research Institute. Investigations studying the stand growth on surrounding mineral

Of the authors, Heikurainen has written the parts concerning the long-term hydrological effects of forest drainage, Kenttämies those concerning the effect of drainage on the quality of waters, and Laine has dealt with the immediate hydrological effects. The results concerning the effect of forest drainage on the stand growth on surrounding mineral soil sites have been previously published in more detail by Laine and Seppälä (1977). The present paper, too, should be considered as preliminary information.

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soil sites and the quality of waters were also carried out outside the above mentioned hydrological experimental fields in northern Tavastia and in Ostrobothnia.

THE LONG-TERM HYDROLOGICAL EFFECTS

For the study, runoff areas were set up. There were five of these on the Lyly experimental field, one in natural condition*) and the four others drained and different in regard to tree stand and drainage age. At Muhos, there were three runoff areas, of which one in natural condition*). The experimental lay-out has been explained earlier in more detail (Heikurainen, 1974). In addition to runoff (R) also precipitation (P), interception (I), evapotranspiration (ET), and changes in water storage (S) were measured in the areas. At this stage, evaporation is calculated from the equation:

$$P = R + ET + I \pm S$$

Investigations over the period of several years concerning summer runoff from drained and virgin peatlands showed that both in northern Tavastia and in Ostrobothnia the runoff from virgin peatlands during wet periods was greater and during dry periods smaller than the runoff from drained peatlands (cf. Fig. 2).

Investigations concerned with the snowmelting floods showed that in the case of a distinct snowmelting flood it occurred faster and stronger from the virgin peatland than from the drained peatland. Preliminary results of this part of the study have already been published in a previous connection (cf. Heikurainen, 1976).

Strong snowmelting floods did not occur every spring. These results refer to the Lyly experimental field. Snowmelting floods were not examined at Muhos.

When calculating the water balances of a few weeks and months, the result was obtained that during wet periods the runoff from virgin peatlands was greater than that from the drained peatlands, on which evapotranspiration and especially the interception of the tree stand — born or grown as a concequence of drainage — were greater than those of the virgin peatlands. During dry spells the runoff from virgin peatlands remained low as compared to runoff from drained peatlands, and often ceased altogether at a time when runoff was still going on from the drained area (cf. Fig. 3). Apparently the evapotranspiration from virgin peatlands during dry periods is greater than that from the drained areas. On the other hand, the lack of ditches and other waterways soon makes a runoff threshold, which hinders continued runoff, while in the drained peatlands the threshold hindering runoff is low and thus allows runoff to continue.

The results obtained regarding the long-term hydrological effects of forest drainage seem to support the opinions according to which forest drainage has a levelling influence on the hydrological fluctuations, in other words, it reduces peak runoffs and increases low water runoffs.

*) The area is surrounded by ditches, from which the measurements of runoff took place.

Fig. 1. Measuring weir in runoff area with pluviograph.

Kuva 1. Valuma-alueen mittapato piirturilaitteineen.

THE EFFECT OF FOREST DRAINAGE ON THE QUALITY AND HUMUS LOAD OF WATERS

The Water Research Institute of the National Board of Waters took part in the study concerned with the environmental-ecological effects of forest drainage, more specifically in the part studying the quality of water. Taking and analysing the samples was carried out by the Water District Offices in Oulu and Tampere and by the Water Research Office of the Water Research Institute. The following results were obtained.

Judging by the concentration of organic carbon, the consumption of potassium permanganate and contents of total nitrogen of the discharged water, the undrained and old (20—40 years) drained peatlands did not differ from each other (Fig. 4). However, the pH value was significantly higher in the drained areas both in Ostrobothnia and in Tavastia. The electrolytic conductivity was also higher in the Ostrobothnian drained peatlands. Whether the results referring to acidity and conductivity are due to the choice of the drained peatlands or to drainage itself, remains unclarified in this connection. It should further be noted that the phosphorus contents in drained areas in Tavastia were after PK-fertilizing on an average 6.5 times higher than those of the virgin peatlands.

On the Lyly hydrological experimental fields, the mean values for organic carbon concentration in the water discharging from the drained area were higher in two and lower in two areas than in the undrained comparison area (Fig. 5). The carbon

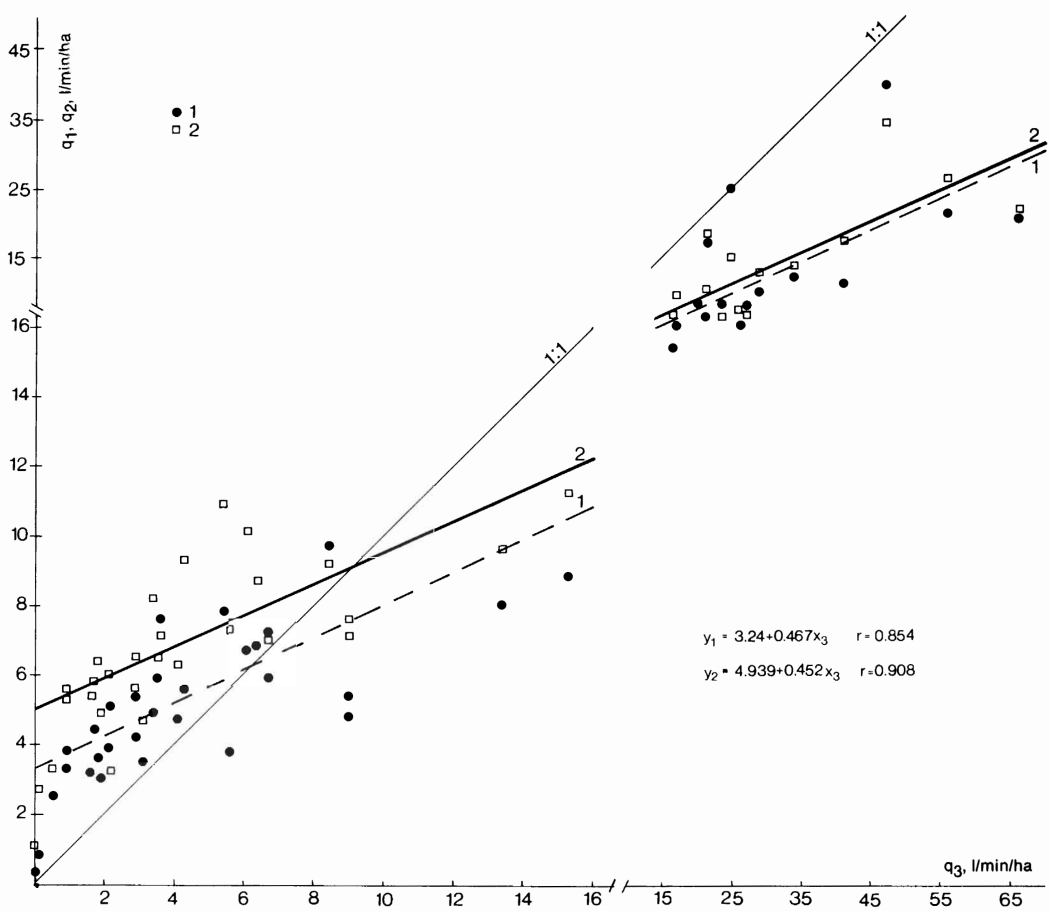

Fig. 2. Regressions of the runoff values for the drained areas (q_1 and q_2) and undrained areas (q_3) on the Muhos experimental field. The runoff values are 5-day means for the years 1974—76. The runoff areas: 1 = pine stand, drained 20 years ago, 32 m^3/ha (originally ordinary sedge pine swamp), 2 = pine stand, drained 40 years ago, 90 m^3/ha (originally ordinary sedge pine swamp), 3 = undrained ordinary sedge pine swamp, 15 m^3/ha.

Kuva 2. Ojitettujen alueiden valuma-arvojen (q_1 ja q_2) ja ojittamattoman alueen valuma-arvojen (q_3) regressiot Muhoksen koekentällä. Valuma-arvot 5 vrk:n keskiarvoja vuosilta 1974—76. Valuma-alueet: 1 = 1950-luvulla ojitettu VSRmu, 32 m^3/ha, 2 = 1930-luvulla ojitettu Ptkg, 90 m^3/ha, 3 = ojittamaton VSR, 15 m^3/ha.

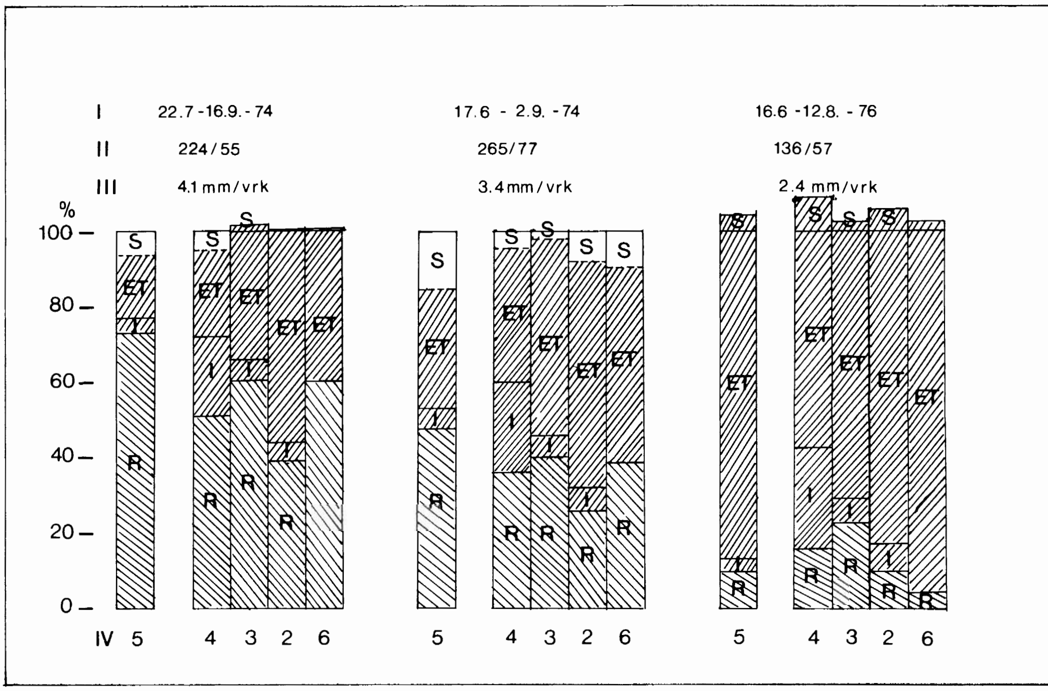

Fig. 3. Short-term water balances for the runoff areas on the Lyly experimental field. I = period for calculating water balance, II = precipitation during period, mm/length of period, days, III = precipitation index, mm/day, IV = runoff areas: 5 = undrained ordinary sedge bog and dwarf-shrub pine swamp, 16 m^3/ha, 4 = pine stand, drained 40 years ago, 87 m^3/ha (originally ordinary sedge pine swamp), 3 = pine stand, drained 30 years ago, 21 m^3/ha (originally ordinary sedge bog), 2 = pine stand, drained in 1968, 35 m^3/ha (originally dwarf-shrub pine swamp), 6 = seedling stand, drained in 1968 (originally ordinary sedge bog). R = runoff, I = interception, ET = evapotranspiration, S = change in water storage.

Kuva 3. Lylyn koekentän valuma-alueiden lyhyen aikajakson vesitaseita. I = vesitaseen laskenta-aika, II = jakson sadanta, mm/jakson pituus, vrk., III = sadantaindeksi, mm/vrk., IV = valuma-alueet: 5 = luonnontilainen VSN ja IR, 16 m^3/ha, 4 = 1930-luvulla ojitettu, Ptkg, 87 m^3/ha, 3 = 1940-luvulla ojitettu, VSNmu, 21 m^3/ha, 2 = 1968 ojitettu, IRmu, 35 m^3/ha ja 6 = 1968 ojitettu VSNmu, taimisto, R = valunta, I = pidäntä, ET = haihdunta ja S = vesivaraston muutos.

concentrations of water from drained pine swamps were statistically significantly or almost significantly lower than the corresponding values for drained, originally treeless bogs. In the Muhos experimental area, all the three areas, the two drained areas and the comparison area, differed significantly from each other, when judged by the organic carbon content of the water. The highest carbon content was found in the comparison area, followed by the younger drained area, and the value for the old drainage area was the lowest.

The amount of organic carbon discharging from the runoff area, calculated as the product of the concentration (mg/litre) and the total runoff (litre/hectare) representing the sampling interval, gives a more accurate picture of the washing-out tendency than the mere concentration. The amounts of washed-out carbon during the latter part of 1974 (Fig. 6) show that in the Lyly experimental areas, approximately the same amount of carbon was washed-out from the drained pine swamps as from the comparison area, while from the drained bogs the washed-out quantities were on an average over 50 % higher. In the Muhos experimental area, the amount of washed-out organic carbon from the comparison area rose to a level more than twice the washed-out amount from the drained pine swamps.

THE IMMEDIATE EFFECTS OF FOREST DRAINAGE

The immediate changes in the hydrology of a peatland area caused by forest drainage were studied in the natural runoff area on the Lyly experimental field, the hydro-

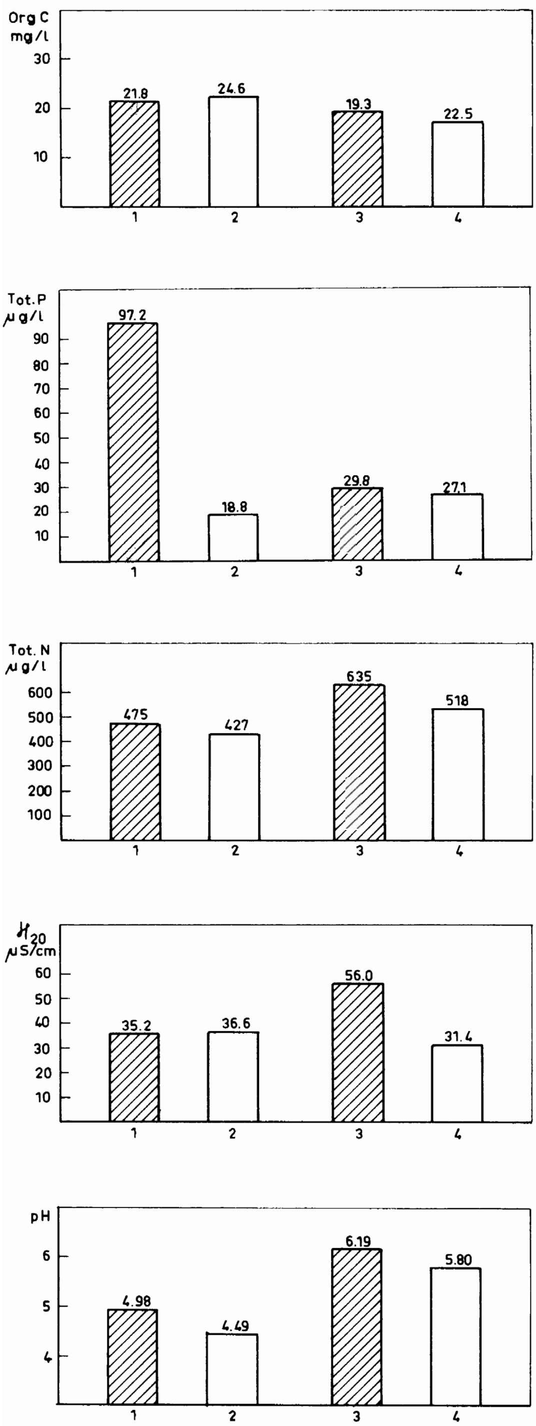

Fig. 4. Arithmetic means of some quality characteristics of water from drained (1. and 3.) — drainage 20—40 years ago — and undrained (2. and 4.) peatland areas in northern Tavastia (1. and 2.) and in Ostrobothnia (3. and 4.).

Kuva 4. Eräiden veden laatua kuvaavien tunnusten keskiarvoja, 20—40 v. sitten ojitetuilta (1. ja 3.) ja ojittamattomilta (2. ja 4.) valuma-alueilta Pohjois-Hämeessä (1. ja 2.) ja Pohjois-Pohjanmaalla (3. ja 4.).

logy of which area had been observed during a four year period before the drainage. Drainage took place in June 1977 (Ditch spacing — ca. 30 m, ditch depth — ca. 1 m).

As a consequence of drainage the water table of the peatland was lowered by about 10 cm along the middle of the strip between ditches as compared to the pre-drainage situation. The relatively small drop in the water table can obviously be explained by the above-average amount of rainfall in the summer 1977.

Drainage had a distinct impact also on the runoff conditions of the peatland. The summer low water flows increased reaching a level approximately five times higher than that before the drainage and the peak flows caused by rainfall approximately doubled (cf. Fig. 7). Owing to the high rainfall in the summer 1977 it was not possible to clarify to what extent the above mentioned aspects were due to the lowering in the original water storage of the peatland; however, there is every reason to suppose that this had a significant impact.

Samples were taken before the drainage, during the digging and thereafter from the water discharging from the area, and these were analyzed in the Water Research Office of the National Board of Waters. The amount of mainly organic suspended solids in the water rose during digging from the pre-drainage level around zero to a level of about one kilo (dry matter) per drained hectare per day. When digging ended, the amounts of suspended solids dropped clearly and reached during August-September, that is about 10 weeks after drainage, the level of 8—70 g per hectare per day. Torrential rainfall caused, also later in the summer, high short-lived rises in the amounts of suspended solids (cf. Fig. 8).

Drawing conclusions has been somewhat hampered by the remarkably abundant rainfall of the summer 1977, wherefore measurements were continued in the summer 1978.

THE EFFECT OF FOREST DRAINAGE ON STAND GROWTH ON THE SURROUNDING MINERAL SOIL SITES

For the study sample material of some 700 trees was measured over the years 1973-76 in tree stands growing on mineral soil sites bordering 30 year old drained peatlands. The radial growth of the sample

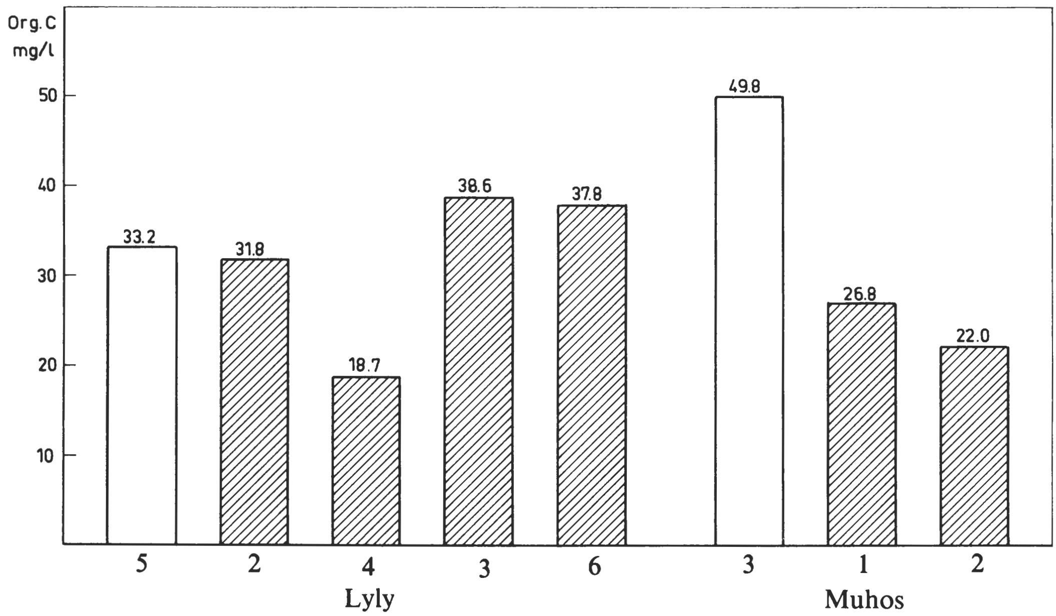

Fig. 5. The means of organic carbon concentrations in water from watersheds monitored monthly in 1973—76. Runoff areas described in Figures 2. and 3.

Kuva 5. Kuukausittain vv. 1973—76 valuma-alueilta otettujen näytteiden orgaanisen hiilen konsentraation keskiarvot. Valuma-alueiden kuvaukset esitetty kuvissa 2. ja 3.

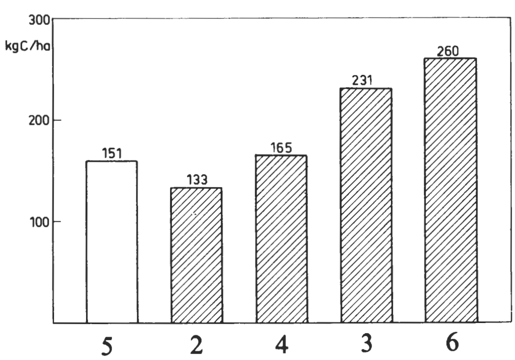

Fig. 6. The total organic carbon loss (kg/ha) in water from peatland watersheds in northern Tavastia. Runoff areas desribed in Figure 3.

Kuva 6. Pohjois-Hämeen valuma-alueiden vesien orgaanisen hiilen kokonaiskuormitus (kg/ha). Valuma-alueiden kuvaukset esitetty kuvassa 3.

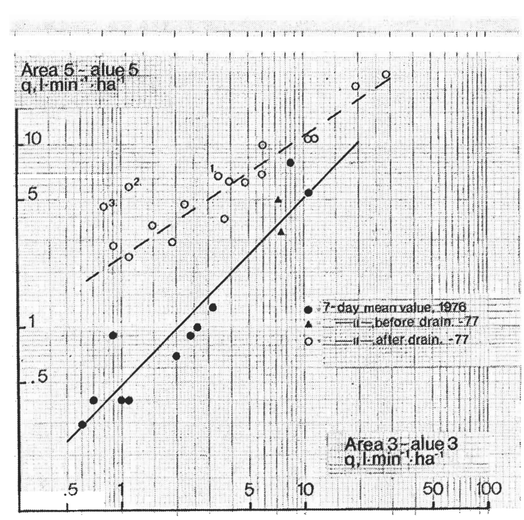

Fig. 7. Correlation (logarithmic scale) of runoff from area 5 and area 3 before drainage (1976, -77) and after drainage of area 5 (1977). The 7-day runoff means have been applied to diminish the variation caused by the different timing of runoff. The first 3 weeks run off values after drainage have been numbered in the figure.

Kuva 7. Alueen 5 ja alueen 3 valunnan suhde (logaritminen asteikko) ennen ojitusta (1976, -77) ja alueen 5 ojituksen jälkeen (1977). 7 vrk:n valuntakeskiarvoja on käytetty valunnan ajoittumisesta johtuvan vaihtelun pienentämiseksi. 3 ensimmäisen ojituksen jälkeisen viikon valuntapisteet numeroitu.

trees was analyzed by five year periods before and after drainage, grouping the material according to site type, distance to ditch etc. Detailed results have been published in a previous paper (cf. Laine & Seppälä, 1977).

The results show that the radial growth of the sample trees in all the groups has clearly increased in the intermediate zone between the trap ditch and mineral soil,

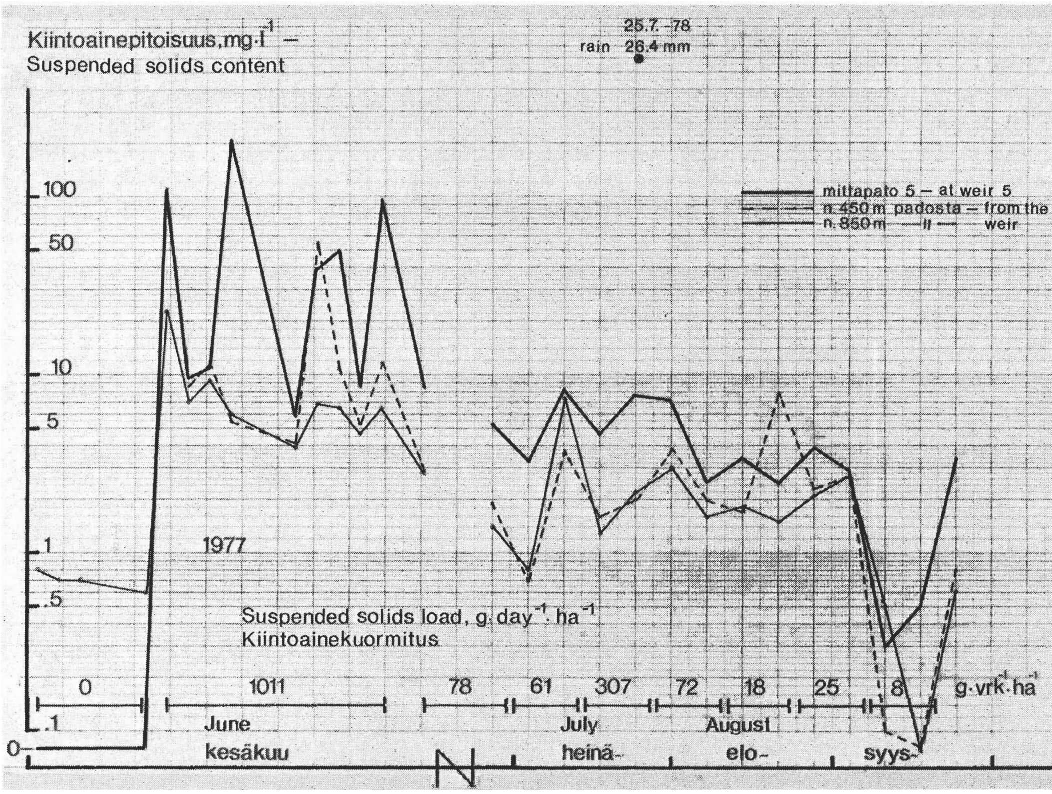

Fig. 8. Content of suspended material (mg/l) in the water at measuring weir 5 and at two distances from the weir before, during and after drainage in 1977. The figure also gives the mean values for 2-weeks periods illustrating the loss of suspended material (g/day, drained hectare, dry matter). The drainage operation began on June 6 and ended on June 17, 1977.

Kuva 8. Kiintoainepitoisuus (mg/l) mittapadolla 5 ja kahdella etäisyydellä mittapadosta ennen ojitusta, ojituksen aikana ja ojituksen jälkeen v. 1977. Kuvassa on esitetty myös kiintoainekuormitusta (g/vrk, ojitushehtaari, kuiva-ainetta) kuvaavat keskimääräiset luvut 2 viikon jaksoille. Ojitustyö alkoi 6. 6. ja päättyi 17. 6. 1977.

classified as peatland. In zones classified as actual mineral soils, no decline in the radial growth caused by drainage could be seen in any group, on the contrary slight increase was often recorded, particularly if the normal development of radial growth along with age is taken into account. Consequently, it seems possible that in some cases peatland drainage may even improve the growth conditions on surrounding mineral soil sites.

SUMMARY AND DISCUSSION

The partly even heated discussion about the environmental consequences of peatland utilization has continued for some time (cf. Baden and Eggelsmann 1964, Ferda 1966, Bay 1967, Mustonen and Seuna 1971, Klueva 1971, Uhden 1972, Ferda 1976, Heikurainen 1976, Masing 1976, Pyavtsenko 1976, Shaposhnikov 1976, etc.). The present series of investigations is yet another addition to the debate. The results in this paper should be considered as preliminary information. One should also bear in mind that these results have been obtained under Finnish climatic conditions, i.e. in an area of cool and relatively humid climate. Detailed results will be published later on.

The investigations showed that no harmful effects are caused by forest drainage on the stand growth on the mineral soil sites bordering the drained area. In the vicinity of ditches the impact is one intensifying the stand growth, in some cases the same was found even at a longer distance from the ditch. The fear that growth conditions on the surrounding mineral soil sites would deteriorate as a consequence of peatland drainage seems, thus, to be unfounded.

Forest drainage as such does not seem

to have very clear lasting effects on the quality of waters discharging from the area. There are no significant differences in the contents of organic carbon between over twenty year old, already afforestated, drainage areas and virgin areas. The same is true also with regard to the consumption of potassium permanganate and to total nitrogen. If the areas are left unfertilized, the content of total phosphorus in the drained areas does not rise either. During digging and for a short period thereafter the amount of organic material washing out with the waters increases significantly, but already in a couple of months the quantity of these impurities is lowered.

Thus it is evident that the increase in the washed-out organic material is limited to the short transitional period of decreased water storage. On the other hand, the washing-out of suspended solids, mainly caused by ditch erosion, continues longer and is concentrated on peak flow periods.

This investigation gives clear indications that the adverse impact of forest drainage on the quality of water is limited as regards time. Consequently, the total regional influence is determined rather by the annual new drainage area than by the cumulative total drainage area. The effects of forest drainage on rivers and lakes would thus gradually decrease from the present level along with remarkably diminishing new drainage already in the 1980's. On the other hand, the maintenance of drainage areas, ditch cleaning and re-drainage after first rotation have their own impact on the total situation in the future.

The investigation indicates that there were differences in the washing-out intensity between the different peatland types, but whether the basic reason is to be found in the differences in the tree stand, or eg. in the peat type or degree of humification, remains unclarified in this connection.

The immediate influence of drainage on the hydrological conditions can be seen in the very strong rise of summer low water flow, but also the peak runoffs caused by rainfall were increased. Particularly the intensified low water flows are apparently a consequence of the decline in the peatland's water storage, which takes place during a couple of postdrainage months.

The long-term hydrological effects seem in general to be of a levelling nature on the fluctuations, the peak runoffs caused by spring-time snowmelting and high rainfall are reduced, and the summer low water runoffs are increased. During dry periods runoff from drained areas continues longer than from the undrained areas. The causes for these primarily positive changes are obviously the changes in the runoff threshold and in the water storage capacity brought along by drainage and the strongly increased interception due to the growth of the tree stand after drainage. Apparently also the reduced evaporation caused by drainage is an important factor.

Thus, it seems that forest drainage as it is applied in Finland and under Finnish climatic conditions is inclined to cause primarily positive hydrological effects. Similar results in other countries have previously been obtained by several researchers (eg. Burke 1963, Baden and Eggelsmann 1964, Ferda 1966, Bay 1970, Pyavtsenko 1976). Contradictory opinions have also been presented (eg. Conway and Millar 1960, Shaposhnikov 1976), partly, however, on the basis of results obtained in more or less arid areas (Klueva 1973). The effects during drainage and the immediate short period thereafter are, however, harmful. The organic material discharging with the waters may have at least temporarily a deteriorating influence on the quality of waters even in a broader sense.

Owing to the common appearance of peat soils in Finland there is plenty of humus material in the natural Finnish waters. As a consequence of decomposition and sedimentation, the lakes detain a considerable part of also the dissolved humus coming to them. According to Laaksonen (1970), the variance in the colour of water is best explained by the proportion of lakes in a watercourse, but the area of drained peatlands makes already the next important factor. The proportion of lakes correlates negatively, the area of drained peatlands positively with the colour of the water. However, only a few rising trends in regard to the colour of water could be observed in the main watercourses, although during the investigation period (1962—1970) the area drained was doubled (Laaksonen and Wartiovaara, 1973). It is obvious that the disadvantages of forest drainage, which mainly consist of the suspended solids sedimenting in the rivers and creeks, are limited to the immediate vicinity of drained areas and to a relatively short period after drainage. Similar results have also been obtained in some foreign investigations (eg. Ferda 1976, Farnham 1976).

Finally, it deserves mentioning that the continued maintenance and utilization of drained areas bring along their own special features to the factors examined above. It can be concluded that runoff is increased especially by clearfelling on the drained areas (eg. Heikurainen and Päivänen 1970), and that ditch cleaning and redrainage after first rotation have the same effect on the quality of waters as new drainage. No complete enough studies concerned with these aspects have been carried out, and the results in this paper cannot as such be applied to these problems.

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LYHENNELMÄ:

METSÄOJITUKSEN YMPÄRISTÖVAIKUTUKSET

Kirjoitus selostaa metsäojituksen seurausvaikutuksia koskevia tutkimuksia, joita Helsingin yliopiston suometsätieteen laitoksessa on tehty vuodesta 1972 alkaen. Vesien laatua koskevat tutkimukset on tehty yhteistyössä Vesihallituksen vesientutkimuslaitoksen kanssa.

Kirjoittajat ovat esitelleet tässä julkaistavia tuloksia Suoseuran kokouksessa 18. huhtikuuta 1978. Julkaisua on syytä pitää edeltävän tiedonannon luontoisena. Yksityiskohtaiset tutkimusjulkaisut tulevat ilmestymään myöhemmin.

Tutkimukset osoittivat, että metsäojitus ei aiheuta ojitusaluetta lähellä olevilla kangasmailla kasvavien metsien kasvussa haitallisia vaikutuksia. Ojien lähettyvillä vaikutus on metsien kasvua lisäävä, eräissä tapauksissa samaa havaittiin kauempanakin ojasta. Pelko siitä, että ojituksen vaikutuksesta kasvuolosuhteet huonontuisivat ympäröivillä kankailla näyttää siis aiheettomalta (vrt. Laine ja Seppälä 1977).

Metsäojituksella sinänsä ei näytä olevan selviä pysyviä vaikutuksia alueelta purkautuvien vesien laatuun. Orgaanisen hiilen pitoisuuksissa ei ole merkitseviä eroja yli kaksikymmentä vuotta vanhojen, jo metsittyneiden ojitusalueiden ja luonnontilaisten suoalueiden välillä. Samoin on asian laita kaliumpermanganaatin kulutuksen ja kokonaistypen suhteen. Ojituksen aikana ja jonkin aikaa sen jälkeen lisääntyy vesien mukana huuhtoutuva orgaaninen aines merkittävästi, mutta jo parissa kuukaudessa näiden epäpuhtauksien määrä laskee.

Onkin ilmeistä, että liuenneen orgaanisen aineen huuhtoutuman kasvu rajoittuu nopeaan vesivaraston muutoskauteen. Sen sijaan lähinnä ojaeroosiosta johtuva kiintoainehuuhtoutuma jatkuu pitempään keskittyen ylivirtaamakausiin.

Tämä tutkimus antaa selviä viitteitä siitä, että ojituksen haitalliset vaikutukset veden laatuun ovat ajallisesti rajoittuneita. Ojituksen vesistövaikutukset tulisivat siis vähitellen pienenemään nykyisestä tasosta uudisojitusten vähentyessä ratkaisevasti ja 1980-luvulla.

Ojituksen välitön vaikutus hydrologisissa olosuhteissa näkyy kesän alivalumien erittäin voimakkaana kasvuna, myös sateiden aiheuttamat ylivalumat suurenivat. Valumien suureneminen on osittain suon vesivaraston pienenemisen seurausta, joka tapahtuu valtaosaltaan parin ensimmäisen ojituksenjälkeisen kuukauden aikana.

Ojituksen pitkäaikaiset hydrologiset vaikutukset näyttävät yleisesti ottaen olevan vaihteluita tasoittavia, maksimivalumat pienenevät ja kesän kuivien kausien minimivalumat suurenevat. Kuivina kausina valunta jatkuu ojitetuilta alueilta pitempään kuin luonnontilaisilta alueilta. Kevään lumensulamiskauden aineisto on pieni, eikä siten anna aihetta pitkälle meneviin yleistyksiin.

Näiden lähinnä edullisina pidettävien muutoksien syyt ovat ilmeisesti seuraavanlaiset: Ojituksen vaikutuksesta valuntakynnys alenee, josta seuraa veden varastoimiskyvyn lisääntyminen. Toinen vaikuttava tekijä lienee pidännän voimakas kasvu ojituksen vaikutuksesta lisääntyneen puuston ansiosta. Ilmeisesti myös evaporaation pieneneminen ojituksen vaikutuksesta on merkittävä tekijä.

Näyttää siis siltä, että metsäojitus, ainakin sellaisena kuin sitä Suomessa ja Suomen ilmasto-oloissa harjoitetaan, on omiaan aiheuttamaan lähinnä positiivisia hydrologisia seurausvaikutuksia. Tällaisiin tuloksiin ovat aikaisemmin päätyneet useat muutkin tutkijat (esim. Baden ja Eggelsmann 1964, Ferda 1966, Bay 1971, Pyavtsenko 1976). Päinvastaisiakin käsityksiä on esitetty (esim. Masing 1976, Shaposhnikov 1976), osaksi kuitenkin enemmän tai vähemmän aridisilla alueilla saatujen tulosten perusteella (Klueva 1973). Ojituksen aikaiset ja välittömästi sitä seuraavan lyhyen aikajakson vaikutukset ovat sen sijaan haitallisia. Vesien mukana kulkeutuvalla orgaanisella aineksella saattaa olla ainakin tilapäisesti vesien laatua laajemmaltikin pilaava vaiktus.

Lopuksi on syytä todeta, että ojitusalueiden jatkuva hoito ja käyttö tuovat omat erikoispiirteensä edellä tarkasteltuihin tekijöihin. Voidaan päätellä, että ojitusalueilla suoritettavat hakkuut lisäävät valuntaa (esim. Heikurainen & Päivänen 1970) ja ojien perkaukset sekä ojituksen uusiminen vaikuttavat vesien laatuun saman suuntaisesti kuin uudisojitus. Varsinaisia tutkimuksia näistä seikoista ei ole riittävästi olemassa, eivätkä nyt selostetut tutkimustulokset ole sellaisenaan sovellettavissa näihin ongelmiin.