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LONG-TERM INFLUENCE OF FORESTRY DRAINAGE ON THE HYDROLOGY OF AN OPEN BOG IN FINLAND

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A control basin method was used for studying the hydrological effects of forestry drainage in Finland. Two adjacent natural basins, each 5 km^2 in area, were calibrated against each other from 1936 to 1957. In 1958—1960, 40 per cent of one basin was drained for forestry. Using regression equations for the calibration period it was computed that runoff increased considerably due to the draining. In 1961—1969 the average increases were as follows: Mq 29 per cent (decrease in evapotranspiration); $Hq_{snowmelt}$ 31 per cent; Hq_{summer} 131 per cent (accelerating effect of ditches) and Nq many times over due to draining. Throughout the whole treatment period (1961—1979) there was a decreasing trend in the influence of drainage. For mean annual runoff and low flows the purified trends were statistically significant. Two reasons for these trends were evident: (1) an increase in evapotranspiration caused by a new stand of pines, (2) impairment of the ditches. The runoff had not quite fallen to the pre-drainage level 15—20 years after drainage.

Index words: hydrological effects, forestry drainage, trends.

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1. INTRODUCTION

Draining peatlands for forestry has been used in a number of countries as a way of increasing timber production. Finland has 10 · 10^6 ha of peatland 10 per cent of the earth's total peatland area. Of this 10 · 10^6 ha about 7 · 10^6 ha are suitable for draining. By the end of 1979, some 5.5 · 10^6 ha had been drained. Hence, almost one fifth of the land area of Finland is now being treated in a manner which has considerable hydrological significance.

2. METHOD

In this research a control basin method and trend analysis were used. In the control basin method the research basins are kept in their natural state during a calibration period. After the calibration the experimental basin is treated in the manner to be studied (= drained) and the other basin is kept in its natural state as a control basin throughout the study period. Regression equations are computed for the desired runoff quantities of the treatment and control basins for the calibration period. These equations are used after the treatment for the calculation of what the runoff would have been if draining had not been performed. The difference between the calculated and observed runoffs indicates the change caused by draining, provided there has been no other treatment. The statistical significance of the change can be determined using the t-test or F-test. In this case the analysis of covariance and the F-test were used (Kovner and Evans 1954).

Trend analyses were carried out for the runoff during the post-drainage period 1961—1979. This was done using mostly purified runoff changes. The purification was performed by correlating the computed runoff changes of each year with the observed runoff of the treatment basin. The correction factor given by this regression line was subtracted from the original change to obtain the purified effect of time. Purification was needed for two reasons. Firstly, the change in runoff depended on the magnitude of runoff. Secondly, there was also a decreasing 'trend' in runoff of the control basin throughout the observation period due to climatological variation.

3. BASINS AND TREATMENTS

The two 5 km^2 research basins discussed in this paper are situated in southeastern Finland (61 °N and 29 °E) (Fig. 1). Various hydrological observations have been made on these adjacent basins starting in 1935. The altitude of the experimental basin (Huhtisuo) varies in the range 100—125 m and that of the control basin in the range 80—130 m a.s.l. The basins are similar in certain respects (Table 1).

The control basin (Latosuo) contains pine and spruce swamps comprising 15 per cent of the drainage area, and a large cultivated area (19 per cent), which was reclaimed long ago from peatland. In the experimental basin (Huhtisuo) there are no cultivated areas. Open bogs and swamps with a poor growth of pine comprise about 45 per cent of the basin. Before draining, the peat layer was about 1.5 m thick. The mineral soil below the peat is mostly sand and gravel. The control basin also contains some sandy soils (12 per cent). Both basins are uninhabited.

The climate in the region is humid. Mean annual precipitation is about 700 mm with a range of 500—850 mm. Approximately 270 mm of the total precipitation is discharged and 430 mm evaporates as a long-term average. Much of the precipitation is in the form of snow. The average water equivalent of snow on 15 March is about 120 mm. Thus spring runoff forms a considerable part, about 50 per cent, of the total annual runoff. Precipitation is fairly evenly distributed throughout the year so that most of the rain falls in August, about 80 mm, and least in March, about 40 mm. The mean annual temperature is 4 °C with a range of +1 to +6 °C. The warmest month is July with a mean temperature of 17 °C, and the coldest is February, mean —9 °C.

Draining was carried out in 1958—1960. The main ditches, 130 cm deep, were dug in the Huhtisuo basin in 1958. Draining was completed in 1960 by digging small forest ditches, 60 cm deep. The drainage density was 80 m of main ditch and 225 m of forest ditch per drained hectare. The drained area comprised 40 per cent of the Huhtisuo basin.

The period 1958—1960 was not studied separately because of its short duration. The treatment period was therefore considered to begin in 1961, while the calibration period extended from 1936 to 1957.

When a control basin method is used both basins must be kept unchanged throughout the research period except for the treatment of the experimental area. In this case this was not quite possible. Before 1956 changes in the basins were insignificant. In 1956 some forest draining and clearcutting was carried out in both basins. The drained area in the Huhtisuo basin was four per cent and in Latosuo seven per cent. Clearcutting accounted for 12 and 9 per cent of the two basins, respectively. Both draining and clearcutting increase runoff (Mustonen 1965; Mustonen and Seuna 1971).

Table 1. Data on the research basins of Huhtisuo and Latosuo.

Basin	Drainage area (km^2)	Peatland (%)	Cultivated land (%)	Mean slope (%)	Tree stand (m^{3}ha^{-1}) 1958	Tree stand (m^{3}ha^{-1}) 1970
Huhtisuo	5.03	44	0	5.0	58	39
Latosuo	5.34	15	19	8.2	58	74

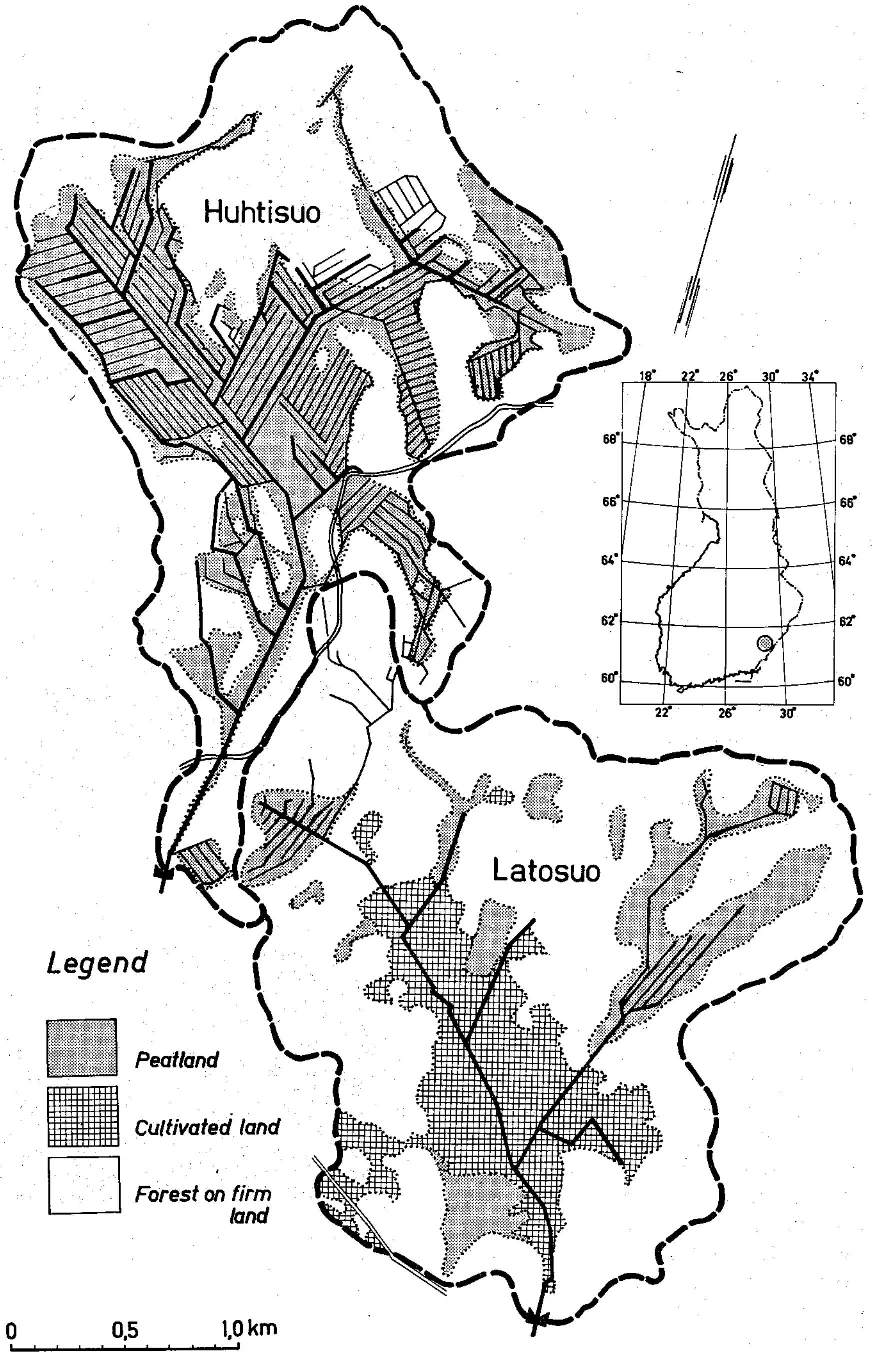

Fig. 1. Huhtisuo and Latosuo (control) research basins. Heavy lines show main ditches, thin lines forest ditches.

The percentages justify the conclusion that the effects of these treatment are largely eliminated in the changes computed. For this reason they have not been taken into account in the computations of runoff changes.

During the period 1958—1970 the volume of growing stock increased in the Latosuo basin and decreased in the Huhtisuo basin because of the differences in silvicultural treatment (Table 1). Because of these changes the volumes of growing stock differed by 35 m^3 ha^{-1} in 1970 as compared with the situation in 1958. Cuttings in 1960—1961 from 60 per cent of the total cuttings in Huhtisuo after 1958 and the rest of the cuttings are evenly distributed over the period 1962—1970. Hence the average difference in tree stands was 28 m^3ha^{-1} during the period 1961—1969. It has been shown (Mustonen 1965) that a decrease of 10 m^3ha^{-1} in growing stock causes an increase of 7.7 mm in annual runoff. On this basis, the average increase in annual runoff was 22 mm in 1961—1969. No tree stand measurements are available after 1970. However, we can assume that there have been no major changes in the volume of growing stock since 1970. On the other hand, the coverage of the tree stand may have increased considerably due to pine plants of the peat area of the Huhtisuo basin.

It has not been possible to take the changes in growing stock into account in any runoff quantities other than annual runoff. However, changes in growing stock may have a slight effect on other runoff quantities, because of the changes in melting conditions and interception.

The volume of water stored in the soil varies and the observed changes is runoff may be 'too small' of 'too big' for a single year. However, these under or overestimates cannot be corrected because of the lack of soil moisture observations. On the other hand, groundwater level and laboratory tests on the air space of the peat are available, ant the settling of the peat surface has also been measured. The total settling during the period 1961—1969 was 120 mm and the increase in the air space of the peat was 50 mm. The total decrease in the water storage of peatland was thus 170 mm. Calculated for the whole basin and for one single year the depletion of the water storage contributed on average $0.40 \cdot 170/9 = 8$ mm to the annual runoff. Obviously the annual contribution was considerably greater than 8 mm in the first post-drainage years and somewhat smaller in the last few years.

As with the changes in tree stand, the effects of soil water depletion have been taken into account only in the computation of annual runoff.

In Fig. 2 the same area of the Huhtisuo basin is shown in 1960, 1971 and 1980.

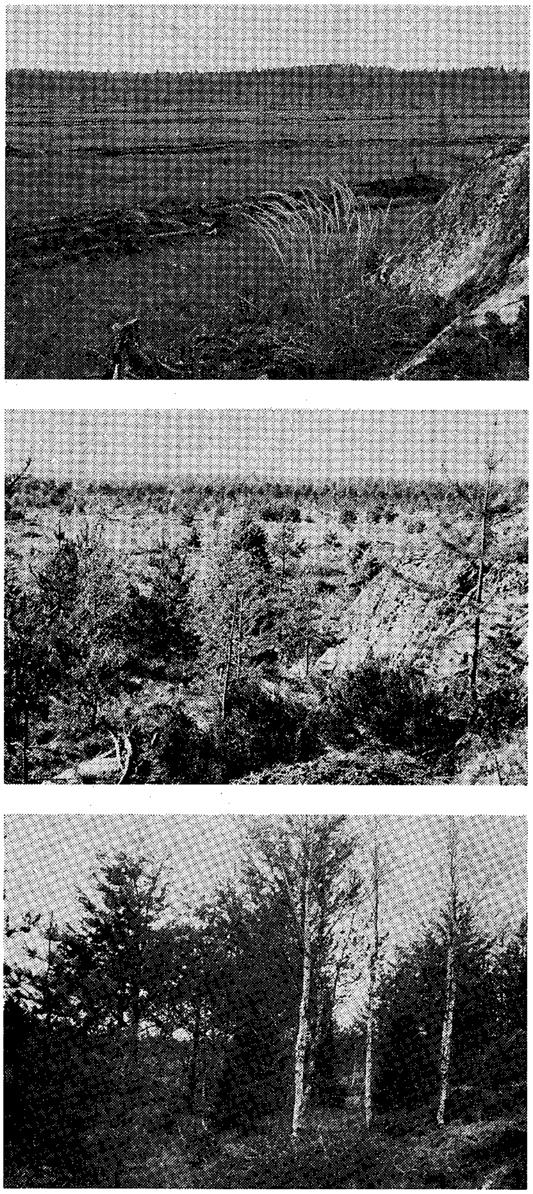

Fig. 2. A view of the Huhtisuo basin in 1960 right after the drainage (above), in 1971 (middle) and in 1980 (below).

4. RESULTS

In Table 2 the values of runoff quantities are shown before and after the drainage. As a result of forestry drainage all runoff quantities increased, especially in the first post-treatment years. The changes of different runoff quantities are discussed in more detail below.

Table 2. Mean annual runoff Mq, spring and summer maximum runoffs Hq_w and Hq_s, winter and summer minimum runoffs Nq_w and Nq_s (30 days) in l s^{-1} km^{-2} (H = Huhtisuo, L = Latosuo).

Year	Mq		Hq_w		Hq_s		Nq_w		Nq_s	
	H	L	H	L	H	L	H	L	H	L
1936	6.59	8.57	180	94	13	23	0.70	2.84	0.03	1.33
1937	5.43	7.08	166	128	13	12	0.19	1.01	0.01	0.72
1938	7.19	9.06	105	94	20	21	0.20	2.02	0.00	0.65
1939	2.77	5.16	104	93	1	4	0.00	1.79	0.00	0.48
1940	2.64	4.62	51	39	15	49	0.00	0.96	0.00	0.37
1941	1.68	3.32	63	39	19	42	0.00	0.36	0.00	0.21
1942	5.54	8.26	96	78	29	59	0.00	0.53	0.09	1.63
1943	10.94	12.79	113	86	59	64	0.06	2.56	1.16	3.65
1944	7.77	9.63	135	88	17	19	0.35	2.24	0.00	1.17
1945	6.95	8.88	171	121	21	26	0.76	2.67	0.00	2.51
1946	6.57	9.81	218	175	18	54	0.00	1.54	0.00	2.00
1947	2.56	5.02	108	120	6	18	0.00	0.53	0.00	0.73
1948	4.90	8.91	88	63	22	28	0.39	0.53	0.00	1.70
1949	6.03	8.78	88	87	12	17	1.79	3.21	0.09	1.01
1950	6.45	8.13	86	77	18	15	0.00	0.96	0.00	1.44
1951	5.23	8.47	183	107	1	7	0.16	2.72	0.00	0.67
1952	6.39	10.27	99	121	29	54	0.57	1.39	0.22	2.26
1953	7.71	8.52	145	71	48	38	0.44	2.73	1.43	2.38
1954	8.37	8.61	56	23	38	78	0.08	1.47	0.11	3.06
1955	7.50	11.01	217	154	9	9	1.07	2.55	0.00	0.33
1956	8.78	10.75	214	147	43	82	0.08	1.70	0.46	3.49
1957	12.35	15.46	257	186	65	82	0.90	2.92	1.97	3.48
1958	10.12	9.20	135	115	25	52	0.93	2.25	3.10	1.68
1959	9.48	8.89	142	124	22	20	2.73	3.04	3.07	1.19
1960	10.09	9.11	78	80	63	68	1.34	1.24	4.90	3.58
1961	13.98	11.75	203	137	296	153	4.32	4.80	4.48	1.95
1962	18.82	16.24	213	92	204	132	2.97	2.78	7.65	5.57
1963	6.11	5.66	124	80	24	19	1.45	2.08	0.96	0.51
1964	6.46	5.62	95	67	22	23	0.78	1.17	0.84	0.70
1965	8.44	8.61	285	109	45	45	1.66	2.90	2.78	2.46
1966	12.03	12.47	317	204	82	86	1.81	2.40	3.36	4.03
1967	8.28	8.03	116	73	27	30	1.73	1.94	1.12	0.84
1968	8.83	8.79	62	54	49	40	0.68	0.53	1.62	1.13
1969	7.60	7.47	183	94	34	26	1.02	1.23	1.05	0.63
1970	6.90	7.59	164	124	26	28	0.94	1.78	0.78	0.67
1971	8.04	8.65	104	82	7	9	3.04	3.30	0.82	1.08
1972	5.24	5.53	81	50	6	9	1.02	1.28	0.62	0.60
1973	4.57	4.92	31	34	18	19	0.84	1.05	0.37	0.54
1974	12.04	13.54	53	49	37	42	1.56	2.47	2.68	3.57
1975	6.24	7.06	70	64	8	7	3.42	5.20	0.62	0.87
1976	3.73	4.92	60	53	12	11	0.37	1.22	0.65	1.08
1977	7.84	9.41	90	79	20	26	0.77	1.76	1.02	1.29
1978	4.17	5.62	49	45	11	17	0.82	2.40	0.42	1.29
1979			85	59	23	26	0.49	1.48	1.47	2.29
M 1936—57	6.38	8.69	134	100	24	36	0.35	1.78	0.25	1.60
M 1961—69	10.06	9.40	178	101	87	62	1.82	2.20	2.65	1.98
M 1970—79[1)]	6.53	7.47	79	64	17	19	1.33	2.19	0.95	1.33
σ 1936—57	2.59	2.69	59	42	17	25	0.46	0.91	0.54	1.11
σ 1961—79	3.82	3.22	81	40	74	41	1.10	1.22	1.81	1.39

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1) Mq 1970—78

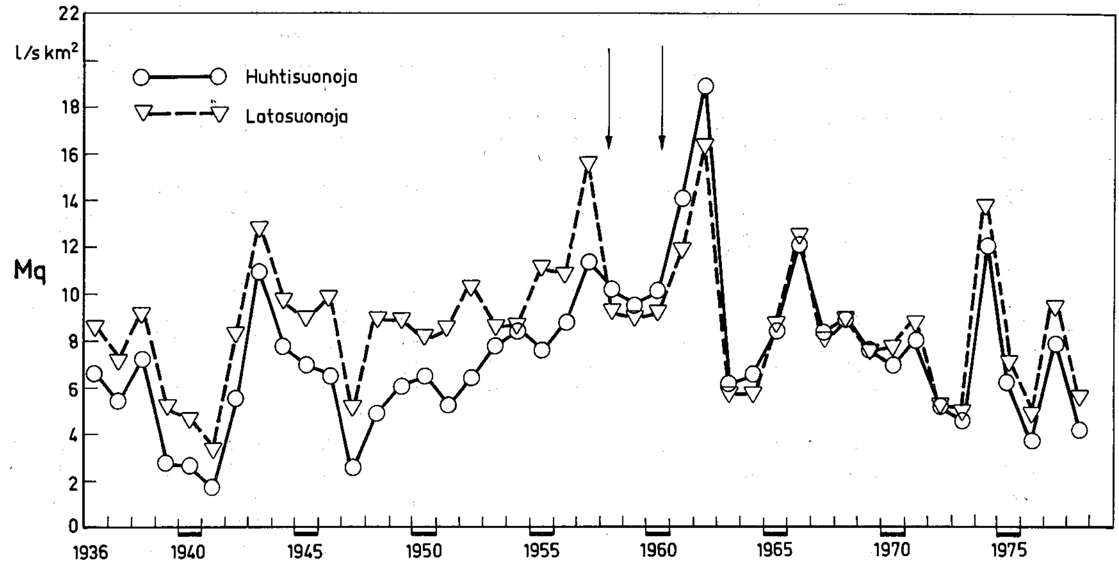

Fig. 3. Mean annual runoff Mq of the research basins in 1936—1978. The arrows show the ditching date.

4.1 Annual runoff

The variation in mean annual runoff of the treatment basin and the control basin have been fairly great during both the calibration period and the post-treatment period (Fig. 3). The average increase in mean annual runoff in 1961—1969 was 3.02 ls^{-1} km^{-2} or 95 mm (Fig. 4). This is 43 per cent of the value calculated on the basis of the calibration period and is statistically highly significant (risk $<$ 0.1 per cent). Of this 95 mm the depletion of the water storage contributed about 8 mm per year and tree cutting about 22 mm per year, as mentioned earlier. Hence the net increase in runoff due to the decrease in evapotranspiration was 95—8—22 = 65 mm per year, on average. This is 29 per cent of the mean 'undrained' annual runoff in 1961—1969. The decrease in evapotranspiration is evidently due to the drop in the groundwater table and to drying of the upper layer of the peatland.

The average annual increase in the second half of the post-treatment period (1970—1978) was 1.29 ls^{-1} km^{-2} or 41 mm, which is 18 per cent of the 'undrained' runoff. If the correction factors discussed above are taken into account, the net annual increase in the second half of the period after drainage was around 15 mm, in view of the fact that the depletion factor has further decreased.

The trend analysis was carried out using observed changes without the corrections mentioned above. This can be regarded as justified because it is the trend in changes that is being considered and

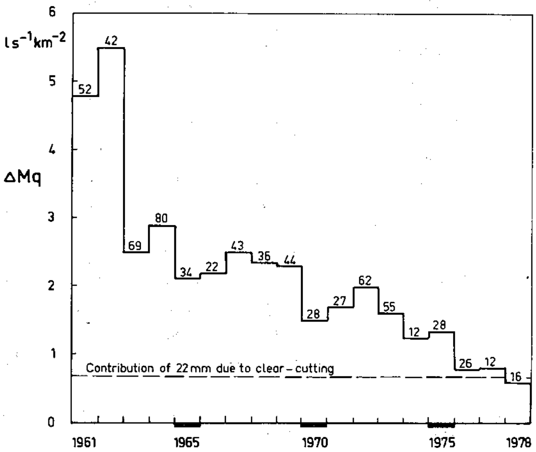

Fig. 4. Increase in mean annual runoff (Δ Mq) caused by drainage in the Huhtisuo basin. Figures above the columns indicate the increase in per cent.

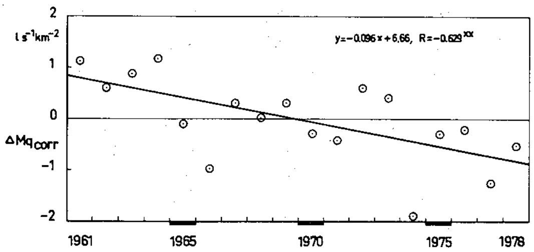

Fig. 5. Purified trend of mean annual runoff after drainage in the Huhtisuo basin. y = ΔMq_{corr} = change in runoff corrected for the magnitude on runoff, x = year — 1900.

the constant correction does not affect it. The depletion factor is not constant during the post-treatment period, but as a real contribution caused by drainage it was included in runoff trends.

There was a clear decreasing trend in the influence of drainage (Fig. 4). The unpurified trend could be expressed by a linear regression equation $y = -0.204x + 16.4$, $R = -0.856$, where y = annual increase in runoff in ls^{-1} km^{-2}, and x = year —1900 (e.g.$x_{1979} = 79$). This trend was statistically highly significant (risk < 0.1 per cent). The purified trend was statistically significant, too, but at a lower level, risk < 1 per cent. In this case the trend equation was $y = -0.096x + 6.66$, $R = -0.629$, when the purification was done as explained earlier (Fig. 5).

The runoff after 15—20 years appeared to settle down to the level before drainage, if the contribution caused by clearcutting is taken into account (Fig. 4).

4.2 Maximum runoff

Both spring and summer maximum runoff increased clearly in the first post-drainage years as a result of draining (Figs. 6—12). In 1961—1969 spring maximum runoff increased by 42 ls^{-1} km^{-2} or 31 per cent, and the summer maximum by 49 ls^{-1} km^{-2} or 131 per cent, on average, as compared with 'undrained' runoff. The increases were statistically significant at 1 and 0.1 risk, respectively. The increases in maximum runoffs were largely due to the accelerating effect of the ditches on the flow. The flood lakes that normally formed on natural peatlands of the Huhtisuo type also disappeared and their levelling effect on runoff was eliminated. The increase in infiltration caused by drying of the surface layer of the peatland was rather slight. During heavy summer rains in particular the moisture deficit of the peat was rapidly satisfied and the runoff peak was not markedly reduced by increased infil-

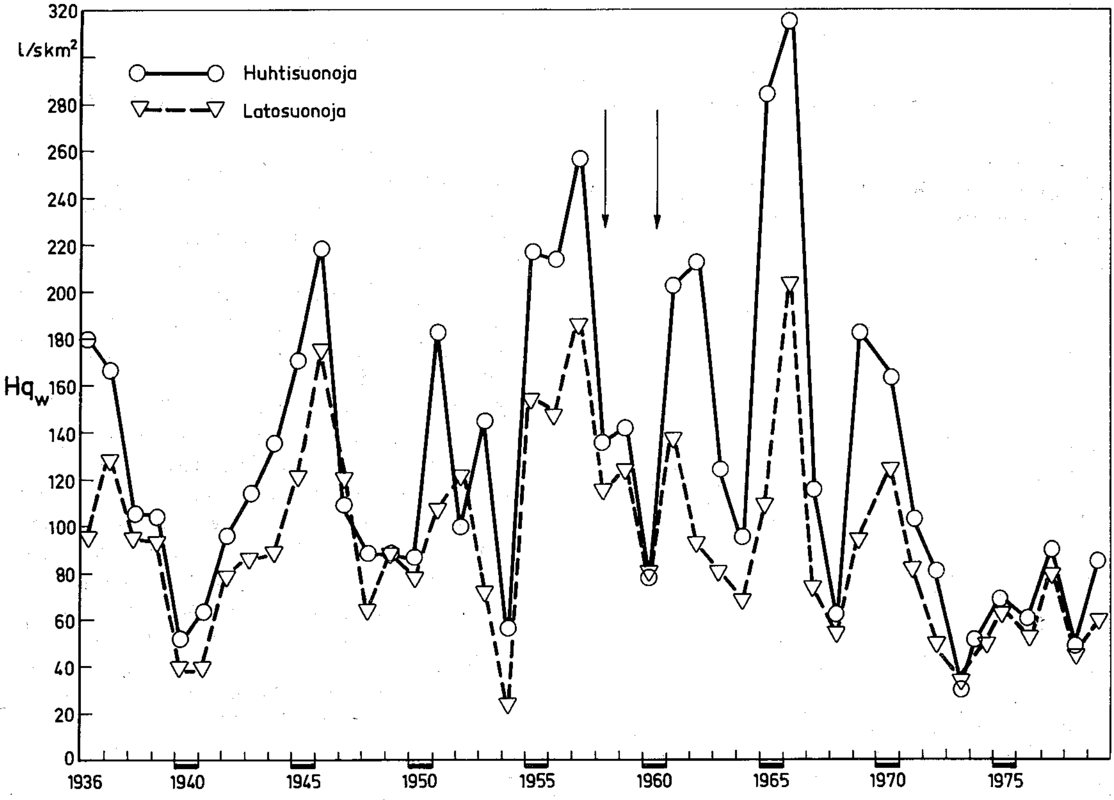

Fig. 6. Spring maximum runoff Hq_w of the research basins in 1936—1979. The arrows show the ditching date.

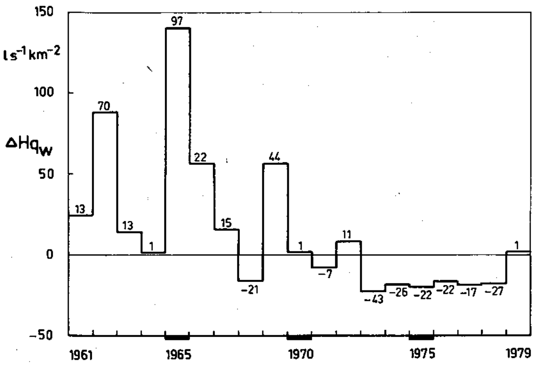

Fig. 7. Change in spring maximum runoff (Δ Hq_w) caused by drainage in the Huhtisuo basin. Figures at the top of the columns indicate the change in per cent.

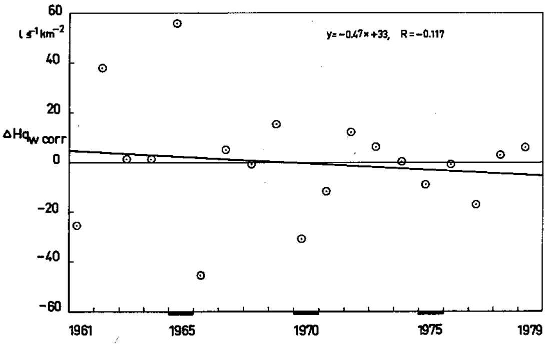

Fig. 8. Purified trend of spring maximum runoff after drainage in the Huhtisuo basin. $y = \Delta Hq_{w\ corr}$ = change in runoff corrected for the magnitude of runoff, x = year — 1900.

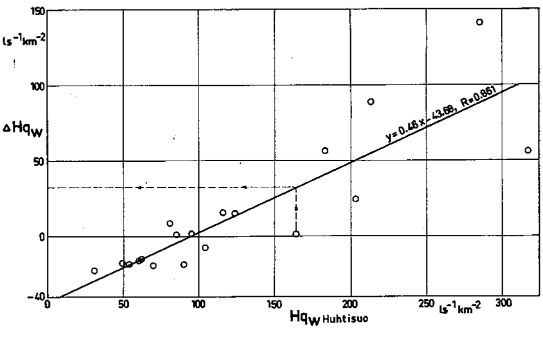

Fig. 9. The purification method. A regression equation is calculated between Δq and q. Using this equation a correction factor (indicated with dashed line) is then subtracted from the original change Δq. A purified trend is the trend of Δq — the correction factor.

tration. Thus the runoff caused by heavy rains increased most, in relative terms.

There was evidence that after drainage, in 1961—1969, spring runoff came 1.5 days earlier on average than without draining. This may be partly due to clearcutting but partly due to draining. When a drained area is situated in the upper part of a river basin it increases the flood peak of the river for the reason mentioned above.

In the second half of the post-treatment period, i.e. 1970—1979, the average change in spring maximum runoff was negative, —11 ls^{-1} km^{-2}, or —13 per cent as compared with the calculated runoff. For summer maximum runoff the change in 1970—1979 was still positive, but only 2.7 ls^{-1} km^{-2}, or 19 per cent of the calculated value, on average. This was probably due partly to the fact that flood peaks were in general lower in the second half than in the first half. This corresponds both with spring and summer maximum runoff. As stated earlier the highest peaks increased most and the increases in low peaks were eliminated by storage in the drained upper layer of the peat. The growing tree stand probably had some decreasing effect on runoff by changing snowmelt conditions and by increasing interception. The third reason could be impairment of the ditches. The conveyance of the ditches was undoubtedly reduced causing a drop in the flood peaks. For these reasons drainage and its co-effects could even reduce small peaks at later stages (Figs. 7 and 11).

When an unpurified trend was calculated for spring maximum runoff, the regression formula was $y = -4.60x + 336$, $R = -0.599$, where y = change in spring maximum runoff (ls^{-1} km^{-2}) and x = year — 1900. The trend was statistically significant at 1 per cent risk. However, because of uneven distribution of high and low peaks during the post-treatment period the uncorrected trend cannot be considered reliable in this case. The purified trend was very weak, $y = -0.47x + 33$, $R = -0.117$, and had no statistical significance (Fig. 8). The purification method is illustrated in Fig. 9.

For summer maximum runoff the unpurified trend was statistically significant at the 1 per cent level ($y = -5.55x + 413$, $R = -0.595$ but again the data were unevenly distributed throughout the whole period (Fig. 11). No purified trend of statistical significance was noticed in this case either ($y = 0.12x - 8.66$, $R = 0.120$) (Fig. 12).

To summarize the findings concerning maximum runoff, no indisputable trends can be presented in the lack of high peaks in the latter decreasing trend would be quite logical. On the other hand draining apparently did not increase

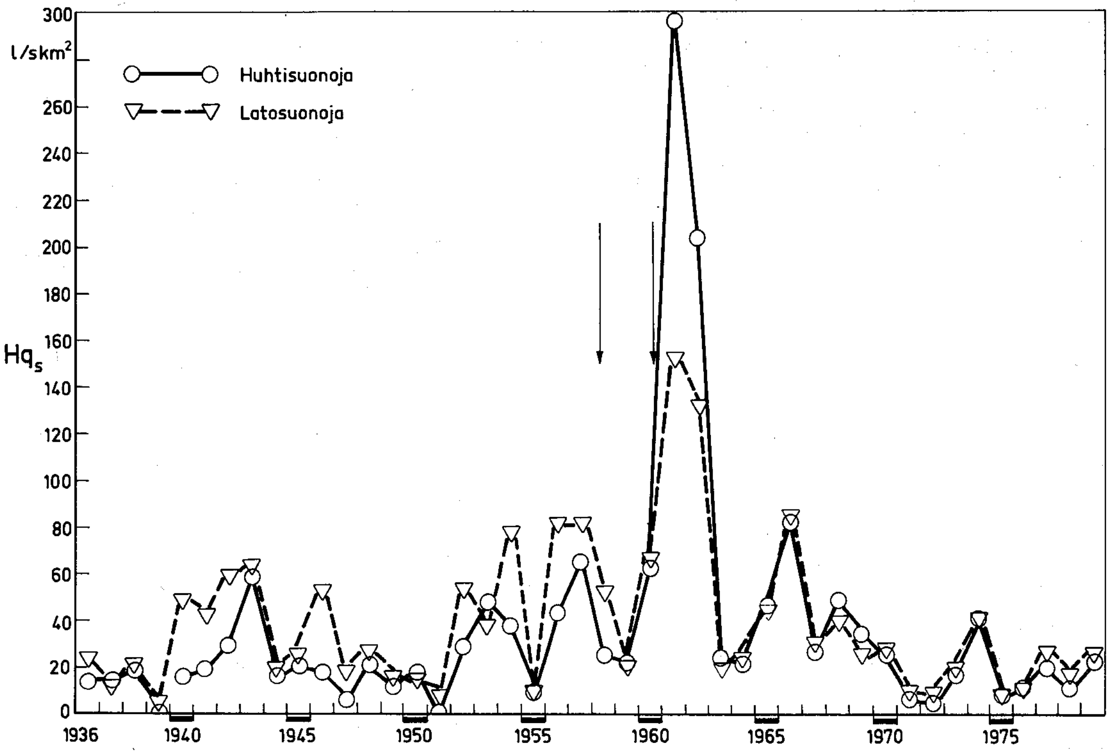

Fig. 10. Summer maximum runoff Hq_s of the research basins in 1936—1979. The arrows show the ditching date.

low peaks after the depletion of the water storage of peatland.

4.3 Minimum runoff

The minimum runoff for both winter and summer increased markedly (Figs 13—18). The increase in both cases was statistically significant at 0.1 per cent risk in 1961—1969. Draining made the Huhtisuo basin somewhat similar to the control basin in terms of minimum runoff. This was largely because the ditches made flow possible in all seasons of the year. The main ditches reached the pervious mineral soil, which acted as underground drainage and intensified the effect of drains. Before draining there was only a short, shallow, natural channel in the lower part of the Huhtisuo basin.

Both winter and summer minimum runoffs decreased during the post-treatment period to some extent. For the 30-day winter minimum runoff the purified trend was $y = -0.016x + 1.09$, $R = -0.527$, where y and x are as explained earlier. This trend was statistically significant at the 1 per cent risk level.

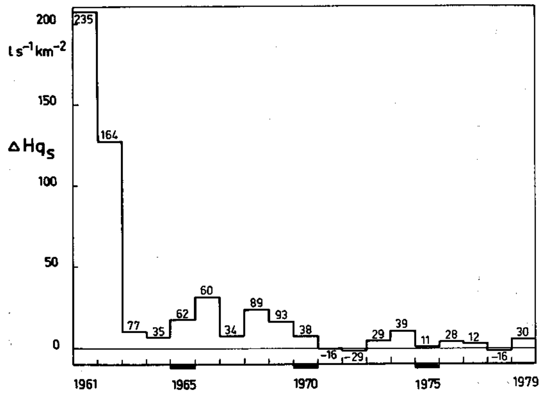

Fig. 11. Change in summer maximum runoff (ΔHq_s) caused by drainage in the Huhtisuo basin. Figures at the top of the columns indicate the change in per cent.

The purified trend for the 30-day summer minimum runoff was $y = -0.014x + 0.96$, $R = -0.512$. This trend was statistically significant at a probability of almost 99 per cent.

The decreasing trend was quite logical, especially for summer minimum runoff considering the increase in evapotranspiration due to the growing tree stand. However, at the end of the post-treatment period minimum runoffs for both winter and summer still exceeded the 'undrained' values. For summer minimum runoff one must keep in mind the clearcutting mentioned earlier, which may raise the level of runoff changes during the post-drainage period as shown in Fig. 4 for mean annual runoff.

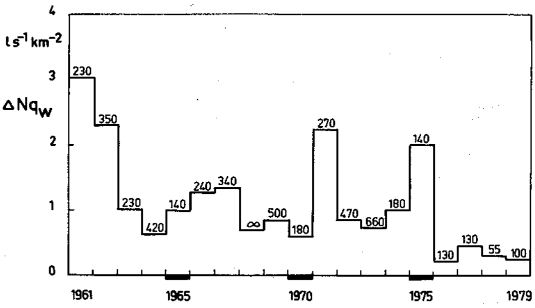

Fig. 14. Change in the 30-day winter minimum runoff (ΔNq_w) after drainage in the Huhtisuo basin. Figures above the colums indicate the increase in per cent.

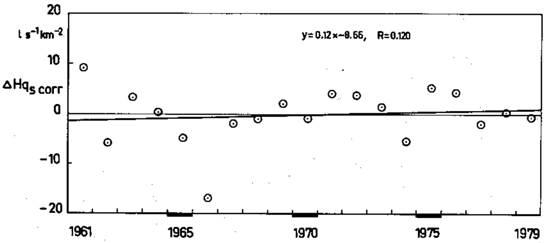

Fig. 12. Purified trend of summer maximum runoff after the drainage in the Huhtisuo basin. $y = \Delta Hq_{s\ corr}$ = change in runoff corrected for the magnitude of runoff, x = year — 1900.

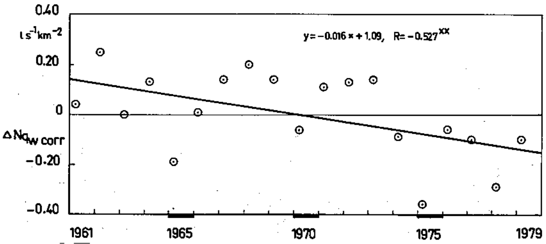

Fig. 15. Purified trend for the 30-day winter minimum runoff after drainage in the Huhtisuo basin. y = $\Delta Nq_{w corr}$ = change in runoff corrected for the magnitude of runoff, x = year — 1900.

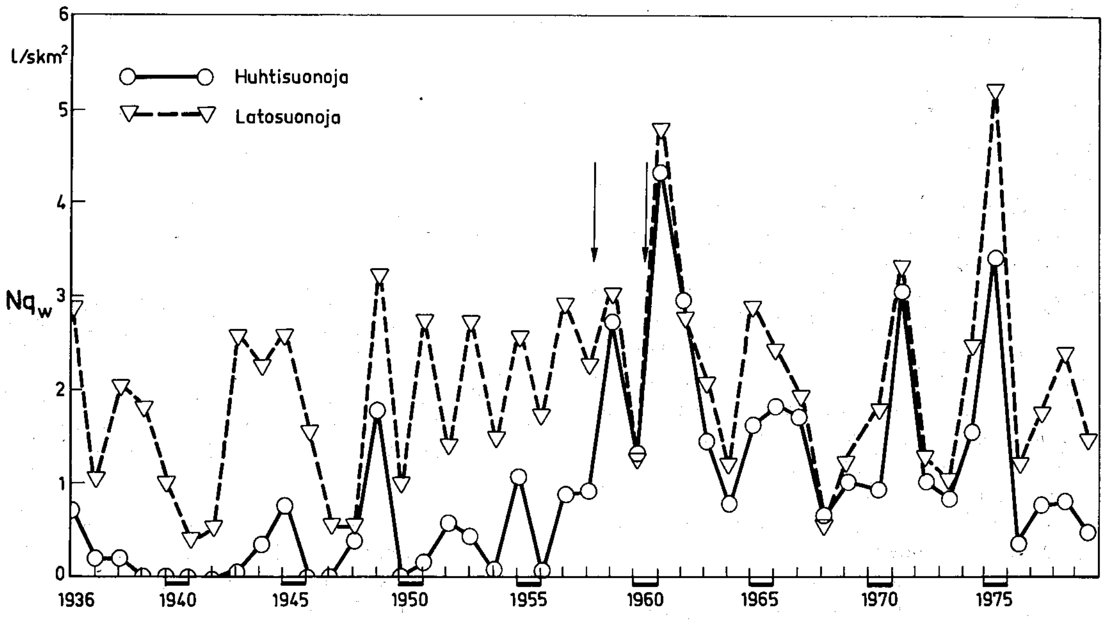

Fig. 13. Winter minimum runoff Nq_w (30 days) of the research basins in 1936—1979. The arrows show the ditching date.

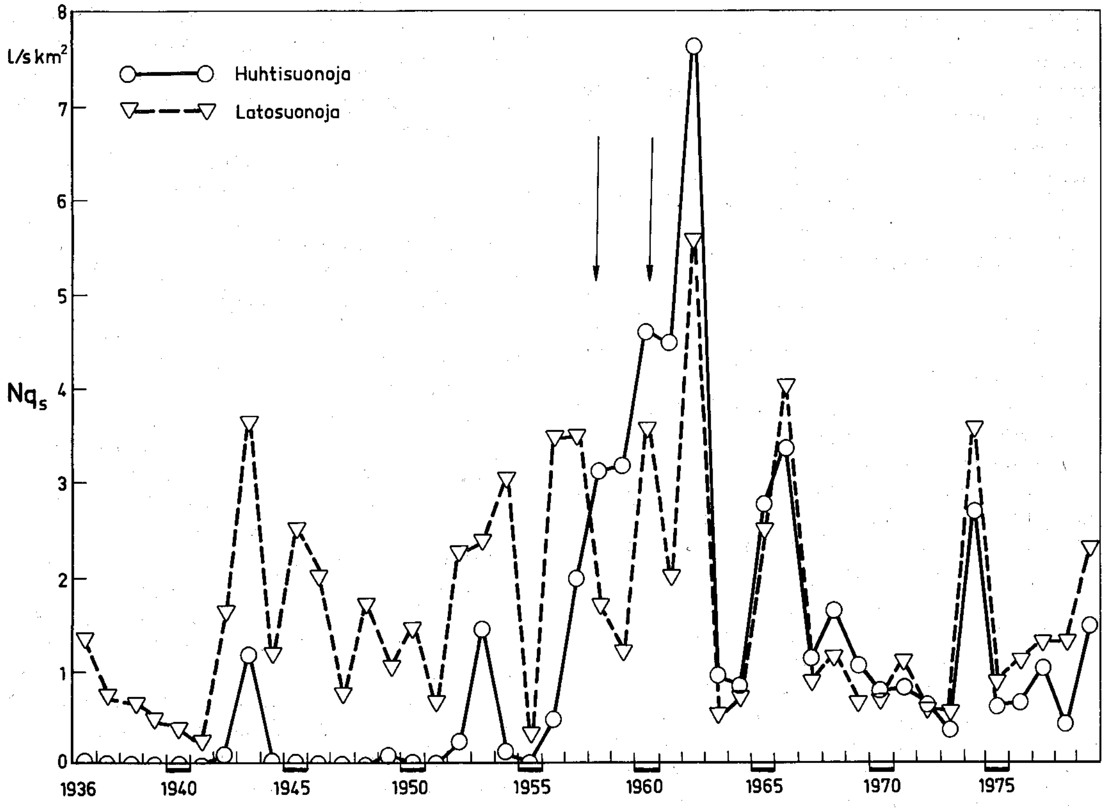

Fig. 16. Summer minimum runoff Nq_s (30 days) of the research basins. The arrows show the ditching date.

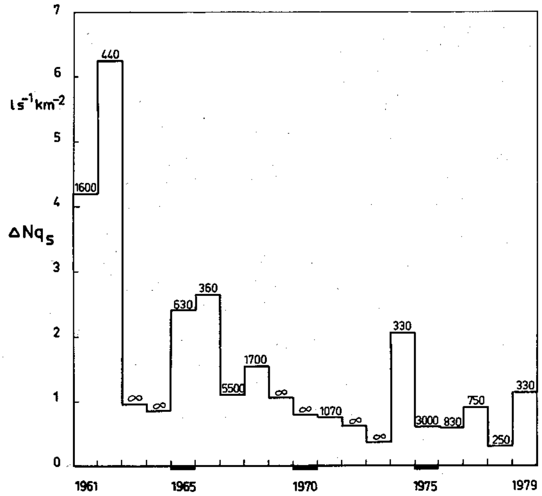

Fig. 17. Increase in the 30-day summer minimum runoff (Nq_s) caused by drainage. Figures above the columns indicate the increase in per cent.

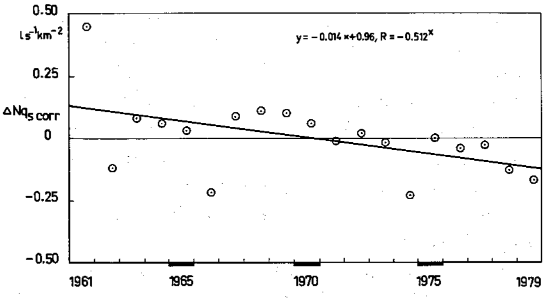

Fig. 18. Purified trend of the 30-day summer minimum runoff after drainage in the Huhtisuo basin. $y = \Delta Nq_{s\ corr}$ = change in runoff corrected for the magnitude of runoff, x = year — 1900.

LOPPUTIIVISTELMÄ

Tutkimuksessa on tarkasteltu metsäojituksen aiheuttamia hydrologisia muutoksia vertailualuemenetelmää käyttäen välittömästi ojituksen jälkeen ja pidemmän ajan kuluessa. Noin 5 km^2 suuruiset valuma-alueet pidettiin niin luonnontilaisina kuin mahdollista vuodesta 1936 vuoteen 1957. Tänä aikana alueet kalibroitiin toisiinsa, ts. laskettiin eri valumasuureille lineaarinen riippuvuus alueiden välillä. Ojitus suoritettiin toimenpidealueella, Huhtisuolla siten, että kevättalvella 1958 kaivettiin 130 cm syvät valtaojat ja kesällä 1960 varsinaiset metsäojat. Ojitettu suoalue on tällöin käsittänyt noin 40 % valuma-alueen alasta ja ojamäärä on ollut 225 m ojitettua hehtaaria kohden.

Kalibrointijakson regressioyhtälöitä käyttäen on laskettu, kuinka suuri toimenpidealueen valuma olisi ollut 1961—1979, ellei ojitusta olisi suoritettu sekä edelleen, paljonko valumat ovat muuttuneet. Valuman muutoksille on laskettu trendit kaudelle 1961—1979. Osalle valuntasuureista on laskettu suorat, korjaamattomat trendit, mutta yleensä on trendien korjaus eliminoimalla valuman muutoksista valuman suuruuden vaikutus ollut välttämätöntä. Syynä tähän on ollut muutoksen korreloiminen itse valuman kanssa sekä valuman absoluuttiarvojen epätasainen suuruusjakauma (trendi) kaudella 1961—1979 myös vertailualueella.

Ojituksen vaikutuksesta kaikki valumasuureet kasvoivat jyrkästi. Kasvu on ollut voimakkainta välittömästi ojituksen jälkeen, mikä on luonnollista suossa olleen vesivaraston tyhjentymisen vuoksi. Vuosivalunnan muutoksien laskennassa on vesivaraston tyhjentyminen vähennetty koko muutoksesta, jolloin haihdunnan pienenemisestä aiheutuneeksi vuosivalunnan kasvuksi on muodostunut 1961—1969 keskimäärin 65 mm a^{-1} eli 29 %. Tämä muutos on tilastollisesti merkitsevä alle 0.1 % riskillä. Jaksolla 1970—1979 on keskimääräinen lisäys ollut noin 15 mm a^{-1}. Ojituksen vaikutuksen pienenemistä osoittava Mq:n puhdistettu trendi (kuva 5) on ollut laskeva 3 mm a^{-1} ja tilastollisesti merkitsevä alle 1 % riskillä.

Kevätylivaluma kasvoi ojituksen vaikutuksesta kaudella 1961—1969 keskimäärin 42 l/km^2 eli 31 %. Lisäys oli tilastollisesti merkitsevä 1 % riskillä. Ojituksen jälkeisen kauden jälkipuoliskolla kevätylivaluman muutos oli keskimäärin —13 %. Vaikka korjaamaton trendi on ollut varsin selvästi laskeva, ei tilastollisesti merkitsevää korjattua trendiä ole esiintynyt (kuvat 7 ja 8). Tämä on johtunut siitä, että tulvahuiput ylimalkaan ovat olleet keskimääräistä pienempiä ojituksen jälkeisen kauden jälkipuoliskolla.

Kesäylivaluma kasvoi ojituksen vaikutuksesta keskimäärin 49 ls^{-1} km^{-2} eli 131 % kaudella 1961—1969. Lisäys oli tilastollisesti merkitsevä 0.1 % riskillä. Erityisesti suuret ylivalumat kasvoivat. Kaudella 1970—1979 ojituksen aiheuttama kesäylivaluman lisäys oli keskimäärin 19 %. Tilastollisesti merkitsevää korjattua trendiä ei ole esiintynyt, vaikka korjaamattomat valunnan muutokset viittaavatkin laskevaan trendiin.

Alivalumat kasvoivat hyvin voimakkaasti (riski < 0.1 %) sekä talvella että kesällä ojituksen vaikutuksesta (kuvat 14 ja 17). Ojituksen jälkeisellä kaudella valuman lisäyksillä on ollut tilastollisesti merkitsevä laskeva trendi (kuvat 15 ja 18).

Ylimalkaan valumasuureilla oli laskeva trendi, vaikka se ei ylivalumien osalta olekaan ollut kiistaton. Laskevan trendin selittävät taimiston kasvamisesta johtuva haihdunnan kasvu ja lumen sulamisolojen muuttuminen, ojien vedenjohtokyvyn heikkeneminen sekä suossa olleen vesivaraston tyhjentyminen. Viimeksimainittu on otettu huomioon vuosivalunnassa, mutta yli- ja alivalumien muutoksissa sen aiheuttamaa laskevaa trendiä on mukana.

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