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Effects of maintaining ditch networks on the development of Scots pine stands

Kunnostusojituksen vaikutus rämemänniköiden kehitykseen

Risto Lauhanen & Erkki Ahti

Risto Lauhanen. The Finnish Forest Research Institute, Kaironiementie 54, FIN-39700 Parkano, Finland. (email: risto.lauhanen@metla.fi)
Erkki Ahti, The Finnish Forest Research Institute, P.O.Box 18, FIN-01301 Vantaa, Finland

This study aimed at finding out the effects of maintaining ditch systems by ditch cleaning and complementary ditching on volume growth of drained Scots pine (Pinus sylvestris L.) stands. Volume growth during the first ten post-treatment years was increased by 0.16 m^3 ha^{-1} a^{-1} after ditch cleaning, 0.36 m^3 ha^{-1} a^{-1} after complementary ditching, and 0.48 m^3 ha^{-1} a^{-1} after the combined treatment. The average growth reactions during the second five-year period were considerably higher than during the first one. No drastic reductions in stand growth, however, occurred in the untreated plots during the post-treatment period of ten years.

Keywords: complementary ditching, ditch cleaning, forest drainage, peatland, Pinus sylvestris L., tree stand, volume growth.

INTRODUCTION

According to the 8th national forest inventory (1989–94), the area classified as drained peatland in Finland was about 4.7 million hectares. Additionally, 1.1 million hectares classified as paludified mineral forest sites had been drained for forestry (Tomppo 1999). The total annual growth was 17.7 million cubic metres on sites classified as peatland. The annual growth increment due to forest drainage of peatlands is presently estimated at 10.4 million m^3 (Tomppo 1999).

Forest ditches degenerate gradually, and with time vegetation and sediments disturb water movement in ditches more and more (Multamäki 1934, Lukkala 1949, Heikurainen 1957, 1980). Inventories estimating the need for ditch network maintenance have been carried out (e.g. Keltikangas et al. 1986, Lauhanen et al. 1998). According to the 8th national forest inventory, the annual need for ditch network maintenance is nowadays about 146 000 hectares (Tomppo 1999). During the recent years, about 70–80 000 hectares of ditch networks have been maintained annually (Sevola 1999).

Ditch cleaning and complementary ditching have been reported to lower the wet-period level of the water table by 4 cm and 6 cm, respectively (Ahti & Päivänen 1997). In northern Finland, complementary ditching increased the radial growth of individual Scots pines more clearly than ditch cleaning during the first 5–8 years after treatment. In southern Finland, ditch network maintenance had no clear effects on the radial growth of Scots pines (Ahti & Päivänen 1997). In a simulation based on the same experiments (Hökkä 1997), maintenance of ditch systems increased the growth of Scots pine stands by 0.3–1.8 m^3 ha^{-1} a^{-1} during a 15-year post-treatment period.

The aim of the study was to find out empirically the effect of ditch network maintenance on stand volume growth. In addition, the ditch condition after ditch network maintenance was investigated.

MATERIALS AND METHODS

Twelve field experiments including different treatments of ditch network maintenance were established in 1982–1985 (Päivänen & Ahti 1988, Ahti & Päivänen 1997; Fig. 1, Table 1). The sites were Scots pine stands of varying site quality which had been drained for forestry by using open ditches and with stand volumes between 9.0 and 97.3 m^3 ha^{-1} (Table 2). When selecting the study sites, thinning and fertilization were not allowed during the ten-year period preceding the experiment.

Ten of our twelve experiments included all treatments, i.e. ditch cleaning, complementary ditching, the combined treatment, and control plots representing the original (non-maintained) ditching. The trees along the ditch lines were felled and removed. There was no complementary ditching in the Parkano experiment, and no combined treatment at Haapajärvi. The entire series of experiments included 29 control plots, 39 ditch cleaning plots, 35 complementary ditching plots, and 38 plots with the combined treatment. The number of replicates by treatment varied within and between the experiments (Table 1).

Table 1. Some basic data on the experiments. nf = no fertilizations.

Taulukko 1. Kokeiden taustatiedot. nf = ei lannoituksia.

Experiment *Koe*	Temp. sum *Lämpösumma* (d.d. °C)	Original site type [1] *Alkuper. suotyyppi* [1]	Peat layer *Turvekerros* (m)	Ditch spacing *Sarkaleveys* (m)	Original ditching year *Uudisojitusvuosi*	Fertiliz. years *Lannoitusvuodet*	Initial growing stock [2] *Lähtöpuusto* [2] (m^3 ha^{-1})	Number of plots [3] *Koealojen määrä* [3] 0	a	b	ab
Leivonmäki	1178	VSR	0.2–>1.0	51	1955	1970	52	2	4	6	4
Joroinen	1173	IR	>1.5	63	1953	1971	54	1	1	2	2
Parkano	1132	TR	0.5–1.3	67	1954	nf	54	1	4	0	5
Viitasaari	1070	VSR	1.1–>1.5	48	1935	1966	58	1	2	1	2
Ähtäri	1069	IR	0.6–>1.5	46	1952–53	1963	31	1	3	3	3
Sonkajärvi	1044	PsR	0.7–>1.5	47	1958	1964	54	3	4	3	3
Haapajärvi	1044	PsR	0.5–0.7	43	1926	1974	61	2	1	1	0
Pyhäntä	1024	PsR	0.2–0.6	50	1958	1966, -79	39	4	4	4	4
Yli-Ii I	1002	IR	>1.5	35	1967	1968	19	3	3	4	4
Yli-Ii II	1002	LkR	>1.5	35	1967	1968	19	2	2	2	2
Kuhmo	982	TR	0.6–>1.0	45	1967	1969, -84	21	4	4	4	4
Puolanka I	951	TR	0.7–>1.5	44	1930	1965	21	2	2	1	2
Puolanka II	951	TR	0.8–>1.5	44	1930	1965	43	1	3	2	1
Taivalkoski	867	RhSR	>1.0	45	1966	1967	20	2	2	2	2

[1] Site types according to Laine and Vasander (1990). *Suotyypit Laineen ja Vasanderin (1990) mukaan.*
[2] Mean stand volume after opening of ditch lines before ditch network maintenance. *Puuston keskitilavuus ojalinjahakkuiden jälkeen ennen kunnostusojitusta.*
[3] Number of plots, explanations: 0 = control, a = ditch cleaning, b = complementary ditching, ab = combined treatment. *Koealojen lukumäärä; selitykset: 0 = kontrolli, a = ojanperkaus, b = täydennysojitus ja ab = yhdistelmäkäsittely.*

The stand characteristics were determined at the time of establishment and every fifth year after it. All trees were numbered. The breast height diameter of all trees was measured in each plot. Simultaneously, about thirty sample trees (every n^{th} tree, n depending on estimated stem number) in each plot were selected to represent the stem diameter distribution. From the sample trees, height, stem diameter at the height of six metres and height increment during the five last years were determined. Stand volume and volume growth per hectare were calculated using the KPL software of the Finnish Forest Research Institute (Heinonen 1994).

Depth, top width and bottom width of the ditches were measured ten years after the treatments. The ditch condition was estimated visually by using the five classes of Keltikangas et al. (1986), class 1 representing the best ditch condition and class 5 representing the poorest.

The statistical calculations were performed both individually for each experiment and for the entire material. For the experiments at Yli-Ii and Puolanka, which included considerable site variation, the calculations were performed by experimental blocks.

For the individual experiments and blocks, one-way analysis of variance (Ranta et al. 1989) was applied to test the effects of ditch network maintenance on volume growth, which was the main variable of interest in this study. The statistical significances of the differences in growth

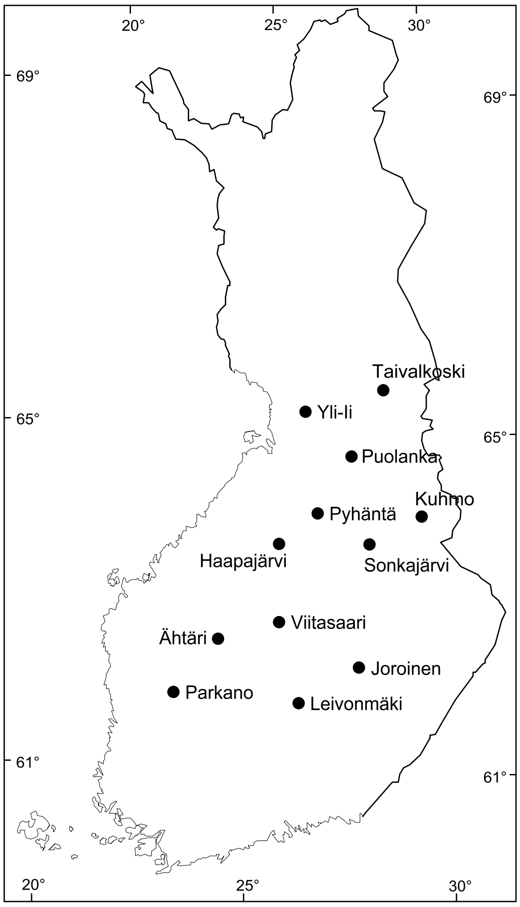

Fig. 1. Location of field experiments

Kuva 1. Kenttäkokeiden sijainti

Table 2. Characteristics of the experimental plots after opening of ditch lines. All experiments (141 plots) included.

Taulukko 2. Kokeiden yleistiedot ojalinjahakkuiden jälkeen. Mukana kaikki kokeet (141 koealaa).

Variable *Muuttuja*	Mean *Keskiarvo*	S.D. *Keskihajonta*	Range *Vaihteluväli*
Site variables – *Kasvupaikkamuuttujat*			
Peat thickness – *Turvekerroksen paksuus* (cm)	107	41	35–>150
Temperature sum – *Lämpösumma* (dd °C)	1039	82	867–1178
Elevation a.s.l. – *Korkeus m.p.y.* (m)	149	37	90–220
Ditch spacing – *Sarkaleveys* (m)	47	9	35–67
Stand variables – *Puustotunnukset*			
Mean $d_{1.3}$ – *Keskimääräinen* $d_{1.3}$ (m)	8.9	2.0	5.8–14.3
Mean height – *Keskipituus* (m)	6.9	1.6	4.2–10.7
Stem number – *Runkoluku* (stems ha^{-1})	1199	385	401–2449
Stand basal area – *Pohjapinta-ala* (m^2 ha^{-1})	8.3	3.3	2.9–16.8
Initial stand volume – *Lähtötilavuus* (m^3 ha^{-1})	38.8	20.6	9.0–97.3

and ditch depth between the plots including ditch network maintenance and the control plots were estimated with Tukey's test.

The effects of ditch network maintenance on volume growth were analyzed by using a model, in which the effects of the variation in initial volume (covariate) was taken into consideration by using separate slopes of regression for each experiment:

$$y_{ij} = c + t_i + b_j + \beta_j x_{ij} + \varepsilon_{ij} \qquad (1)$$

where y_{ij} = mean volume growth, alternatively for the years 1–5, 6–10 and 1–10 after treatment, c = overall intercept, t_i = the effect of treatment (control, ditch cleaning, complementary ditching, combined treatment), b_j = the effect of experiment (Yli-Ii and Puolanka given by the blocks), $\beta_j x_{ij}$ = the effect of initial volume (x_{ij}, covariate) within the individual experiments, and ε_{ij} = an error term.

The computations were carried out by SAS and BMDP-90 software packages (SAS … 1985, BMDP… 1990).

RESULTS

Ditch characteristics after ditch network maintenance

The cleaned ditches and the complementary ditches were still considerably deeper ($p<0.01$) than the original ditches ten years after ditch network maintenance (Table 3). In most sites, the depth of the 10-year old ditches appeared to be sufficient for satisfactory drainage. The cleaned ditches were somewhat deeper and wider than the complementary ditches, but the differences were nonsignificant.

Table 3. Ditch characteristics (means ± standard deviations, cm) ten years after drainage maintenance by experiment and treatment. 0 = control, a = ditch cleaning, b = complementary ditching.

Taulukko 3. Ojien ominaisuuksia (keskiarvot ± -hajonnat, cm) kokeittain ja käsittelyittäin kymmenen vuoden kuluttua kunnostusojituksesta. 0 = kontrolli, a = ojanperkaus, b = täydennysojitus.

Experiment *Koe*	Treatment *Käsittely*	Ditch depth *Syvyys*	Top width *Pintaleveys*	Bottom width *Pohjaleveys*	Ditch cond. class *Kuntoluokka*
Viitasaari	0	32 ± 3	87 ± 21	53 ± 32	5.0 ± 0.0
	a	50 ± 5	123 ± 11	67 ± 19	3.2 ± 0.4
	b	47 ± 6	117 ± 15	55 ± 13	3.0 ± 0.0
Joroinen	0	39 ± 5	57 ± 15	37 ± 12	4.0 ± 0.0
	a	71 ± 10	112 ± 16	77 ± 19	2.8 ± 0.8
	b	60 ± 7	117 ± 13	59 ± 17	3.0 ± 0.8
Kuhmo	0	46 ± 7	86 ± 12	37 ± 8	4.8 ± 0.3
	a	104 ± 11	101 ± 12	42 ± 14	2.0 ± 0.0
	b	94 ± 11	88 ± 11	41 ± 16	2.0 ± 0.0
Sonkajärvi	0	38 ± 6	70 ± 12	27 ± 4	5.0 ± 0.0
	a	76 ± 10	96 ± 7	36 ± 7	2.2 ± 0.4
	b	77 ± 6	96 ± 8	31 ± 4	2.0 ± 0.0
Pyhäntä	0	43 ± 10	81 ± 19	44 ± 22	4.4 ± 0.8
	a	72 ± 10	122 ± 11	70 ± 19	2.0 ± 0.5
	b	68 ± 6	110 ± 15	63 ± 20	2.1 ± 0.4
Yli-Ii	0	47 ± 16	98 ± 16	39 ± 9	4.6 ± 1.0
	a	84 ± 10	138 ± 17	59 ± 15	2.0 ± 0.0
	b	81 ± 5	133 ± 9	44 ± 12	2.0 ± 0.0
Taivalkoski	0	43 ± 17	87 ± 21	35 ± 13	3.7 ± 0.9
	a	92 ± 6	144 ± 6	60 ± 17	1.1 ± 0.3
	b	85 ± 11	145 ± 9	63 ± 18	1.3 ± 0.5

Effects of ditch network maintenance on stand volume growth

On the basis of the linear model of equation (1), ditch cleaning increased volume growth during the first ten post-treatment years by 0.16 m^3 ha^{-1} a^{-1}, while the corresponding increase caused by complementary ditching was 0.36 m^3 ha^{-1} a^{-1}, and that of the combined treatment 0.48 m^3 ha^{-1} a^{-1}. Significant increases in volume growth were observed especially during the second five-year period. During the first five years, the treatment effects were small (Tables 4 and 5).

In addition to using initial stand volume as covariate, the effect of the pre-treatment variation in stand volume was partly eliminated by subtracting the yield of the first 5-year period from the second one, and then by using these differences when comparing the treatments with the control. In this way, the reaction of the tree stand to the treatments became less sensitive to variation in volume within the experiments, and the positive effects of ditch network maintenance were more clearly revealed in all experiments except Leivonmäki (Appendix 1). In the entire material, the difference between the 5-year periods was statistically significant for ditch cleaning ($p<0.05$) complementary ditching ($p<0.01$) and the combined treatment ($p<0.001$). At Sonkajärvi the positive effects of ditch network maintenance became evident when comparing the yields of the two 5-year periods with each other, even if the treated plots showed lower growth rates than the controls. Irrespective of initial stand volume, the positive growth reaction of the tree stand could be seen during the second 5-year period (Appendix 1).

DISCUSSION

The study aimed at finding out empirically, how ditch network maintenance influences stand volume increment in drained Scots pine mires. No dramatic reductions in the growth of the control plots were observed during the 10-year study period. Significant increases in growth were observed during the second five-year period after drainage maintenance.

According to the simulations of Hökkä (1997) for a 15-year period, ditch network maintenance increased stand growth by 0.5–1.8 m^3 ha^{-1} a^{-1} in the southern Finland and by 0.3–1.3 m^3 $ha^{-1}a^{-1}$ in northern Finland. In our study, the mean increase in annual growth was somewhat smaller. The difference may partly be explained by the delayed reaction of the stands which plays a more important role during a shorter time period, and the fact that Hökkä (1997) did not compare the growth of the treated plots with that of the control plots, but used a specific basic growth rate for 15 years without treatment effects as the point of comparison. Further, the simulations were made for a better site than the average in this study.

Table 4. Anova tables for the linear model ($y_{ij} = c + t_i + b_j + ß_j x_{ij} + \varepsilon_{ij}$; eq. 1) describing the effects of ditch network maintenance on annual stand growth, alternatively for the years 1–10, 1–5 and 6–10 after treatment. t_i = the effect of treatment, b_j = the effect of experiment and $ß_j x_{ij}$ = the effect of initial volume (x_{ij}, covariate) within the individual experiments.

Table 4. Kunnostusojituksen kasvuvaikutuksia kuvaavan lineaarisen mallin (yhtälö 1) varianssianalyysitaulukko jaksoille 1–10, 1–5 ja 6–10 vuotta käsittelyn jälkeen. t_i = käsittelyn vaikutus, b_j = kokeen vaikutus ja $ß_j x_{ij}$ = alkupuuston tilavuuden vaikutus (kovariaatti).

	1–10 years			1–5 years			6–10 years		
Source – *vaiht. lähde*	b_j	t_i	$ß_j x_{ij}$	b_j	t_i	$ß_j x_{ij}$	b_j	t_i	$ß_j x_i$
df – *vapausasteet*	13	3	14	13	3	14	13	3	14
SS – n*eliösumma*	17.4	4.02	26.7	10.4	0.22	27.6	26.4	14.9	27.9
MS – k*eskineliö*	1.34	1.34	1.91	0.802	0.074	1.97	2.03	4.96	1.99
F value – *F-arvo*	10.5	10.5	14.9	6.70	0.62	16.5	9.76	23.8	9.58
p value – *p-arvo*	<0.001	<0.001	<0.001	<0.001	0.606	<0.001	<0.001	<0.001	<0.001

Hytönen and Aarnio (1998) simulated the future growth of part of our pine stands after ditch network maintenance by using Hökkä's (1997) prediction model, and also obtained higher predicted volume increments for the post-treatment period of 20 years than is indicated by our empirical data for the first 10 post-treatment years. As in the case of Hökkä's (1997) simulatons, the difference may partly be explained by the delayed reaction of the stands which plays a more important role during a shorter time period. The difference is most conspicious in the well-stocked stands of southern Finland, and might also be due to the fact that Hökkä's (1997) model does not take into account the biological drainage of the stands or their actual hydrological situation and therefore overestimates the hydrological need for ditch network maintenance.

The lack of statistically significant growth reactions in some stands especially in southern Finland was most probably due to the fact that no acute need for ditch network maintenance existed even if the technical condition of the ditches was poor. With the development of the stands, the decreasing drainage of the deteriorating ditch system might have been compensated by increased water uptake and transpiration by the stand itself. In such a situation, the level of the ground water table will remain deep enough as long as tree growth and the evapotranspiration from the stand remain high enough, and the shallow ditches will still be deep enough to collect the surface runoff. As a whole, the hydrological balance will be much more based on the evapotranspiration and the interception of the stand than earlier, i.e. the stability of the hydrological balance will become dependent on the stability of stand development.

Table 5. Increase in mean volume growth (m^3 ha^{-1} a^{-1}) after ditch network maintenance on the basis of the linear model of eq. 1 and Table 4, alternatively for the years 1–10, 1–5 and 6–10 after treatment. Significance of change: * p<0.05, ** p<0.01, *** p<0.001.

*Taulukko 5. Kunnostusojituksen vaikutus puuston keskimääräiseen tilavuuskasvuun (m^3 ha^{-1} a^{-1}) yhtälössä 1 ja taulukossa 4 esitetyn lineaarisen mallin perusteella jaksoille 1–10, 1–5 ja 6–10 vuotta käsittelyn jälkeen. Kasvumuutoksen merkitsevyys: * p<0,05, ** p<0,01, *** p<0,001.*

Treatment *Käsittely*	1–10 years	1–5 years	6–10 years
Ditch cleaning *Ojanperkaus*	0.16	–0.03	0.39**
Complem.ditching *Täydennysojitus*	0.36***	0.07	0.70***
Combined treatment *Yhdistelmäkäsittely*	0.48***	0.06	0.96***

Ditch network maintenance is usually performed in connection with thinning, which would temporarily reduce the interception and the uptake of water by the stand (Heikurainen & Päivänen 1970) and accordingly emphasize the hydrological role of the ditch system. Our stands were not thinned in connection with or ten years prior to maintaining the ditch systems, and consequently the present study probably underestimates the growth reactions of peatland pine stands to ditch network maintenance in practical forestry.

The aim of ditch cleaning and complementary ditching should be to preserve stand growth at the potential level of a site rather than to increase it. The rather limited growth reactions of the pine stands indicate that the hydrological need for ditch network maintenance is less urgent than expected. Even if maintenance of the ditch systems is necessary, delays in performing it will probably not cause drastic growth reductions or irreversible changes in the development of the stands.

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TIIVISTELMÄ:

Kunnostusojituksen vaikutus rämemänniköiden kehitykseen

Tutkimuksen tavoitteena oli selvittää kunnostusojituksen vaikutusta puuston kasvuun ojitetuissa rämemänniköissä. Tutkimuksen 12 kenttäkoetta perustettiin vuosina 1982–1985 (Päivänen & Ahti 1988, Ahti & Päivänen 1997). Eteläisin koe sijaitsi Leivonmäellä (N 61°45') ja pohjoisin Taivalkoskella (N 65°45') (Taulukko 1, Kuva 1, Taulukko 2). Kuhmon koetta lukuunottamatta, joka oli lannoitettu 1984, kokeilla ei ollut tehty hakkuita tai lannoituksia kymmeneen vuoteen. Kenttäkokeiden koejäseniä olivat kunnostusojittamaton vertailukäsittely, ojan perkaus, täydennysojitus sekä perkauksen ja täydennysojituksen yhdistelmä.

Kokeiden puustot mitattiin kunnostusojitusvuonna sekä viisi ja kymmenen vuotta sen jälkeen. Puustotunnukset laskettiin Metsäntutkimuslaitoksen KPL-ohjelmistolla (Heinonen 1994). Viisivuotisjaksojen kasvuiksi määriteltiin peräkkäisissä mittauksissa saatujen tilavuuksien erotus. Ojien mitta- ja kuntotiedot kymmenen vuotta käsittelyjen jälkeen olivat käytettävissä seitsemältä kokeelta.

Seitsemästä kokeesta kuuden ojat olivat mi-

toiltaan hyvässä tai tyydyttävässä kunnossa kymmenen vuotta kunnostusojituksen jälkeen (Taulukko 3). Perkausojien ja täydennysojien keskisyvyydet eivät poikenneet tilastollisesti merkitsevästi toisistaan.

Kaikki koejäsenet sisältäneillä kokeilla ojien perkaus tuotti keskimäärin 0,16:n m^3 ha^{-1} a^{-1}:n kasvunlisän kymmenen vuoden mittausjaksolla (Taulukko 5). Vastaavasti täydennysojitus tuotti 0,36 :n ja yhdistelmäkäsittely 0,48:n m^3 ha^{-1} a^{-1}:n kasvunlisän. Toisella 5-vuotisjaksolla vastaavat luvut olivat 0,39, 0,70 ja 0,96 m^3 ha^{-1} a^{-1}.

Kun kunnostusojituksen jälkeisten kahden viisivuotisjakson tuotoksia verrattiin keskenään, kunnostusojituksen kasvua lisäävä vaikutus näkyi selvemmin kuin vertaamalla käsittelykohtaisia kasvuja. Leivonmäen koetta lukuunottamatta vertailuruutujen kasvusuunta oli kunnostusojitettuihin ruutuihin verrattuna aleneva (Liite 1).

Eräiden kokeiden vaatimattomat kasvureaktiot etenkin Etelä-Suomessa johtuvat todennäköisesti siitä, että niillä ei ollut välitöntä kunnostusojituksen tarvetta, vaikka ojien tekninen kunto oli heikko. Näyttää siltä, että puuston kehityksen myötä sen lisääntyvä vedenotto ja transpiraatio kompensoivat huomattavasti ojaston vedenjohtamiskyvyn heikkenemistä, eikä pohjavesipinta nouse haitallisen korkealle ennenkuin puuston kasvu ja vedenotto heikkenevät ulkopuolisista syistä. Matalatkin ojat riittävät märkien jaksojen pintavesien kuljettamiseen, joiden merkitys ojitusalueiden hydrologiassa on merkittävä, mutta suometsän vesitase kokonaisuutena on tällaisessa tilanteessa paljon enemmän puuston haihdunnan ja latvuspidännän varassa kuin aikaisemmin, ja vesitaseen vakaus näyttäisi riippuvan aikaisempaa enemmän siitä, miten vakaana puuston kasvu ja vedenotto jatkuvat.

Käytännön metsätaloudessa kunnostusojitukset tehdään yleensä hakkuiden yhteydessä. Harvennushakkuutkin vähentävät oleellisesti puuston vedenottoa ja latvuspidäntää (Heikurainen & Päivänen 1970), jolloin ojaston ja valunnan merkitys ojitusalueen vesitaseessa korostuvat. Koska tämän tutkimuksen kokeissa ei tehty hakkuita kunnostusojituksen yhteydessä, tutkimuksen tulokset todennäköisesti hieman aliarvioivat kunnostusojituksen vaikutusta suopuustojen tuotokseen.

Kunnostusojituksella ei niinkään pyritä ojitusalueen puuston kasvun lisäämiseen, vaan pikemminkin säilyttämään kasvu kasvupaikan ravinteisuustason edellyttämällä tasolla. Tässä tutkimuksessa havaitut kunnostusojituksella saadut kasvunlisäykset viittavat siihen, että kunnostusojituksen tarve on pienempi kuin aiemmin on arveltu. Vaikka kunnostusojitus on suopuustojen suotuisan kehityksen kannalta tärkeä toimenpide, sen viivästyminen ei näytä aiheuttavan äkillistä kasvun taantumista.

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Appendix 1. Effects of ditch network maintenance on the increase in volume growth in Scots pine stands by experiment. Legend: n = number of plots, dV_0 = timber removal when opening ditch lines ($m^3\ ha^{-1}$), V_0 = initial stand volume after opening of ditch lines ($m^3\ ha^{-1}$), V_{10} = stand volume ten years after drainage maintenance ($m^3\ ha^{-1}$), I_{total} = mean annual growth, including natural removal, during the whole 10-year period ($m^3\ ha^{-1}\ a^{-1}$), I_{net} = mean annual net growth during the whole 10-year period ($m^3\ ha^{-1}\ a^{-1}$), I_{1-5} = net yield during years 1–5 ($m^3\ ha^{-1}$), I_{6-10} = net yield during years 6–10 ($m^3\ ha^{-1}$), $I_{6-10} - I_{1-5}$ = difference between net yields of years 6–10 and years 1–5 ($m^3\ ha^{-1}$), — = data not available. Significant differences between control and ditch network maintenance according to Tukey's test, * = $p<0.05$, **= $p<0.01$, ***= $p<0.001$.

Liite 1. Kunnostusojituksen vaikutus puuston tilavuuskasvuun kokeittain. Selitykset: n = havaintojen lukumäärä, dV_0 = *ojalinjahakkuussa poistettu puusto* ($m^3\ ha^{-1}$), V_0 = *puuston tilavuus ojalinjahakkuun jälkeen* ($m^3\ ha^{-1}$), V_{10} = *puuston tilavuus kymmenen vuoden kuluttua kunnostusojituksesta* ($m^3\ ha^{-1}$), I_{total} = *puuston kymmenen vuoden keskikasvu luonnonpoistuma mukaan lukien* ($m^3\ ha^{-1} a^{-1}$), I_{net} = *puuston kymmenen vuoden keskimääräinen nettokasvu* ($m^3\ ha^{-1} a^{-1}$), I_{1-5} = *puuston nettotuotos vuosina 1–5* ($m^3\ ha^{-1}$), I_{6-10} = *puuston nettotuotos vuosina 6–10* ($m^3\ ha^{-1}$), I_{6-10}–I_{1-5} = *puuston nettotuotosten erotus vuosien 6–10 sekä 1–5 välillä, — = puuttuva tieto. Merkitsevyydet kunnostusojittamattoman vertailun ja käsittelyjen välillä Tukey'n testin mukaan * = p<0,05, **= p<0,01, ***= p<0,001.*

Experiment *Koe*	Treatment *Käsittely*	n	dV_0	V_0	V_{10}	I_{total}	I_{net}	I_{1-5}	I_{6-10}	$I_{6-10} - I_{1-5}$
Leivonmäki	0	2	0.0	44	85	4.3	4.1	17.3	23.2	+5.9
	a	4	0.2	56	95	4.5	3.9	15.8	23.3	+7.5
	b	6	4.3	48	90	4.6	4.2	18.9	23.2	+4.3
	ab	4	5.2	60	104	5.0	4.4	18.5	25.9	+7.4
Joroinen	0	1	0.0	67	138	7.2	7.1	38.5	32.6	–5.9
	a	1	4.5	63	140	7.8	7.7	38.3	38.8	+0.5
	b	2	2.8	50	120	7.1	7.0	34.4	35.2	+0.8
	ab	2	4.4	48	119	7.2	7.1	34.8	36.5	+1.7
Parkano	0	1	0.0	56	84	3.6	2.8	17.9	10.8	–7.1
	a	4	0.4	60	89	3.3	2.9	15.8	13.3	–2.5
	b	0	—	—	—	—	—	—	—	—
	ab	5	3.5	59	94	3.8	3.5	16.6	18.1	+1.5
Viitasaari	0	1	0.0	85	143	6.2	5.8	25.4	32.6	+7.2
	a	2	0.1	60	113	5.5	5.3	23.4	30.0	+6.6
	b	1	7.8	97	152	5.9	5.5	20.3	34.2	+13.9
	ab	2	5.8	66	129	6.5	6.3	24.3	38.2	+13.9
Ähtäri	0	1	0.0	18	29	1.1	1.1	4.7	5.8	+1.1
	a	3	0.1	41	57	1.9	1.6	6.3	10.1	+3.8
	b	3	1.8	28	42	1.6	1.4	5.3	9.3	+4.0
	ab	3	4.0	29	45	1.8	1.6	5.6	10.4	+4.8
Sonkajärvi	0	3	0.0	66	106	4.5	4.0	23.3	17.1	–6.2
	a	4	2.9	51	90	4.1	3.9	21.0	18.0	–3.0
	b	3	5.4	49	87	4.0	3.8	18.4	19.2	+0.8**
	ab	3	6.6	51	86	3.9	3.5	17.0	17.9	+0.9**
Haapajärvi	0	2	0.0	58	85	2.8	2.8	11.0	16.7	+5.7
	a	1	1.2	63	97	3.4	3.4	11.4	22.3	+10.9
	b	1	3.1	73	113	3.9	3.9	13.2	26.2	+13.0
	ab	0	—	—	—	—	—	—	—	—

Continued ...

Appendix 1. continues.... *Liite 1 jatkuu.*

Experiment *Koe*	Treatment *Käsittely*	n	dV_0	V_0	V_{10}	I_{total}	I_{net}	I_{1-5}	I_{6-10}	$I_{6-10} - I_{1-5}$
Pyhäntä	0	4	0.0	42	64	2.3	2.3	11.9	11.0	–0.9
	a	4	0.5	44	68	2.4	2.4	11.2	12.6	+1.5
	b	4	3.1	37	61	2.5	2.4	12.0	12.4	+0.4
	ab	4	4.8	40	65	2.4	2.4	10.3	13.9	+3.6**
Yli-Ii	0	5	0.0	18	30	1.0	1.0	6.9	4.6	–2.3
	a	5	0.6	21	37	1.5	1.5	8.9	7.4	–1.5
	b	6	2.7	17	32	1.4	1.3	7.3	7.5	+0.2
	ab	6	4.5	19	36	1.6	1.5	7.6	9.3	+1.7**
Yli-Ii I	0	3	0.0	20	29	0.9	0.9	6.1	3.3	–2.8
	a	3	0.6	20	33	1.2	1.2	7.3	5.6	–1.7
	b	4	2.8	16	27	1.0	1.0	5.9	5.0	–0.9
	ab	4	5.6	20	33	1.2	1.2	6.4	7.0*	+0.7*
Yli-Ii II	0	2	0.0	17	31	1.3	1.3	7.8	6.3	–1.5
	a	2	0.5	22	44	2.0	1.9	11.2	10.3*	–0.9
	b	2	2.5	18	40	2.1	2.0	10.0	12.4**	+2.4
	ab	2	2.4	18	42	2.2	2.2*	10.1	13.9**	+3.8*
Kuhmo	0	4	0.0	22	45	2.3	2.3	14.5	8.6	–5.9
	a	4	0.8	23	51	2.8	2.8	15.6	12.3	–3.3
	b	4	3.0	19	49	3.0	3.0	15.9	13.6	–2.3
	ab	4	3.2	22	54	3.3	3.2	16.8	15.6*	–1.2*
Puolanka	0	3	0.0	23	41	1.8	1.8	9.5	8.4	–1.1
	a	5	0.5	40	67	2.7	2.7	12.5	14.1	+1.6
	b	3	1.2	27	49	2.2	2.2	9.8	12.2	+2.4
	ab	3	2.2	31	59	2.9*	2.8*	12.3	15.9*	+3.6*
Puolanka I	0	2	0.0	19	36	1.7	1.7	9.2	7.6	–1.6
	a	2	0.2	19	42	2.3	2.3	11.1	11.6	+0.5
	b	1	1.3	18	40	2.2	2.2	10.6	11.1	+0.5
	ab	2	2.1	25	56	3.1	3.1	13.4	17.4	+4.0
Puolanka II	0	1	0.0	32	53	2.0	2.0	10.3	10.1	–0.2
	a	3	0.7	54	83	2.9	2.9	13.3	15.6	+2.3
	b	2	1.2	31	53	2.2	2.2	9.4	12.7	+3.3
	ab	1	2.5	43	66	2.4	2.3	10.2	12.9	+2.7
Taivalkoski	0	2	0.0	22	41	2.0	1.9	9.8	9.2	–0.6
	a	2	0.2	17	35	1.7	1.7	8.2	9.2	+1.0*
	b	2	1.9	22	44	2.2	2.2	10.5	11.6	+1.1*
	ab	2	1.1	19	39	2.0	2.0	8.6	11.7	+3.1**
Mean for all complete experiments	0	26	0.0	35	61	2.6	2.6	13.9	12.0	–1.9
Kaikki käsittelyt	a	34	0.9	40	69	3.0	2.9	14.2	15.3	+1.1*
sisältävien	b	34	3.2	34	64	3.0	3.0	14.1	15.8	+1.7**
kokeiden ka.	ab	33	4.0	36	68	3.2	3.2	14.2	17.7*	+3.5***