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THE INFLUENCE OF PEATLAND FOREST DRAINAGE ON RUNOFF PEAK FLOWS[3]

SOIDEN METSÄOJITUKSEN VAIKUTUS YLIVIRTAAMIIN

1. INTRODUCTION

The influence of forest drainage on peatland hydrology is not without controversy in Finland. Both beneficial and detrimental changes in runoff following drainage have been reported. Because of the large area of peatland that has been drained for forestry purposes, the debate is especially important in Finland. Of approximately 9.7 million ha of land covered by peat some 5.3 million ha have now (1980) been drained.

Forest drainage on peatlands is mainly criticised because it is considered to increase the frequency of flooding downstream. The occurrence of flooding is related directly to peak flow rates and, therefore, the essential question is: does drainage increase peak flows?

The effects of forest drainage on runoff vary according to the size of runoff areas and the location of the runoff recording stations in relation to downstream effects. The aim of this paper is to review the results of several recent investigations dealing with peatland drainage and peak flows. Emphasis is laid upon the runoff leaving the actual ditching area rather than whole catchments (Mustonen and Seuna 1971) or river basins (cf. Hyvärinen and Vehviläinen 1978).

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2. HYDROGRAPH MODELS

Runoff response can be described graphically by the *hydrograph,* the characteristics of which are given in Figure 1. The analysis of hydrographs from drained and non-drained sample catchments in Finland has, however, produced conflicting results. A similar situation can be seen in the results from Germany (Baden and Eggelsmann 1968) and in the UK (Green 1973). Essentially, two schools of thought can be identified.

One school (represented by model A in Figure 2), considers that drainage shortens the duration of peak flows, i.e. base time is reduced, peak flow levels are increased, and base flow is decreased. Surface and subsurface runoff (direct runoff) bring water to the ditch network which have an accelerating effect on the discharge from the catchment. A less stable, ''flashy'' hydrograph with accentuated peak flows is thus observed (e.g. Mustonen and Seuna 1971; Ahti 1980).

The second school (represented by model B in Figure 2), considers that peak flow levels are reduced but that the duration of the peak flow event is extended, while base flow levels are increased as a result of drainage. The more uniform flow over time that results effectively ''levels out'' the hydrograph. Exponents of this model include Multamäki (1962), Burke 1972 and Heikurainen (1976 and 1980).

[3]This co-authored paper is based on an unpublished PhD thesis chapter by M.R. Starr to be submitted to the University of Sheffield, England. The paper was presented at the XVII IUFRO Congress, Working Party ''Forest hydrology'' (1.03.02) in Kyoto, Japan, in 1981.

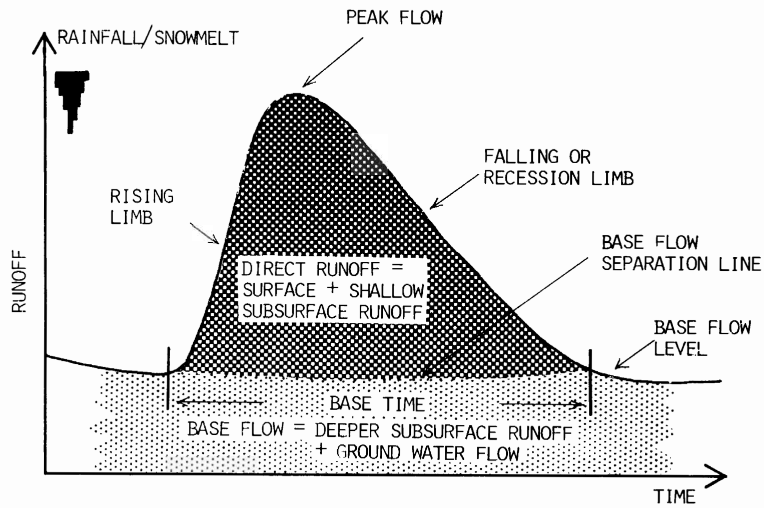

Figure 1. The characteristics of a peak flow hydrograph.
Kuva 1. Ylivirtaaman aikakäyrä.

Similar models have been derived by McDonald (1973) from the relevant British literature. However, a third model (model C), a hybrid between the other two models, may also exist (Seuna 1974 and 1980). Seuna reports that during high peak flows, drainage not only increases the maximum peak flow level but also minimum flow levels. Such a model would clearly increase the total volume of runoff — discharge — after drainage.

3. THE INFLUENCE OF CATHMENT CHARACTERISTICS ON RUNOFF

Other than the slope, topography and area of the catchment involved, the particular characteristics of peatland catchment which are found to be significant to the changes in runoff after drainage include site type, peat type, intensity of drainage, and type of ditch used. To some extent the influence of slope and topography factors are incorporated in the site type and peat type factors since the vegetation composition is closely related to physical habitat conditions.

Because of differences in the composition and structure of vegetation, evapotranspiration and interception capacities vary with site type and consequently, so does runoff. The post-drainage stand increment is also related to the site type (e.g. Laine and Starr 1979). Therefore, the long-term influence of drainage on the peatland water balance is dependent on site type too.

The vegetation used to define the site type eventually forms peat and, therefore, the site type and peat type classifications are correlated. Different peat types have different infiltration capacities and hydraulic conductivities (e.g. Päivänen 1973) and thus will react differently to drainage.

Water, once in the ditch network, is capable of being rapidly removed from the catchment. The potential rate of removal is determined by the features of the ditch network itself the position, orientation and condition of the ditches. Therefore, in discussing the intrinsic influence of drainage on runoff, one should concentrate on those factors relating to the entry of water into the ditches *within* the catchment area. One of these factors is ditch spacing (Huikari 1968).

A direct effect of reducing the spacings between the ditches is to reduce correspondingly runoff distances to the nearest ditch and increase the hydraulic gradient. Thus, Ahti (1980) found that monthly maximum peak flows from a drained open catchment were inversely related to ditch spacing.

A further consideration is the type of ditch used. Päivänen (1976) has examined the affect of three different types of contour ditch (ordinary open ditch, covered plastic pipe drain, and narrow vertical-walled ditch) on the hydrology of an open bog. The result from the study showed that the highest peak flows were recorded from catchments drained with open ditches.

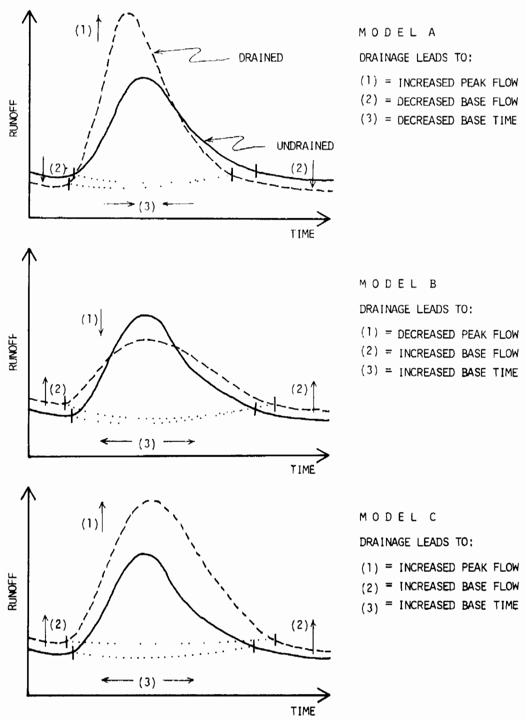

Figure 2. Hydrograph models (cf. McDonald 1973).

Kuva 2. Ojituksen mahdolliset vaikutustyypit virtaaman aikakäyrään (vrt. McDonald 1973).

4. THE INFLUENCE OF PRECIPITATION CHARACTERISTICS ON RUNOFF

The character of the incoming rainfall significantly affects the runoff response from drained catchments. Most researchers make a distinction between the runoff response during "dry" and "wet" periods. These terms are used in a relative sense, but they can be considered to correspond to the terms base flow and peak flow, respectively. The response of the peak flow to drainage is dependent upon the intensity and duration of rainfall.

During periods of low rainfall the utilization of the water storage capacity of the surface peat layer and the interception of the tree stand are maximized. Drainage leads to an increase in both these components since the water table level is lowered and stand growth increased. Runoff is, therefore, reduced and largely comprised of base flow. The role of soil water storage capacity and the effects of the stand are considered by Ahti (1980), to be effective only during rainfall events of low intensity (cf. Heikurainen 1976). This provides a plausible explanation for the reduced base flows exhibited in the hydrograph model A.

Heikurainen (1976) attributes the increase in base flow presented in model B, to the influence of the "runoff threshold" i.e. the distance to the water table at which direct runoff ceases. Despite a deeper water table, runoff still continues from a drained area while that from an undrained area may have ceased. The runoff threshold lies nearer the surface on undrained peatlands. Due to increased evapotransporation and subsurface runoff that takes place nearer the surface, after a peak flow event the water table rapidly drops below the runoff threshold and, consequently, runoff ceases. Due to the effect of the ditches the runoff threshold lies deeper in drained peatlands and, therefore, the water table will remain above the threshold depth for a longer period of time. This results in an increased base flow from drained areas.

Seuna (1980) attributes increased base flows experienced during low rainfall periods to the accelerating effect of the ditches. The effect of timber harvesting carried out on the same catchments during the post-drainage period may also lead to increased base flows. Clear-felling of peatland forests leads to increased catchment runoff (Päivänen 1974). Nevertheless, Seuna (1980) also noted that the increase in base flow observed after drainage, significantly declines over time. This decline Seuna associated with concurrent increases in stand interception and evapotranspiration.

The increased soil storage and stand interception capacities due to drainage are considered by Heikurainen (1976) to still be effective in absorbing normal average rainfall events. These capacities are lower on undrained open catchments and are quickly filled, resulting in a quicker runoff and more intense runoff responses. However, during more extreme rainfall events, shortlived but higher runoff peak flows from drained forested catchments were recorded. During such events, the interception capacity of the stand and the infiltration capacity of the peat in the drained catchment are exceeded and direct runoff occurs. The higher peak flows are due to the accelerating effect of the ditches which collect this runoff.

On drained catchments runoff peaks caused by heavy rainfall are increased, relatively, the most (Seuna 1980). Increases in the lower peaks were eliminated by storage in the peat and interception by the stand.

5. THE SPRING PEAK HYDROGRAPH

The frequency of summer flooding is low, perhaps one in twenty or fifty years. However, even flooding for periods of on only a few hours are sufficient to induce anaerobic conditions in the soil and cause serious root damage (Coutts and Armstrong 1976).

High water table levels in the peat during the summer have a detrimental effect on root growth (Vompersky 1968). Under Finnish conditions, water tables artificially maintained near to the soil surface during July—August has been shown to reduce the growth of pine (Pelkonen 1975).

Spring floods, although occurring perhaps one in every two years, take place before the growing season and therefore cause little direct damage to agricultural crops or tree stands compared to summer floods. Nevertheless, the size and frequency of spring flooding causes serious damage to buildings, roads and bridges etc., and can lead to the progressive deterioration of soils through leaching.

The characteristics of rainfall induced peak flows are determined by the balance that is achieved between precipitation, interception, infiltration, and water storage. The character of the spring runoff peak, however, is determined mainly by the conditions for melting, in particular the weather conditions and the water equivalent of snow, but also the water storage capacity of the soil.

Advocates of the hydrograph model A, envisage drainage as having a similar affect on the spring peak flow as summer peak flows, i.e. intensified peak flows. However, the effect on the spring peak flow may be relatively smaller than for summer peak flows. This is because of the large quantity of water released during snowmelt which may be expected to behave indifferently to the presence or absence of a ditch network. Relatively smaller changes in the spring peak flow have been reported by Seuna (1974). Thus, during the first nine years after drainage, the spring maximum flow from a sparsely forested catchment increased by 31 % on average. The corresponding value for the summer maximum flow was 131 %. Nevertheless, the occurrence of flooding is related to actual peak flow levels regardless of any relative changes.

Advocates of model B on the other hand argue for decreased spring peak flows due to drainage. The decrease in the spring peak flow Heikurainen associates with a delay in snowmelt caused by the presence of the tree cover and to a zone that lies between the water table and the lower limit of soil frost. This zone is completely lacking in undrained peatlands.

6. CONCLUSIONS

Drainage clearly increases the potential for greater runoff. However, whether this potential is realised depends upon the characteristics of rainfall (or snowmelt), the intensity of drainage, and the presence or absence of a tree stand.

Although the area of peatland forest drainage is extensive, compared to agricultural drainage and drainage for fuel peat production the ditching intensity used in forestry must be considered low. Further, taking into account the annual total runoff and the presence of a developing tree stand, any increase in runoff experienced after drainage are reduced in the longterm, and possibly even to below that of undrained areas.

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LYHENNELMÄ:

SOIDEN METSÄOJITUKSEN VAIKUTUS YLIVIRTAAMIIN

Soiden metsäojitusta on kritisoitu lähinnä sen vuoksi, että on katsottu sen aiheuttavan tulvariskin kasvua vesistön alapuolisissa osissa. Tulvan esiintyminen on suorassa yhteydessä ylivirtaamiin. Täten oleellisimmaksi kysymykseksi muodostuu, lisääkö metsäojitus ylivirtaamia?

Selvityksessä tarkastellaan metsäojituksen vaikutusta ylivirtaamiin eräiden viimeaikaisten tutkimusten perusteella. Metsäojituksen havaitut hydrologiset vaikutukset vaihtelevat valuma-alueen koon ja virtaaman mittausaseman sijainnin mukaan. Tarkastelun kohteena on erityisesti ollut ojitusalueelta purkautuva virtaama; vähemmälle huomiolle on jätetty tässä yhteydessä koko valuma- tai vesistöalue.

Virtaamatapahtumia kuvataan yleensä virtaaman aikakäyrän avulla, jossa voidaan erottaa nousukäyrä, huippu- eli ylivirtaama, resessiokäyrä sekä pohjavirtaama (ks. Kuva 1 ja Anon. 1976, s. 137). Ojitetun ja ojittamattoman suon virtaamien aikakäyrien analysointiin pohjautuvat tutkimukset ovat tuottaneet toisistaan melkoisestikin poikkeavia tuloksia. Eräiden tutkimusten perusteella ojitus lyhentää huippuvirtaaman esiintymisaikaa, nostaa huippuvirtaaman ja alentaa pohjavirtaaman tasoa (Malli A Kuvassa 2; ks. Mustonen ja Seuna 1971, Ahti 1980). Toisaalta on havaittu ojituksen pidentävän huippuvirtaaman esiintymisaikaa sekä alentavan huippuvirtaaman ja nostavan pohjavirtaaman tasoa (Malli B Kuvassa 2; ks. Multamäki 1962, Burke 1972, Heikurainen 1976 ja 1980). Edelleen voidaan olettaa, ja tämän suuntaisia havaintojakin on tehty, että edellä esitettyjen virtaaman aikakäyrien yhdistelmätyyppikin on olemassa (Malli C Kuvassa 2; ks. Seuna 1974 ja 1980).

Kirjoituksessa pohdiskellaan valuma-alueen ominaisuuksien (topografia, kaltevuus, koko, kasvupaikka, turvelaji, pintaturpeen vedenvarastoimiskyky, ojituksen tehokkuus, ojatyyppi jne.) ja sadetapahtuman ominaisuuksien (sateen intensiteetti, puustopidäntä) vaikutuksia virtaaman aikakäyrään. Eri tutkimuksissa saadut toisistaan poikkeavat tulokset selittynevätkin ainakin osaksi edellä mainittujen tekijöiden avulla.

Tarkastelun perusteella on pääteltävissä, että ojitus ilmeisestikin lisää virtaamien suurenemisen mahdollisuutta. Virtaamien todelliset muutokset riippuvat kuitenkin oleellisesti sadetapahtuman (tai lumen sulamisen) luonteesta, ojituksen tehokkuudesta ja alueen kasvillisuudesta, erityisesti puustosta.

Vaikka metsäojitettu pinta-ala on maassamme suuri verrattuna suoviljelystä ja turpeenkorjuuta varten kuivatettuun alaan, metsätaloudessa käytettyä ojitusta on kuitenkin pidettävä tehokkuudeltaan suhteellisen alhaisena. Edelleen otettaessa huomioon vuotuinen kokonaisvalunta ja ojitusalueen elpyvä puusto, ojituksen vaikutuksesta mahdollisesti lisääntyvä valunta tulee aikaa myöten pienenemään ja jopa asettumaan ojittamattoman vertailualueen valunnan alapuolellekin.

ström kirjoitti muistelmat, samoin muistelmat metsähallituksen metsäojitustöistä ja Laatokan Karjalasta. Tämänlaatuinen kirjoittelu oli yksi hänen harrastuksiaan.

Vaikka Bockström oli innokas ojittaja, hän oli myös suuri luonnon ihailija ja valokuvasi ja myöhemmin filmasi innokkaasti soita. 1960-luvulla hän sai suurtyönsä valmiiksi: metsähallitus rauhoitti hänen esityksestään suuren määrän suoalueita, näin Bockström oli uranuurtaja myös soiden rauhoitustyössä.

Bockström oli virkamatkallaan säännöllisesti koko lumettoman kauden ja kulki ristiin rastiin Suomea. Innokkaana filatelistina hän mm. keräsi postipysäkkien nimileimakokoelman, jonka hän lahjoitti Posti- ja lennätinlaitokselle. Tähän työhön hän käytti kaikkia mahdollisia yhteyksiä, mm. jakeli valmiiksi itselleen kirjoitettuja kortteja ja käski jättää sille ja sille pysäkille. Eräs hänen harrastuksistaan oli sienten keruu, tänäkin vuonna hänen pakastimensa on täynnä sieniä. Myös erilaisten puiden istutusta hän harrasti Viitasaaren ja Kangasniemen tonteillaan ja puuhasi muutenkin uutterasti puutarhassaan.

Metsäteknikoiden koulutuksesta Bockström oli kiinnostunut. Hän luovutti suuren määrän metsäalan kirjallisuutta oppilaitoksille ja lahjoitti myös stipendejä jaettavaksi oppilaille.

Eläkkeellä ollessaan hän seurasi kiinteästi alansa kehitystä ja kantoi suurta huolta monesta hänen mielestään virheilmiöistä metsässä, esim. raskaiden metsätraktoreiden kesäajosta juurivaurioineen. Myöskään monesta muusta uutuudesta hän ei pitänyt, ''ne ovat niitä herrojen touhuja tai vehkeitä''. Vielä nykyvuosina sain usein kuunnella hänen ärhentelyään pieleen menevistä uusista virtauksista. Näiden ärhentelyjen ja vihaisten puheiden takana oli kuitenkin lämminsydäminen, luontoarakastava hyvä ihminen. Metsäojitus on menettänyt erään suuren poikansa.

Espoossa 17. 9. 1981
Esko Lehtimäki

CORRECTION

In Suo N:o 3, 1981, page 81 the following was mentioned ''Seuna (1980) attributes increased base flows experienced during low rainfall periods to the accelerating effect of the ditches''. This is not the case. In the references listed (Mustonen & Seuna 1971, Seuna 1974, Seuna 1980) the increase in low flows is explained as follows:'' . . . the ditches made flow possible in all seasons of the year. The main ditches reached the pervious mineral soil, which acted as underground drainage . . .'' It is clear that also the decrease in evapotranspiration caused by drainage increases low flow in summer and especially in the first post-drainage years.

The accelerating effect of the drains mentioned in the text by Starr and Päivänen especially affects the maximum runoff (f.eg. Seuna 1980). Thus a peakier runoff is very often obtained after drainage, although the maximum runoff is a sum result of many influencing factors.

Pertti Seuna