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# The effect of thinning and ditch network maintenance on the water table level in a Scots pine stand on peat soil

Juhani Päivänen and Sakari Sarkkola

*Juhani Päivänen & Sakari Sarkkola, Department of Forest Ecology, Box 24, FIN-00014 Helsinki University, Finland*
*(e-mail: juhani.paivanen@helsinki.fi, sakari.sarkkola@helsinki.fi)*

The effect of tree stand thinning and ditch network maintenance on the water table level was studied in an uneven-aged Scots pine (*Pinus sylvestris* L.) stand growing on a drained dwarf shrub pine bog in southern Finland. The water table level was monitored once a week during the growing seasons (May–September) of 1991–1999. This time span is divided into the following treatment periods: calibration (1991–1992), thinning (1993–1994), ditch cleaning (1995), and proper ditch network maintenance (1996–1999). The growing season of 1995 was not included in the calculations because the ditch cleaning treatment failed. The layout included three thinning intensities (9.5, 15.0, and 28.1% removal of the initial stand volume) and an unthinned control. For the ditch maintenance treatment there was an additional control sample plot. The effect of the treatments on the water table level was evaluated both by a graphical approach and linear regression analysis. Only a slight, ecologically insignificant rise in the water table level was caused by the thinning cuttings. Ditch maintenance seemed to eliminate this change. It was concluded that in the planning stage, a careful evaluation of the real need of maintaining the ditch network (ditch cleaning or complementary ditching) should be done in connection with the first commercial thinning in order to avoid unnecessary costs.

Keywords: Ditch cleaning, complementary ditching, forest drainage, hydrology, peatland, tree harvesting

## INTRODUCTION

About 5.4 million ha of peatlands — more than half of the total peatland area — have been drained for forestry in Finland. Most of the ditching has been performed during the last 40 years. However, the era of ditching for forestry has come to an end and emphasis is now shifting to activities aimed at maintaining the productivity of the sites. The large proportion of seedling and sapling stands as well as stands in the young thinning stage on drained peatlands means that extensive first commercial thinnings have to be performed in the near future (Paavilainen & Päivänen 1995). On the operational scale, thinnings are usually followed by ditch network maintenance. However, the real necessity of ditch cleaning may depend on the condition of the ditches and the intensity of thinning.

In southern Finland most of the studies dealing with the effect of cutting on the water table level in peat soil have been conducted in well-

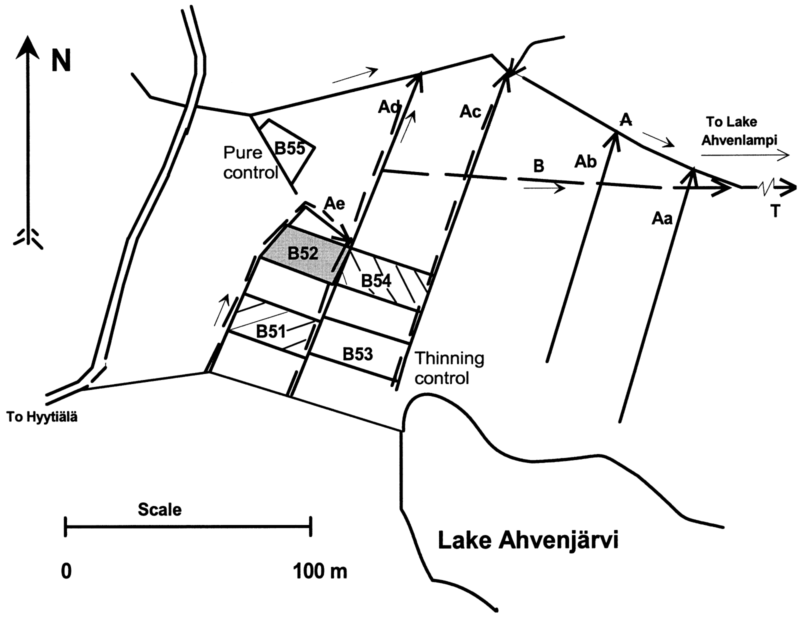


Fig. 1. The experimental design in Ahvenräme. A and B are main ditches and Aa–Ae are counter ditches. T indicates the location of the rocky threshold. Solid lines with short dashed lines are the ditches cleaned in September 1994. The long dashed line is complementary ditch B dug in June 1996.

stocked stands of Norway spruce (*Picea abies* (L.) Karst)) or Scots pine (*Pinus sylvestris* L.). A rise in the water table level has been demonstrated after a heavy thinning or clearcutting (Heikurainen & Päivänen 1970, Päivänen 1974, 1982). The water table response to cutting has usually been proportional to the volume removed. In northern Finland, the rise in the water table after a thinning cutting has been shown to be small (Hökkä & Penttilä 1995. In a comprehensive study performed in several locations in southern and central Finland, ditch cleaning and complementary ditching lowered the water table level by 4 and 6 cm, respectively, and simultaneous ditch cleaning and complementary ditching by 10 cm (Ahti & Päivänen 1997).

In these studies, however, treatments including both cutting and ditch network maintenance were not included.

The aim of this study was to assess, firstly, the effect of thinning cutting of different intensities, and secondly, the effect of ditch network maintenance on the water table level in a Scots pine stand growing on deep peat soil drained for forestry. The study site represents the developmental stage of a tree stand where the first commercial thinning is usually recommended for improving the stand structure.

## MATERIAL AND METHODS

### Study area and measurements

The study was carried out in southern Finland (61°51´N; 24°16´E). The altitude of the area is about 170 metres a.s.l. The annual mean temperature in the region is + 3°C. The annual rainfall is about 600 mm and in the summer months (June–September), about 320 mm.

A set-up of permanent sample plots was established in an uneven-aged Scots pine (*Pinus sylvestris* L.) stand growing on an ombrotrophic pine bog (Ahvenräme) (Fig. 1). The site had been drained about 30 years earlier and represented the dwarf-shrub type according to the classification system developed for drained peatland forest sites (Laine 1989). Four sample plots (B51–B54) were marked from ditch to ditch and measured for tree stand characteristics in 1989, 1993 (immediately after the thinning cuttings) and 1998 (six years after the thinning cuttings). The average volume of the stand before the thinning cuttings was about 95 m$^3$ per ha, and thinning intensities varied from 9.5 to 28% of stand volume. An additional reference sample plot (so called pure control, sample plot B55) was established near the above-mentioned sample plots (see Fig.1) to provide comparison with a situation where no thinning and no ditch network maintenance was done during the whole study period. This sample plot was measured for tree stand characteristics only once (in 1998). For the stand characteristics at the time of the thinning cuttings, see Table 1.

Each sample plot was supplied with six groundwater wells, which were generally monitored once a week during the snow and frost free periods during 1991–1999. The vertical distance to the water table level (WTL) was measured with an accuracy of 1 mm from a benchmark following the slight swelling-shrinkage movement of the peat soil surface.

### Treatments

The growing seasons 1991 and 1992 formed the calibration period (without treatments).

The thinning treatments were randomized for sample plots B51–54, sample plot B53 being a control for thinning, and B55 both for thinning and for ditch network maintenance. The experiment did not include replicates for the treatments. It was assumed that the possible thinning effects on the water table level would turn out in the order of thinning intensities. Tree harvesting was done carefully by using manual work for cutting and a light forwarder for hauling the trees to the roadside during winter 1992–1993. The strip roads were laid outside the sample plots. The ditches were not damaged much by the harvesting operation.

Ditch cleaning was done by a ditch digger equipped with a hydraulic power transmission, wide track structure and ditch-digging scoop in September 1994. The aim was to clean the counter ditches (Fig. 1, ditches Ac, Ad, and Ae) to a depth of 90 cm, which is usual when working at an operational scale. Because the gradient was too small and the bad condition of the main ditch resulted in partially defective drainage, the ditch cleaning operation had to be further accomplished by digging a new main ditch (Fig. 1, complementary ditch B) and lowering the runoff threshold in June 1996. This was done to make sure that the counter ditches could be emptied.

### Weather conditions during the growing seasons

The gathered material covered the snow and frost free periods. The water table level is usually close to the soil surface in the spring after the snowmelt. Spring and early summer are often the most arid periods of the year in southern Finland. The water table level gradually drops because of the drainage effect of the ditch network and the evapo-

Table 1. Some pre-treatment and post-treatment stand characteristics at the date of thinning cuttings (spring 1993). B51, B52, B53, B54, B55 = sample plots.

| | Thinning intensity | | | | |
|---|---|---|---|---|---|
| | Control B53 | Light B54 | Regular B51 | Heavy B52 | Pure control B55 |
| Pre-treatment | | | | | |
| Volume $m^3$ $ha^{-1}$ | 94 | 100.7 | 87.5 | 88.3 | – |
| Removal % | 0 | 9.5 | 15 | 28.1 | – |
| Stems $ha^{-1}$ | 1378 | 1410 | 1490 | 1080 | – |
| Removal % | 0 | 14.3 | 41 | 50.5 | – |
| Post-treatment | | | | | |
| Volume $m^3$ $ha^{-1}$ | 94 | 91.1 | 74.5 | 68.9 | 95.5 |
| Stems $ha^{-1}$ | 1378 | 1033 | 760 | 535 | 772 |
| D 1.3 cm | 13.9 | 14.3 | 15.3 | 18.1 | 17 |
| Average stem size, litres | 68 | 89 | 98 | 128 | 123 |
| Average volume growth, $m^3$ $ha^{-1}$ $a^{-1}$ (last 5 yr.) | 4.3 | 4.9 | 4 | 3.9 | 4.7 |

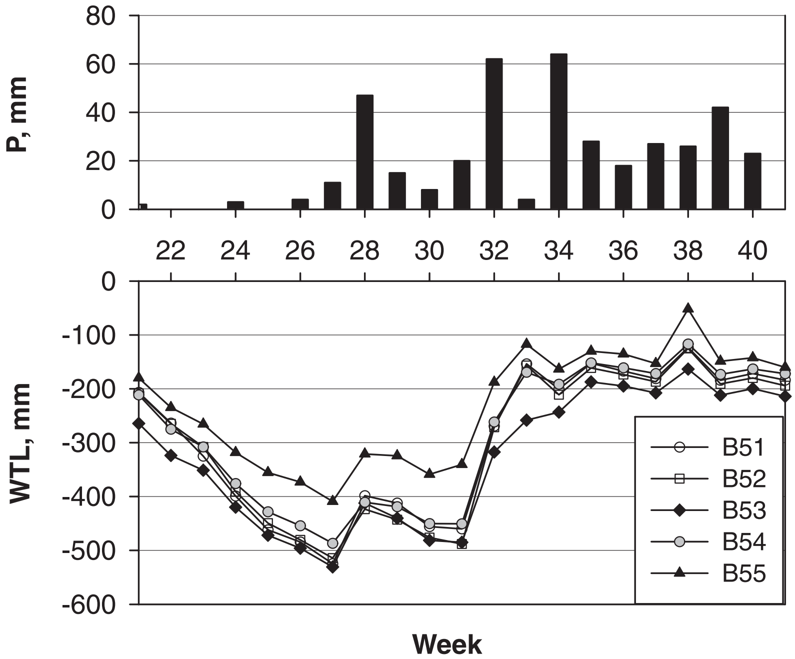


Fig. 2. Precipitation (P) and water table level (WTL) in the sample plots (B51–B55) of Ahvenräme during the calibration period from late May through early October 1992. The bars are the weekly sums of precipitation and the lines indicate the average water table level in the plots.

transpiration of the tree stand. The minimum is usually reached around the middle of July and maximum in the fall, in October–November before the soil freezes (see Fig. 2). However, the irregular pattern of summer precipitation may cause big annual variations in this trend.

Daily precipitation data was received from the Hyytiälä Forestry Station, University of Helsinki, situated 1 km east of the study area (Table 2).

The amount of precipitation during the summer months (June–September) varied from 204 to 431 mm, the long-term average being 320 mm in the area in question (Table 2). The summers during the period representing the effect of thinning (1993–1994) were drier than in the calibration period (1991–1992). The last period representing the four growing seasons after ditch network maintenance had especially large variation in precipitation.

## Study approach

The effects of thinning and ditch cleaning on the water table level were studied by applying the calibration period–control plot–system. The ad-

Table 2. Monthly precipitation values for the summer months 1991–1999 measured at Hyytiälä Forestry Station 1 km east of the study area. The long-term average sum indicates average precipitation during the summer months of the last 30 years.

| | Year | | | | | | | | | Long-term average (1969-1999) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | |
| Month | | | | | | | | | | |
| June | 99.7 | 12.6 | 48.9 | 87.8 | 72.5 | 71.4 | 65.4 | 106.5 | 28 | 63 |
| July | 72.3 | 83.7 | 89.2 | 45.1 | 54.9 | 153.4 | 104.5 | 152.2 | 78 | 94 |
| Aug. | 41.2 | 170.1 | 112.2 | 63.7 | 91.1 | 6.9 | 81.2 | 114.2 | 63 | 90 |
| Sept. | 72.7 | 118.8 | 20.3 | 65.8 | 62.8 | 26 | 83.9 | 58.5 | 35 | 73 |
| Total | 285.9 | 385.2 | 270.6 | 262.4 | 281.3 | 257.7 | 335 | 431.4 | 204 | 320 |

vantage of this approach is that slight original differences between tree stand structure or drainage intensity should not affect the results. It is essential that both the calibration period and the treatment periods are long enough to cover the natural variation of the measured variables.

The growing seasons represent the following periods under the treatments mentioned:

Calibration (without any treatments) 1991–1992
Tree stand thinning 1993–1994
+ Ditch cleaning 1995
+ Ditch network maintenance 1996–1999.

The effect of the treatments on the water table level was evaluated graphically and by linear regression analysis.

The graphical analysis was done in two ways: The average water table levels were first plotted by sample plots and growing seasons to show the temporal variation. The second examination was done with the help of duration curves, which show how long proportionally and at what level the water table stands during the different treatment periods (Päivänen 1982).

By using simultaneous water table levels as data pairs, the regressions between the pure control (sample plot B55) and the treatments were determined. The vertical distance between the regression lines of the calibration period and the post-treatment period was considered to indicate the change caused by the treatment, e.g. thinning or thinning + ditch network maintenance (Ahti & Päivänen 1997). The same principle can be used when comparing the different treatments with each other. The analysis of variance was used in testing the differences between pre/post-treatment slopes and intercepts. These tests were performed by using the statistical BMDP-programme (BMDP 1990).

### Prehandling of the material

As mentioned earlier, the ditch cleaning operation in fall 1994 turned out to be at least partly unsuccessful: the cleaned ditches remined partly water-filled during most of the summer 1995. These field observations were supported by the preliminary graphical analysis. Therefore it was considered appropriate not to include the growing period of 1995 for further examination.

Consequently, periods 1991–1992 (calibration), 1993–1994 (thinning) and 1996–1999 (ditch network maintenance) were accepted for further examination. Only the material representing the growing season (from early May to the end of September) was considered for the calculations.

## RESULTS

The graphical analysis showed only slight changes in the water table levels caused by the treatments (Fig. 3). When the harvested volume was considerable (thinning intensities 15% and 28% of the total volume), the thinning treatment raised the water table. Because of the very small changes in the water table level in sample plots B53 and B54, the regression analysis was only performed for the data of sample plots B51 and B52. Irrespective of treatment and observation period, the differences between these sample plots in the level and the slope of the regression lines seemed to be small as well (Fig. 4). The cuttings raised the water table by ca. 7 cm at the most. The coefficient of determination exceeded 0.90 for all regressions.

In spite of the smaller removal (volume basis), the thinning treatment seems to have influenced the water table more clearly in plot B51 than in plot B52. One explanation could be that the absolute number of trees removed was higher for sample plot B51 than for B52. The slight rise observed in the water table level (period 1993–1994) was again eliminated by successive ditch network maintenance (period 1996–1999, see Figs. 3 and 4, and Table 3). According to the statistical analysis the effect of the thinning treatment on the water table level is significant in both of the sample plots with a risk level of 5% (Table 3).

## DISCUSSION

Thinning and ditch network maintenance showed only minor effects on the ground water level of a peatland area drained earlier for forestry. On the other hand, the experimental lay-out has some weak points which may cause errors in the results. For example, some cuttings performed on

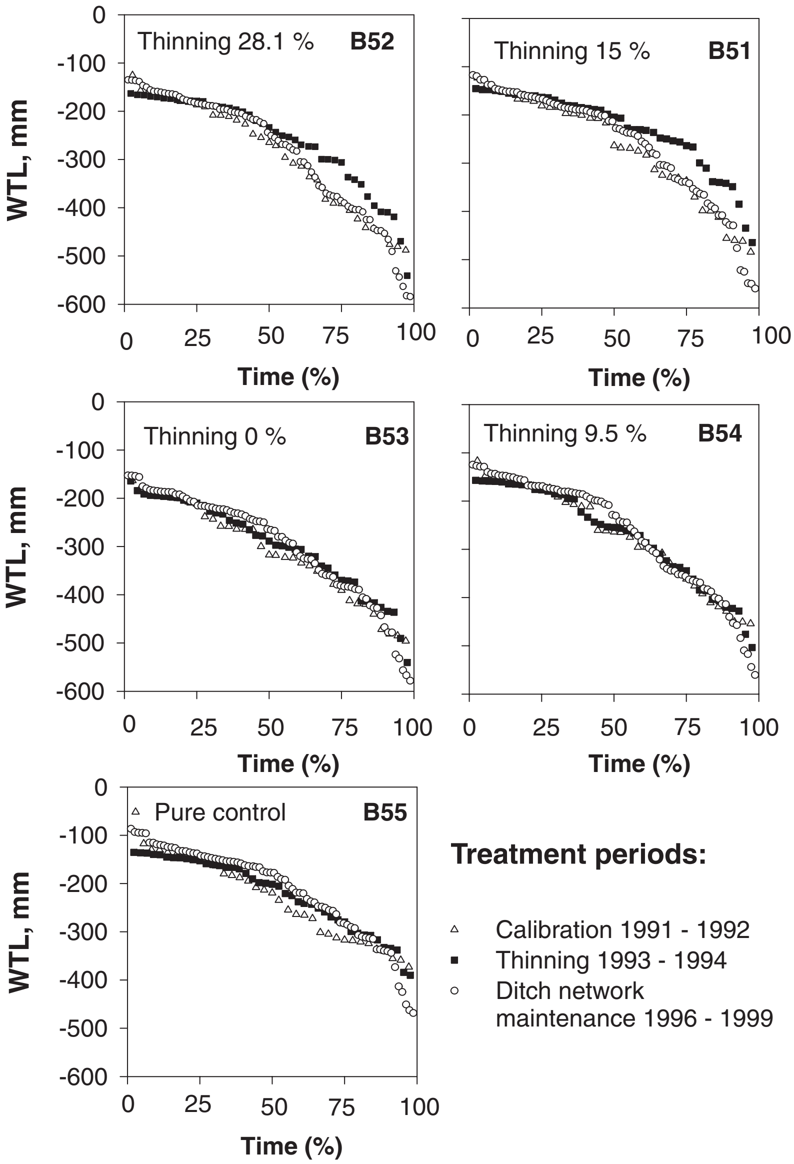


Fig. 3. The duration of the water table levels in the sample plots (B51–B55) of Ahvenräme during the different study periods. Time axis proportional.

Table 3. Statistical significance (p) of the regression equations (slope + intercept) between treatments when the simultaneous water table levels in the sample plots B51 and B52 are compared with the pure control (B55) (see Fig.4). Column WTL indicates the direction of the change in the water table level during the different treatment periods.

| Sample plot | Treatments | WTL | F | p |
|---|---|---|---|---|
| B51 | Calibr. vs. thinning | Rising | 16.876 | 0.000 |
| | Thinning vs. ditch maintenance | Lowering | 68.495 | 0.000 |
| | Calibr. vs. ditch maintenance | Lowering | 1.061 | 0.349 |
| B52 | Calibr. vs. thinning | Rising | 7.407 | 0.001 |
| | Thinning vs. ditch maintenance | Lowering | 38.611 | 0.000 |
| | Calibr. vs. ditch maintenance | Lowering | 3.353 | 0.038 |

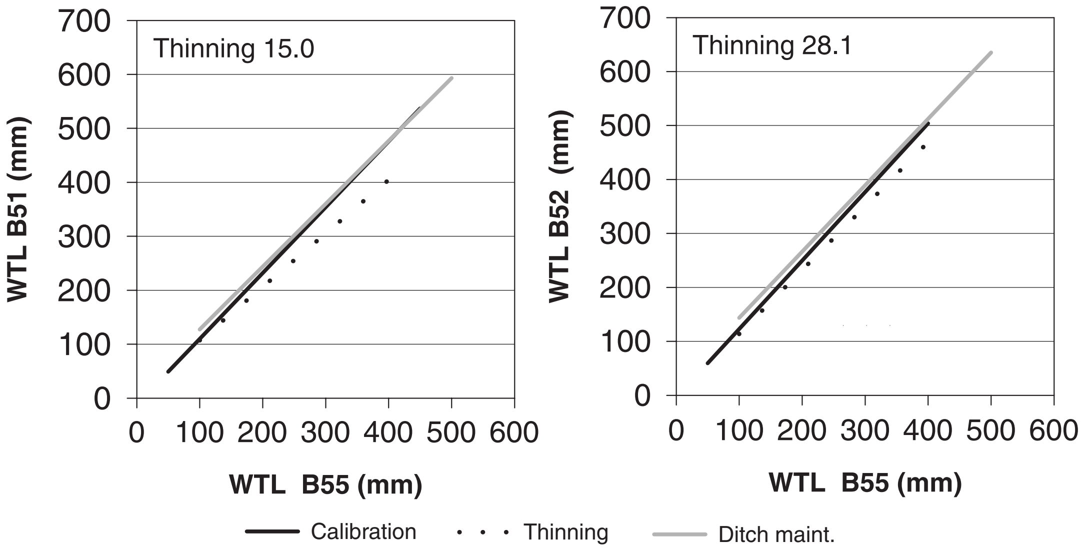


Fig. 4. The regression lines of the water table level (WTL) between pure control (B55) and sample plots B51 and B52 in Ahvenräme during the different treatment periods: Calibration 1991–1992; Thinning 1993–1994; Ditch network maintenance 1996–1999. The percentages indicate the proportional thinning removal of the total volume of the stand. See Table 3 for statistical differences between the regressions.

upland sites near control plot B55 may have slightly changed its hydrological conditions — probably towards wetter conditions. The approach, however, presumed that the conditions in the control plot had not been altered by human activity.

The removing of living stand — even partly — usually raises the water table level because of the diminishing interception loss and transpiration by the tree stand (Heikurainen & Päivänen 1970, Päivänen 1974, 1982). In this study the direction of the cutting effect on the water table level is in accordance with this theory but the absolute raising effect was small. The reason for this is probably the small amount of removed stand volume and careful logging, which did not have any dramatic effect on the stand hydrology.

## CONCLUSIONS

The study shows that in the planning stage, a careful evaluation of the need for the maintenance of ditch network (ditch cleaning and complementary ditching) should be done in connection with the first commercial thinning in order to avoid unnecessary costs. The cutting removal itself (up to 30% of volume) seems to be too small to cause any ecologically harmful rise in the water table level. The necessity of ditch network maintenance is probably more dependent on the extent to which the ditches have deteriorated in connection with the logging operation (Rantonen & Päivänen 1989). The effects of later thinning cuttings or regeneration cuttings on the soil hydrology are probably noticeably larger.

## ACKNOWLEDGEMENTS

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