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Ditch Spacing as a Regulator of Post-Drainage Stand Development in Spruce and Pine Swamps

Sarkaleveys korpi- ja rämemetsiköiden ojituksen jälkeisen kehityksen säätelijänä

Kustaa Seppälä

SUOMEN METSÄTIETEELLINEN SEURA

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DITCH SPACING AS A REGULATOR OF POST-DRAINAGE STAND DEVELOPMENT IN SPRUCE AND IN PINE SWAMPS

KUSTAA SEPPÄLÄ

SELOSTE

SARKALEVEYS KORPI- JA RÄMEMETSIKÖIDEN OJITUKSENJÄLKEISEN KEHITYKSEN SÄÄTELIJÄNÄ

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PREFACE

The present paper deals with a part of a larger investigation into the order of profitability of different forest improvement measures. The project was financed from funds reserved for this very purpose by the National Research Council for Agriculture and Forestry. The study was started in 1967, and is still being continued as a joint effort by the Department of Business Economics of Forestry, the Department of Silviculture and the Department of Peatland Forestry at the University of Helsinki.

The data of the partial study dealt with in the present paper was collected during the period 1967—70 by two field crews, one of which was led by Mr. JUKKA OUNI, B. F., during the period 1967—69 and by Mr. MARTTI ROMPPAINEN, B.F., in 1970, and the other one, by the present author.

Right from the beginning Professor LEO HEIKURAINEN with his valuable supervision and expert advice took part in the performance of the study. The other project leaders, namely Professors VALTER KELTIKANGAS and PAAVO YLI-VAKKURI, read the manuscript and offered valuable criticism. Throughout the course of the project I had repeated discussions on various aspects of its performance with Mr. MATTI KELTIKANGAS, Lic. For., who also read the manuscript.

The drawings used in the paper are the work of Mr. SAULI AHOPELTO, B.F., and I received help from a great many other people. The translation from Finnish was made by Mr. K-J. AHLSVED, B.F.

I am greatly indebted to all those mentioned in the foregoing.

Helsinki 1971

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1. INTRODUCTION

11. On previous studies concerning ditch spacing

In addition to the edaphic and climatic conditions, the efficiency of drainage is a factor of essential importance affecting the post-drainage development of peatland forests. Among the various factors influencing the efficiency of drainage, ditch spacing is probably the most significant one (cf., e.g., HUIKARI 1959), although such factors as the ditch depth (e.g. MESHECHOK 1960, 1969; HUIKARI et al. 1966) and the density, treatment and vitality of the tree stand (e.g. HEIKURAINEN 1966, 1967; HEIKURAINEN and PÄIVÄNEN 1970) also regulate the water relations of drained peat soils quite distinctly.

One may speak about an effective and about a geometric ditch spacing. The former concept indicates the distance between ditches in the direction of the main slope, whereas the latter, which is the only one referred to in the present paper, indicates the shortest distance between ditches (MESHECHOK 1960).

In the early days of forest drainage, ordinary herringbone systems were not used to any extent worth mentioning because it was believed that sufficient drainage could be achieved with large, single ditches. This being the situation, the interrelations between the efficiency of drainage and stand growth could be examined only against the background of the distance between the trees and the nearest ditch. As early as 1899 the director of the Peatland Draining Commission of Western Russia, Shilinskij (according to TANTTU 1915), published a report on the effects of peatland drainage, in which he states that trees grow faster near ditches than at greater distances from them. Likewise, LUKKALA (1929), in his earliest study of tree stands growing on drained peat soil, reached the conclusion that trees revive quicker, the nearer to the ditches they are growing.

The prompt and strong response to drainage of trees growing near ditches is due to several different factors. Soil water conditions, e.g., the changes taking place in the depth of the ground water table, are greater and faster, the nearer is the ditch which causes these changes (cf., e.g., HAINLA 1957). This is probably true for all phenomena which are caused by changes in the water relations, among them the responses of the tree stand. On the other hand, the openings cut through the tree stand when pegging out the ditch lines leave growing space for the trees standing nearest to them. The spoil bank along ditches, which frequently consists of peat of a different type from that occurring in the topmost soil layer, is probably one of the factors leading to better tree growth along ditches than elsewhere in the drained area.

The use of narrow strips between the ditches in a herringbone system also has its drawbacks from the viewpoint of the timber producing capacity of originally forest-covered peatlands. This is because the volume of the original stand is reduced to quite a marked extent in order to provide space for the ditches. If, for example, the openings made in the stands for the ditch have a width of four meters, the volume of the original stand is decreased by 40 % when ditches are spaced 10 m apart, but by only 10 % when the ditches are made at a distance of 40 m from each other. In the treeless area produced in this way at least that taken up by the ditch proper remains as an unstocked waste area. In investigations into the growth of individual trees the importance of the decrease in the volume of the original stand as well as of openings remains unsolved, and this is also true for the capability of the border stand to make use of the resulting free growing space. For a solution to these problems measurements are needed which concern entire stands and are bound to areal units.

The ditch spacing offering the highest degree of advantage from the biological viewpoint, that is to say, from the viewpoint of the development of the tree stand or of single trees, has been studied in several different ways. A number of experiments have been laid out on behalf of the Department of Peatland Forestry of the Finnish Forest Research Institute in order to solve the problems connected with ditch spacing and ditch depth, and in the case of the development of individual trees, certain partial results have already been published (HUIKARI and PAARLAHTI 1967). PAAVILAINEN (1966, 1969) has published some results from measurements carried out on the tree stands of certain experiments in ditch spacing. According to his findings, a rapid increase in growth after drainage takes place only at a ditch spacing of less than 20 m, the best results being obtained at the narrowest spacing employed, i.e. five meters. In this connection it ought to be noted that most of the experimental areas concerned have been drained so recently that the growth has not yet fully revived, not even in the case of the narrowest ditch spacings. In older drainage areas the situation is probably different. Data presented by HEIKURAINEN (1969) on certain hydrological experiments which are being carried out at present imply that, except in the case of the poorest pine swamp sites studied, the optimum ditch spacing from a biological viewpoint would be something over ten meters.

Using experimental areas specifically laid out for ecological research, HUIKARI and PAARLAHTI (op. cit.) have also studied the interrelationships between tree growth and the depth of the ground water table under conditions in which the ground water table was held at constant depths throughout the year. The best growth values were usually recorded on sample plots where the ground water table was located at rather great depths from the soil surface, i.e. 50—70 cm. MESHECHOK (1960, 1969) approached the problems involved with optimum drainage against the background of certain drainage norms as determined on the basis of the average depth of the ground water table during the growing season; these norms show a certain degree of variation depending on, for example, the tree species composition and the cutting class of the growing stock. The results obtained are presented in the form of diagrams from which it is possible to read the ditch spacings and ditch depths required by the norms, for soligenous and for ombrogenous peatlands. Under the conditions prevailing in Norway, which are characterized by a high degree of precipitation and sparsely stocked peatlands, the drainage norms recommended by MESHECHOK seem to lead to rather dense ditch systems.

In Finland, only HEIKURAINEN (1959), in his investigation into the state and the tree crops of peatlands drained for forestry purposes, has presented calculations of any general validity concerning the importance of ditch spacing for the development of crops growing on peat. Owing to the method of study employed in the investigation, however, the influence of the space taken up by the ditches remained beyond observation. Moreover, even the narrowest ditch spacings covered by the study represent relatively extensive drainage conditions.

In the Baltic States BUŠS and SABO (1959), for example, have determined, using strips laid out at different distances from ditches, the optimum ditch spacing from both the biological and the economic viewpoint in the case of sites of varying quality. On the basis of the results of their study, BUŠS and SABO state that the decrease in tree growth, in conjunction with increased distance between the ditches, is greater on barren peatlands than on rich sites (cf. e.g. LUKKALA 1929, HEIKURAINEN 1959). Optimum drainage, according to the calculations performed by BUŠS and SABO, is reached when considerably broader ditch spacing is used than that recommended for use in Finland.

12. Aim of the study

On the basis of the aforesaid it may be concluded that there is a lot of information which can be used to determine the optimum ditch spacing from the viewpoint both of single trees and of tree stands. On the other hand, the information required for determination of the average influence of ditch spacing on the timber production of peatland forests in terms of solid volume or timber assortments has so far been rather vague. That is to say, we do not know to what extent the timber production decreases with increasing distance between ditches when all other factors of influence remain unchanged. Only when this is known we can determine the optimum ditch spacing from the economic viewpoint in different cases.

The aim of the present study is to assess, on the basis of abundant data collected in the field, to what extent the production of timber is decreased on different sites and in various parts of the country with increasing distance between the ditches. The study was performed in peatlands drained more than thirty years earlier; in drainage areas of this age the strongest effects of drainage on the growing stock have already levelled off.

The study was restricted to cover only a few, common peatland site types, which in a virgin state are covered with forest. Preliminary results have already been published during the course of the project (SEPPÄLÄ 1968, 1969).

2. THE DATA OF THE STUDY AND ITS COLLECTION

When the larger study of which the present paper forms a part was started, it was considered best to base it as far as possible on re-measurements of the sample plots that had been used by Heikurainen in his study of 1959. Consequently, before starting the field work of the present study, the sample plots representative of herb-rich spruce swamps (RhK), ordinary spruce swamps (VK), herb-rich (RhSR) and ordinary (VSR) sedge pine swamps, *globularis* pine swamps (PsR), dwarf-shrub pine swamps (IR) and cotton-grass pine swamps (TR) which, according to the results of the earlier measurement, met the following minimum requirements, were selected from the material used by Heikurainen:

- the tree stand should be at an intermediate stage of development, and its silvicultural condition should be at least satisfactory,
- in the spruce swamps the dominant tree species should be spruce, and in the pine swamps, pine,
- the layout of the ditch systems should be of a kind which makes it possible to determine the distance between ditches in an unambiguous way, and the condition of the ditches should be at least satisfactory.

In this way it was attempted to eliminate in advance from the study material stands that were dominated by hardwoods or which were over-aged or otherwise in a state of underproduction. In connection with the field work about one fourth of the sample plots that had been accepted in the preliminary selection had to be abandoned primarily because of regeneration cuttings and complementary drainings that had been performed.

Initially the material used by Heikurainen was drawn by random sampling on sites which had been drained in the 1930's on behalf of the forest improvement districts of the Central Forestry Board Tapio and the forest drainage districts of the National Board of Forestry. On the basis of stand descriptions the necessary sites, which had been indicated on maps, were identified in the field. The sample plots had been marked on the map in advance.

237 of the sample plots of the present study were located in sites previously studied by Heikurainen.

In exactly the same way slightly more than 300 additional sample plots were indicated on the map during the course of the project. These sites were in places that had been drained by the Central Forestry Board Tapio and the National Board of Forestry in the 1930's. From this additional material 174 sample plots were accepted and measured after examination at the site.

The sample plots forming the basis of the calculations concerning the ditch spacing were distributed by peatland site types as follows: 53 were located in herb-rich spruce swamps, 77 in ordinary spruce swamps, 52 in herb-rich sedge pine swamps, 92 in ordinary sedge pine swamps, 32 in *globularis* pine swamps, 55 in dwarf-shrub pine swamps and 50 in cotton-grass pine swamps. Geographically the sample plots were rather evenly distributed over the whole country except for the northernmost parts of Lapland (Fig. 1).

To test the method used in the study, an additional number of 50 sample plot pairs were measured in areas that had been drained in the 1930's in a restricted area in Central Finland. 29 of these sample plot pairs were located in ordinary spruce swamps and 21 in dwarf-shrub or in cotton-grass pine swamps.

The following calculations of the influence of ditch spacing on the growth of trees were consequently based on a total of 411 sample plots. The sample plots had a rectangular form and they were laid out so that one of their long sides was situated along the mid line of the ditch. In nine cases out of ten the length of this side was 50 m. In some cases, however, due to a clear change in the substrate or the site type, it was not possible to lay out sample plots with a length of 50 m, so 40 m, and on a few occasions 30 m, had to be considered as a satisfactory length. The width of the sample plots was always 30 m, and consequently, their area varied from 0.09 to 0.15 ha, the average size being 0.144 ha.

In sites where there was a circular sample plot that had previously been measured by HEIKURAINEN, the rectangular sample plots of the present study were located as shown by Fig. 2. The mid point of the rectangular sample plot was placed on the straight line which, perpendicularly to the ditch, passed through the mid point of the circular sample plot. The exact location of the complementary sample plots was determined before the field work was started using fixed points that could easily be found, for example, ditch crossings. The first thing to be done in the field was to check that the sample plots fulfilled the requirements mentioned in the foregoing (p. 00). When the answer was yes, the tree stand of the plot was measured. If not, the sample plot was not transferred to another place, but abandoned.

To estimate the importance of the efficiency of drainage each sample plot was divided into five strips, parallel to the ditch. The strip that was located nearest to the ditch was 10 m wide, whereas the remaining four strips had a width of five meters each.

The following measurements were taken on the tree stand growing in each strip:

- The trees were tallied using 2 cm breast height diameter classes and rounded off to the class middle. The trees to be removed in the next thinning were recorded separately. Stumps with an age of less than twelve years were also tallied.
- Among the trees having a diameter greater than the estimated average, every nth tree was made a sample tree and among those having a diameter smaller than the average, every 2 · nth tree. The numerical value of x · n varied from case to case depending on the evenness of the stand density and on the tree species composition. In addition, the largest tree of each strip was used as a sample tree. The number of sample trees in each sample plot was 15—38.
- The following measurements were taken on sample trees: the diameter at breast height and at stump height and the taper, all of them to an accuracy of one centimeter, the radial growth during the last five-year period, to an accuracy of 0.5 mm, the tree height to an accuracy of 0.5 m, the double bark thickness to an accuracy of one millimeter and, in the case of coniferous trees, the average annual height growth for the last five-year period to an accuracy of 0.5 dm, in the case of deciduous trees, the crown class (L. ILVESSALO 1929). In the case of each sample tree belonging to the dominant crown classes the age at breast height was also determined and the distance between the tree and the ditch measured.
- All sawtimber trees that had been marked for cutting as well as all other sample trees that met the dimensions and quality of sawtimber trees were measured on the stump for the volume and grade of the obtainable sawlogs. In sawtimber grading the instructions given in »Tapion Taskukirja» (HEISKANEN 1965) were followed.

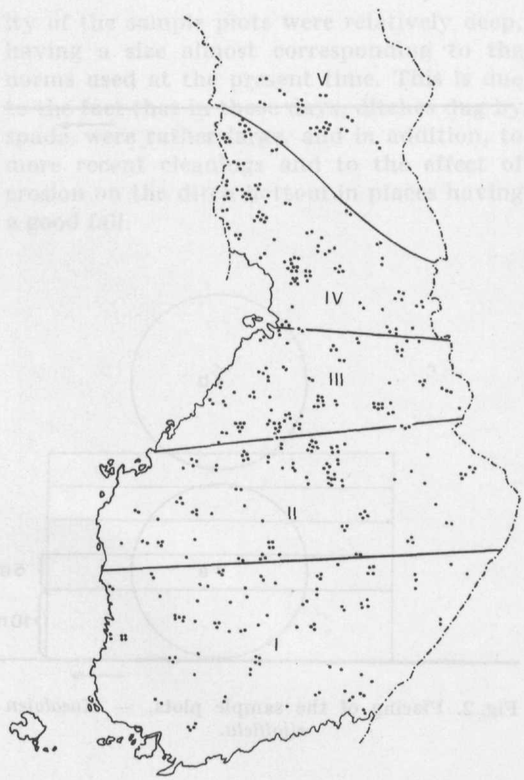

Fig. 1. Geographical distribution of the study material. — *Tutkimusaineiston alueittainen jakaantuminen.*

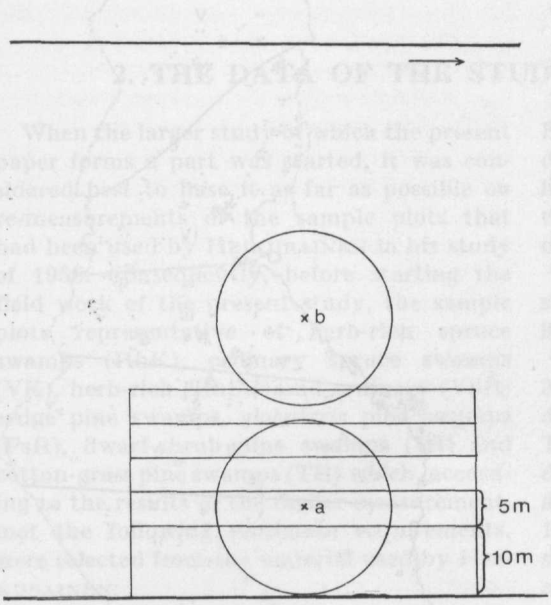

Fig. 2. Placing of the sample plots. — *Koealojen sijoittelu.*

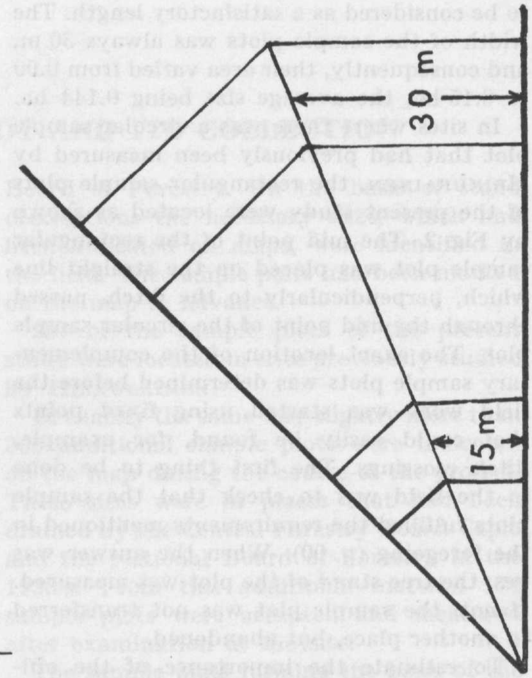

Fig. 3. Placing of the control sample plots. — *Kontrollikoealojen sijoittelu*

The grading was done by measuring the butt log and estimating the top logs ocularly.

The functional capacity of the ditches in the immediate vicinity of the sample plots was estimated in the field by dividing the ditches into three categories: good (I), satisfactory (II) and poor (III) ditches with regard to their condition. The same classification has also been used previously in several connections (cf. e.g. HEIKURAINEN 1957). The following table shows the distribution of the ditches in the vicinity of the sample plots of the present study by classes according to their condition in the site types covered by the study:

Condition of ditch	I	II	III
Site type	% of all ditches		
Herb-rich spruce swamp	60	38	2
Ordinary spruce swamp	52	37	11
Herb-rich sedge pine swamp	43	44	13
Ordinary sedge pine swamp	39	48	13
Globularis pine swamp	29	50	21
Dwarf-shrub pine swamp	44	41	15
Cotton-grass pine swamp	32	49	19

The figures in the table show that the condition of the ditches becomes poorer when moving from sites of good quality to poorer ones, or from true spruce and pine swamps to site types having features of open peatland types. It ought to be noted that sample plots which were in the vicinity of ditches that had become completely filled up and thus were incapable of functioning, were rejected. Consequently, the figures in the table do not represent the average present condition of ditches made during the 1930's, but rather the average situation for the sites covered by the study.

Site type	Ditch depth, cm
Herb-rich spruce swamp	87 ± 7.3
Ordinary spruce swamp	75 ± 3.5
Herb-rich sedge pine swamp	71 ± 3.3
Ordinary sedge pine swamp	71 ± 4.5
Globularis pine swamp	62 ± 3.7
Dwarf-shrub pine swamp	81 ± 5.4
Cotton-grass pine swamp	74 ± 4.9

In the case of one half of the sample plots the depth of the ditch bordering the sample plots was measured halfway along the sample plot side. The following table shows the average depth of the ditches according to site types. The standard error of the mean was included in the table to describe the magnitude of the variation.

The shallowest ditches that were measured had a depth of about 40 cm, and the deepest ones were about two meters deep. On an average the ditches in the immediate vicinity of the sample plots were relatively deep, having a size almost corresponding to the norms used at the present time. This is due to the fact that in those days, ditches dug by spade were rather large, and in addition, to more recent cleanings and to the effect of erosion on the ditch bottom in places having a good fall.

3. TREATMENT OF THE DATA COLLECTED

Final assessment of the importance of ditch spacing for the development of the stock growing on drained peatlands will be possible only after decades, when the experimental areas set up for the study of the problems involved are old enough to form a basis of sufficient strength for the determination of the yields of timber, and eventually, the monetary value of the returns that can be obtained on each separate occasion with different ditch spacing. Considering the fast rate at which the draining programme is being carried out in present-day Finland, it is of essential importance to find approximate figures which can be used as a basis for the execution of the remaining part of the drainage programme.

The present study was based on the assumption that the conditions prevailing on the 10-m strip in the immediate vicinity of the ditch correspond to those at a 20 m ditch spacing, and those on the former plus the next 5 m strip, to the conditions created at a 30 m ditch spacing, etc. This assumption was tested using the results obtained from measurements performed on the control plots mentioned in the foregoing.

The influence of ditch spacing on stand development was examined by observing the changes taking place in the total volume of the growing stock, in the volume of obtainable sawtimber and in the current volume increment during the last five-year period as functions of ditch spacing, determined in accordance with the aforementioned assumption.

The concept total volume refers in this connection to the joint volume of the growing stock at present and the natural and cutting removal, expressed in terms of solid cubic meters including bark. This variable proved much more reliable than using only the present volume of the growing stock in estimations of the response of tree stands to ditch spacing because the intensity of the cuttings performed showed a systematic variation in the strips representative of different ditch spacings.

The volume increment figures presented include the increment of the present stock and that of the cutting removal during the last five-year period.

The volume and increment determinations involved in the study were carried out using the tables worked out by ILVESSALO (1948). The volumes of the sample trees falling within various diameter classes were determined on the basis of the tree species, the breast height diameter, the tree height and the taper, and the values obtained were plotted against the respective diameter classes; thereafter the corresponding volume curves were fitted. This technique was employed because the fitting of curves describing the height and form of trees growing on peat is often rather difficult.

The volume of the cutting removals was determined using the method described by NYYSSÖNEN (1955), which is based on stump measurements.

Determination of the distribution of the timber growing on the sample plots by assortments was performed on the basis of measurements in the field and the timber assortment tables worked out by TIIHONEN (1966, 1969a and b).

In the calculations performed, the tree stands which were at different stages of development and the volumes of which were of different magnitude were made comparable to each other by giving the stand characteristics which are valid for the strip corresponding to 20 m ditch spacing in each sample plot the value 100, and calculating the values of the corresponding characteristics for the other ditch spacings studied in relation to that figure.

The results obtained from calculations concerning individual sample plots were grouped with respect both to the site type and to the geographical location of the plots.

4. RESULTS OF THE STUDY

41. The average influence of ditch spacing on the volume and volume increment of peatland forests

Table 1 shows the relationships between the total volume of tree stands growing on peatlands of different types and at different ditch spacings. The magnitude of the variation is indicated by the standard error of the mean, which has been inserted in the table.

In herb-rich spruce swamps the total volume was of similar magnitude at all ditch spacings from 20 to 60 m. In all other site types covered by the study, the total volume was systematically smaller, the greater the distance between the ditches. In ordinary spruce swamps and in herb-rich sedge pine swamps, the total volumes obtained at 60 m ditch spacing were about five unit per cent lower than those obtained at 20 m spacing. The corresponding difference was about ten unit per cent in ordinary sedge pine swamps and dwarf-shrub pine swamps, and about fifteen unit per cent in *globularis* pine swamps and cotton-grass pine swamps. Generally speaking, it may be concluded that the decrease in the total volume of the tree stand with increasing distance between the ditches is the greater, the poorer the site and the sparser the tree stand growing there prior to draining. Of course, this is true only when the changes are examined in terms of relative figures; when absolute volumes are used in the calculations, the situation may be different because of the variations in the original stock volumes between different sites.

Evidently, the ditch spacing affects the volume of the total post-drainage timber yield to a still greater extent than the total volume of the tree stand at a certain instance because the latter includes the volume of the tree stand present at the time of draining. It may be assumed, however, that using the total post-drainage timber yield in the calculations instead of the total volume of

Table 1. Dependence of the total volume of the growing stock on ditch spacing in the whole country.

Taulukko 1. Kokonaispuumäärän ja sarkaleveyden välinen riippuvuus koko maassa.

Site type	Ditch spacing — Sarkaleveys 20	30	40	50	60
	Volume at different ditch spacings in % of that at 20 m ditch spacing				
Herb-rich spruce swamp (RhK)	100.0	100.0	101.2	101.5	100.2
	—	± 1.3	± 1.5	± 1.8	± 2.0
Ordinary spruce swamp (VK)	100.0	100.5	99.3	96.8	96.2
	—	± 1.2	± 1.4	± 1.5	± 1.7
Herb-rich sedge pine swamp (RhSR)	100.0	100.0	97.4	95.5	94.0
	—	± 1.5	± 2.3	± 2.5	± 2.9
Ordinary sedge pine swamp (VSR)	100.0	98.3	95.6	92.6	90.8
	—	± 1.0	± 1.4	± 1.7	± 1.9
Globularis pine swamp (PsR)	100.0	95.2	91.8	88.4	86.3
	—	± 1.6	± 1.8	± 2.1	± 2.4
Dwarf-shrub pine swamp (IR)	100.0	97.5	93.6	91.0	89.4
	—	± 1.5	± 1.7	± 1.9	± 2.1
Cotton-grass pine swamp (TR)	100.0	93.3	89.4	86.3	83.2
	—	± 1.3	± 2.0	± 2.3	± 2.5

Table 2. Dependence of the volume increment of the growing stock on ditch spacing in the whole country.

Taulukko 2. Kuutiokasvun ja sarkaleveyden välinen riippuvuus koko maassa.

Site type	Ditch spacing — Sarkaleveys				
	20	30	40	50	60
	Volume increment at different ditch spacings in % of that at 20 m ditch spacing				
Herb-rich spruce swamp (RhK)	100.0	100.6	101.1	101.2	99.7
	—	± 1.1	± 1.5	± 1.9	± 2.0
Ordinary spruce swamp (VK)	100.0	100.8	99.4	96.9	96.3
	—	± 1.1	± 1.4	± 1.8	± 2.0
Herb-rich sedge pine swamp (RhSR)	100.0	99.1	95.3	93.0	91.3
	—	± 1.2	± 1.6	± 1.9	± 2.1
Ordinary sedge pine swamp (VSR)	100.0	99.0	96.0	92.9	91.2
	—	± 1.1	± 1.4	± 1.7	± 2.0
Globularis pine swamp (PsR)	100.0	96.1	91.8	88.2	85.9
	—	± 1.8	± 2.4	± 2.5	± 2.9
Dwarf-shrub pine swamp (IR)	100.0	96.8	91.6	88.2	86.1
	—	± 1.1	± 1.4	± 1.8	± 2.0
Cotton-grass pine swamp (TR)	100.0	93.8	87.8	84.0	80.8
	—	± 1.4	± 2.1	± 2.5	± 2.7

the growing stock would cause only minor changes to the results. In fact, the stand volumes have multiplied in the study areas in the course of the post-drainage decades, and consequently, the proportion of the volume of the original tree stand in that of the present stand is inconsiderable.

Table 2 *shows the current volume increment* of the past five-year period as a function of ditch spacing. The figures presented indicate that the influence of ditch spacing on volume increment is both of similar kind and similar magnitude to that on the total volume of the growing stock.

If there is any regional variation in the interrelationships between ditch spacing and the stand characteristics studied, the differences between various sites as indicated by the figures in the table are somewhat distorted because there is a variation in the geographical distribution of sample plots representing different site types.

42. Regional variation in the relationships between ditch spacing and the total volume of the growing stock

Against the background of previous studies (e.g. Heikurainen 1959) it seemed possible *that the changes taking place in the macro*-climatic conditions when moving from south to north could lead to changes in the interrelationships between ditch spacing and stand characteristics so that the influence of ditch spacing would decrease from south to north. In order to find out whether in this instance it is true, the data of the present study was divided into five groups on the basis of the climatic zones for forest drainage set up by Heikurainen (op. cit.) and presented in Fig. 1.

The number of sample plots falling on various peatland site types and climatic zones are shown in the following table:

Site type	Zone I	II	III	IV	V
	Number of sample plots				
Herb-rich spruce swamp	23	7	6	11	6
Ordinary spruce swamp	27	25	15	9	1
Herb-rich sedge pine swamp	—	—	19	25	8
Ordinary sedge pine swamp	21	18	24	21	8
Globularis pine swamp	—	6	8	14	4
Dwarf-shrub pine swamp	19	11	16	6	3
Cotton-grass pine swamp	19	13	14	4	—

As was established in the previous section, the variation in both the total volume and the increment of the growing stock resulting from the variation in ditch spacing are quite similar in character. Owing to this fact, the interrelationships between ditch spacing and stand characteristics will be examined in the present connection only with regard to the total volume.

The next table shows the proportion of the total volumes measured for 60 m ditch spacing as compared with those obtained for 20 m spacing in various climatic zones and for different site types.

Site type	Zone I	II	III	IV	V
	Volume at 60 m ditch spacing in % of that at 20 m ditch spacing				
Herb-rich spruce swamp	103.3	97.0	99.6	95.6	101.0
	± 3.2	± 6.3	± 3.4	± 3.0	± 8.2
Ordinary spruce swamp	97.7	94.4	101.2	90.7	—
	± 2.8	± 3.5	± 3.5	± 3.3	—
Herb-rich sedge pine swamp	—	—	100.0	89.5	93.8
			± 3.6	± 5.0	± 6.8
Ordinary sedge pine swamp	94.6	84.2	94.3	86.5	96.5
	± 3.7	± 3.5	± 4.7	± 3.2	± 6.6
Globularis pine swamp	—	80.8	91.2	84.6	90.5
		± 2.7	± 3.9	± 4.4	± 6.0
Dwarf-shrub pine swamp	98.5	84.1	80.4	91.7	94.0
	± 2.9	± 4.1	± 3.0	± 9.2	± 5.6
Cotton-grass pine swamp	80.4	79.4	89.2	86.4	—
	± 3.1	± 4.0	± 6.5	± 7.6	—

Although, due to the fact that the number of observations was rather small in certain groups, and thus, chance may have influenced the results to some extent, a clear and systematic variation can be observed in the relationships between ditch spacing and volume in various climatic zones. The variation does not follow any clear trend from south to north, however, but the influence of ditch spacing on the volume seems to be greatest in zones II and IV, that is to say, in these zones the decrease in volume with increasing distance between ditches is greater than in other zones. Consequently, it may be concluded that the regional variation in the influence of ditch spacing, as brought about by the division of the data into climatic zones, cannot be due to variations in the macroclimate alone. Moreover, it seems evident that a zone division based on regionality in stand increment cannot fully explain the variation in volume caused by the variation in ditch spacing.

In order to examine this regional variation in more detail, the country was divided into sections bordered by meridians and parallels. For the sample plots located in each of these sections, the deviation of the timber volumes at 60 m and at 20 m ditch spacing in the different site types from the means for the

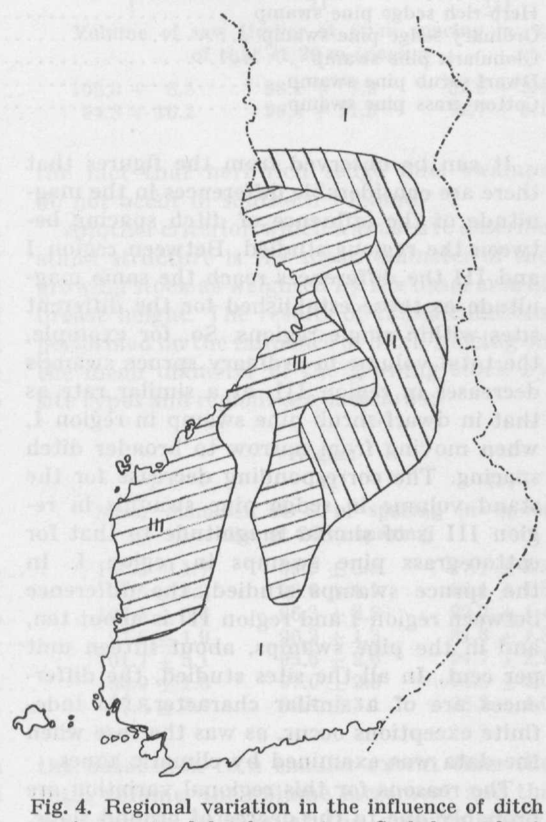

Fig. 4. Regional variation in the influence of ditch spacing on stand development. — *Sarkaleveysalueet.*

whole country was determined in terms of unit per cents. In addition, the mean of the deviations for all sample plots in each section was calculated. The results obtained showed *the regional variation presented in* Fig. 4, which was drawn up by combining sections for which the means obtained were of similar magnitude. In the figure, the country has been divided into three regions, in the first of which the influence of increasing the distance between ditches on the decrease in the timber volumes is smallest, and in the third of which this influence is greatest. Of course the limits of the regions could not be drawn very exactly.

The distribution of the sample plots of the study in the regions in question and by site types were as follows:

Site type	Region I	Region II	Region III
	Number of sample plots		
Herb-rich spruce swamp	25	14	14
Ordinary spruce swamp	30	25	22
Herb-rich sedge pine swamp	17	13	22
Ordinary sedge pine swamp	32	25	35
Globularis pine swamp	7	12	13
Dwarf-shrub pine swamp	32	9	14
Cotton-grass pine swamp	19	10	21

The proportion of the volume of the growing stock at 60 m ditch spacing in that obtained at 20 m spacing was also calculated for these regions, the results obtained being as follows:

Site type	Region I	Region II	Region III
	Volume at 60 m ditch spacing in % of that at 20 m ditch spacing		
Herb-rich spruce swamp	104.3 ± 3.5	98.5 ± 3.0	94.6 ± 2.9
Ordinary spruce swamp	101.1 ± 3.0	94.6 ± 2.4	91.2 ± 2.9
Herb-rich sedge pine swamp	105.5 ± 6.5	95.4 ± 5.3	84.3 ± 2.3
Ordinary sedge pine swamp	97.7 ± 3.9	88.7 ± 3.1	86.0 ± 2.5
Globularis pine swamp	89.3 ± 3.4	88.9 ± 4.3	82.2 ± 3.8
Dwarf-shrub pine swamp	93.6 ± 2.5	92.0 ± 5.5	78.2 ± 3.2
Cotton-grass pine swamp	89.9 ± 3.4	84.7 ± 7.8	76.4 ± 3.1

It can be observed from the figures that there are considerable differences in the magnitude of the influence of ditch spacing between the regions studied. Between region I and III the differences reach the same magnitude as those established for the different sites within single regions. So, for example, the total volume in ordinary spruce swamps decreases in region III, at a similar rate as that in dwarf-shrub pine swamp in region I, when moving from narrow to broader ditch spacing. The corresponding decrease for the stand volume in sedge pine swamps in region III is of similar magnitude to that for cotton-grass pine swamps in region I. In the spruce swamps studied, the difference between region I and region III is about ten, and in the pine swamps, about fifteen unit per cent. In all the sites studied, the differences are of a similar character. No indefinite exceptions occur, as was the case when the data was examined by climatic zones.

The reasons for this regional variation are probably due to the degree of ground slope. The strongest influence of ditch spacing is namely concentrated in regions where most of the peatlands have a plane surface. The regional division presented in this paper shows common features with divisions made on the basis of the average slope of the ground (MUSTONEN 1968). Evidently, a considerable part of the variation in the influence of ditch spacing could have been explained if data on the slope of the ground had been available for each sample plot. No measurements were taken on the slope in the field, however, and later efforts to determine it from maps and other documents were not successful.

43. The interrelationships between ditch spacing and stand structure

Although the tree stands growing in most of the sample plots covered by the study were to quite an extent similar in structure due to the fact that the plots had been laid out in drainage areas of similar age, a certain degree of variation could be observed. On South-Finnish sites of good and medium quality, for example, a considerable part of the growing stock had usually reached saw timber dimensions by the time of measurement, whereas, on poor sites and in the northern parts of the country, trees having reached saw timber dimensions were infrequent.

In the following connection the influence of ditch spacing on stand structure will be examined for the 60 m and 20 m ditch spacings on the basis of the relative quantities of saw timber yielded. As trees which had reached saw timber dimensions occurred only in some of the sample plots, the amount of data recorded for single site types was extremely small. For this reason the total data was divided into larger groups in such a way that all the spruce swamps of the study were dealt with as one group, another group being formed by herb-rich and ordinary sedge pine swamps and *globularis* pine swamps. In the poorer pine swamps, saw timber trees were so rare that they had to be omitted from the examination.

There is a rather strong decrease in the volume of saw timber from south to the north. In the group of spruce swamps the volume of saw timber averages 2 000 f³/ha in climatic zone I, the corresponding value for the group of pine swamps being 650 f³/ha. In zone V the corresponding values are 300 f³ and 50 f³ respectively. A change of this magnitude in the absolute values makes the results obtained through examination of the relative changes inconclusive because of the large dispersion of the data. It should also be observed that most of the sample plots covered by the following examination were located in southern Finland.

Within the framework of the regional divisions presented in the preceding section, the timber volumes at 60 m ditch spacing in per cents of those at 20 m spacing are as follows:

Site type group	Region I	Region II	Region III
	Volume of saw timber at 60 m spacing in % of that at 20 m spacing		
Spruce swamps	103.0 + 6.8	98.1 + 7.9	92.6 + 9.4
Pine swamps	94.8 + 16.2	98.4 + 11.5	79.7 + 6.1

Despite the magnitude of the variation it might be possible to conclude that the relations between the saw timber volumes at different ditch spacing are of approximately the same kind as those concerning the total volumes of the growing stock. The regional variation, too, seems to be of a similar kind although there is some irregularity in the case of pine swamps; this is probably due to the fact that herb-rich sedge pine swamps do not occur in southern Finland.

Another criterion which was used to describe stand structure is the mean diameter of the growing stock as weighted by the basal area at breast height. The results of the calculations performed on the influence of ditch spacing on the mean diameter of the growing stock by site types and regions are as follows:

Site type	Region I	Region II	Region III
	Mean diameter at 60 m spacing in % of that at 20 m spacing		
Herb-rich spruce swamp	100.0 ± 1.7	99.5 ± 3.9	97.7 ± 2.5
Ordinary spruce swamp	97.5 ± 2.2	98.6 ± 1.5	96.1 ± 1.3
Herb-rich sedge pine swamp	107.3 ± 3.6	96.3 ± 2.3	92.7 ± 1.4
Ordinary sedge pine swamp	97.5 ± 1.9	96.2 ± 1.3	91.8 ± 1.3
Globularis *pine swamp*	101.7 ± 5.1	95.6 ± 2.6	94.7 ± 2.1
Dwarf-shrub pine swamp	98.9 ± 1.8	97.0 ± 2.3	94.5 ± 2.0
Cotton-grass pine swamp	90.8 ± 2.9	96.4 ± 3.1	96.2 ± 4.0

It can be seen from these figures that an increase in the distance between ditches decreases the mean diameter as weighted by the basal area to a smaller extent than the total volume, the volume increment and the saw timber volume of the growing stock.

Evidently for this reason the regional differences are inconclusive in the case of some groups, particularly for cotton-grass pine swamps. Generally speaking, the influence of ditch spacing on the mean diameter is greatest in region III. It ought to be observed that the influence of an increase in the distance between ditches on the mean diameter is of similar magnitude within all the site types covered by the study. In all cases the decrease in the mean diameter was less than ten unit per cent when moving from 20 m to 60 m ditch spacing.

5. EXAMINATION OF THE RESULTS

51. Reliability of the results

The sources of errors in the results presented in the foregoing can be divided into two groups, the first of which includes those caused by the fact that nature produces such large variations, those due to errors involved in measurement, those caused by disregarding important factors and those caused by the fact that the study material may have been insufficient in certain cases. Thus, the question is about the kind of errors which are more or less common to all studies based on data which is collected through observations on nature. The second group is formed by the errors that may occur owing to the possibility that the work hypothesis on which the study was based might have been incorrect. As was mentioned earlier, the treatment of the data was performed in accordance with the assumption that the strips into which the sample plots were divided would correspond, with regard to their stand characteristics, to those of tree stands actually growing at different ditch spacing in herringbone systems, even if the sample plots were located in areas where the true distance between ditches was 70—90 m.

A few general statements can be made about the factors involved in the study material and its collection which cause uncertainty in the results. First, it is clear that chance is a factor of considerable importance affecting the results obtained for single sample plots. Dispersion within the regions and site types studied is caused, for example, by the differences in the tree stands of the sample plots at the time of draining, by the differences in the absolute level of the volume and increment of the growing stock between sample plots and by the smallness of the size of the sample plots, especially the narrowest strips, etc. The errors caused by these factors are not systematic, however, but accidental, and it might be expected that their influence on the results has been practically eliminated because of the fact that the number of measurements was so large. In the present paper the importance of these sources of error is shown by the standard error of the mean which is indicated in the tables in conjunction with the various results presented. The calculation of the standard error of the mean was involved with a certain degree of at least theoretical weakness, this being due to the fact that the distribution of the sample probably did not fully correspond to the normal distribution.

As, except in the case of the calculations concerning the volumes of saw timber, the range of the error of the mean was only a few unit per cent, it might be concluded that the means presented describe the average conditions prevailing in nature to a reasonable degree of accuracy. Indeed a flaw in collecting the data, however, was the fact that ground slope determinations were not made in the field; this made investigations into the influence of other factors, such as climatic factors, on the interrelationships between ditch spacing and stand characteristics almost impossible.

As already has been mentioned, the second category of sources for possible errors is connected with the study method proper. During the course of work it was considered possible that the hypothesis on which the study was based, i.e., that stand development is similar on strips of certain widths as laid out in the present work and at corresponding ditch spacing, might lead to a systematic error in the results. To find the truth in this respect, a number of control sample plots were measured in Central Finland, as mentioned in the section concerning the collection of the data.

On each occasion two control plots were laid out in the manner shown by Fig. 3 so that one of them was representative of 30 m, and the other one, of 60 m ditch spacing. The fact that the plots were very small was a drawback; this makes data concerning single plots inconclusive. There is also the possibility of systematic errors that exaggerate the importance of ditch spacing because, in cases where ditches are located in the way shown in Fig. 3, the water usually flows in a direction towards the point of the angle formed.

According to the regional division presented in the foregoing, the control plots were distributed so that sixteen pairs of the plots located in spruce swamps fell in region I, and thirteen, in region III. In the case of pine swamps, the corresponding figures are six and fourteen. Theoretically, if no systematic error occurs in the study method, the ratio between the stand characteristics representative of the control plots should fall between the corresponding values for regions I and III as determined from stripwise measurements. In the case of spruce swamps these ratios should fall approximately in the middle between the values for region I and III, and in the case of pine swamps, somewhat closer to those for region III.

The following table shows the decrease in the total volume and the volume increment for the control sample plots when moving from 30 m to 60 m ditch spacing. For comparison, the corresponding ratios for regions I and III, as determined from the stripwise sample plots, have been included.

Site type	Sample plot and region	Total volume	Volume increment
		60 m ditch spacing in % of 30 m spacing	
Ordinary spruce swamp	Control	94.1 + 4.9	93.1 + 4.8
	Strip, region I	98.0 + 1.6	96.8 + 1.4
	Strip, region III	93.3 + 2.2	92.2 + 2.3
Dwarf-shrub pine swamp	Control	81.7 + 4.9	85.3 + 5.7
+ Cotton-grass pine swamp	Strip, region I	93.4 + 1.4	91.9 + 1.9
	Strip, region III	85.3 + 1.8	81.6 + 2.3

Consequently, in the case of the control sample plots, increasing the ditch spacing from 30 to 60 m decreased the total volume and volume increment of the growing stock to a greater extent than in the case of strips of corresponding widths in region I. In fact, the difference is statistically significant only in the case of the joint group of dwarf-shrub pine swamps and cotton-grass pine swamps. Except in the case of the same site group, the decrease in the average values of the stand characteristics for the control sample plots with increasing distance between the ditches is smaller than for the corresponding sample strips in region III, although the difference is in no case statistically significant. Consequently, no systematic error due to the method of study could be established on the basis of the control performed.

On the basis of the facts presented in the foregoing, it may be concluded that the calculations performed on the interrelationships between stand characteristics and ditch spacing using material collected from strips of the kind described in this paper fairly well describe the real conditions prevailing at different ditch spacing, thus forming a suitable basis for conclusions concerning the problems involved.

52. Conclusions

According to the results of the study, increasing the distance between ditches usually decreases the increment of peatland forests, which in turn decreases the timber yields. Likewise, due to the same fact, the development of the dimensions of the trees forming the stands is somewhat slower at broad than at narrow ditch spacings. The decrease in the development of the tree stand is more distinct the poorer the site and the sparser the original stock existing at the time of draining. A clear regional variation in the degree of the importance of ditch spacing could also be observed; it was established, for example, that in areas having a more or less plain surface, ditch systems of greater density were needed to reach a similar drainage efficiency than in regions with a greater topographical variation. On the basis of the degree of the importance of ditch spacing, the country was divided into three regions, in the first of which increasing the ditch spacing slowed down stand development to the smallest, and in the third, to the greatest degree.

In the case of rich sites, increasing the ditch spacing does not seem to decrease the total volume of the growing stock to any essential degree. This, however, must not be understood to mean that ditch spacing would not be of any importance at all. It should be kept in mind that the superior growth at narrow ditch spacing is used, to a large extent, to compensate for the losses in the original stand due to the formation of the ditch lines and for the growing space lost in this way. If this space is assumed to have an average width of four meters in the case of every ditch, the original stand is decreased by one fifth at 20 m spacing, and by 6.7 % at 60 m ditch spacing. If an increase in the efficiency of drainage were of no importance for the stand development, the ratio of the timber volume at 20 m ditch spacing to that at 60 m spacing would be 100/116.6.

In any case, according to the calculations presented, ditch spacing has a surprisingly small influence on both the total volume and the structure of the tree stand, even if there is a considerable variation in the case of single sample plots. According to the groupwise examination performed, it seems that a decrease in the ditch spacing from 60 m to 20 m increases the total volume of the growing stock by only slightly more than 20 %; for the mean diameter as weighted by the basal area the corresponding increase is only about ten per cent.

On the basis of the aforesaid it might be concluded that there is no reason to use very narrow ditch spacing when draining peatlands covered by forest because the rise in the costs involved with the draining operation is probably sharper than that produced by the stand development. It ought to be stressed, once more, that the conclusions presented in this study only refer to peatlands having a forest cover in their natural state. In completely treeless peatlands, or in those growing only scattered trees, the situation is probably different. In such cases, no losses in the original stand occur, and this makes the use of rather narrow ditch spacing possible.

6. SUMMARY

The paper is based on data collected from peatlands which had been drained in the 1930's. The study material comprised a total of 411 sample plots, located in various parts of Finland, and in sites of different quality. The purpose of the study was to determine the influence of ditch spacing on the volume, increment and structure of timber crops growing on drained peatlands.

Since the stands covered by the study grew on peatlands where the ditches had been spaced 70—90 m apart, the following method was used to study the influence of ditch spacing:

The sample plots were divided into strips parallel to the ditch along which they were laid out, the one touching the ditch having a width of ten meters, and the rest of the strips, a width of five meters. The strip which was located nearest to the ditch was considered as corresponding to 20 m ditch spacing, this strip plus the next one, as corresponding to 30 m spacing, etc. To test the reliability of the method, a sample consisting of fifty pairs of control sample plots was used. The results obtained from the control plots were then compared with those obtained from stripwise measurement. According to the results, there was no systematic differences between the methods, and so it was concluded that the results obtained from stripwise measurements were representative of the conditions actually prevailing at different ditch spacings.

The results of the study indicate that the influence of ditch spacing on both the total volume and the volume increment is greater, the poorer the site. On the other hand, the influence of ditch spacing on the structure of the stand as described by means of the mean diameter as weighted by the basal area, seems to be of similar magnitude in all the sites covered by the study. Generally speaking, however, the influence of ditch spacing on stand development is surprisingly small, even in extreme cases. The total volume and the increment of the growing stock decrease by about 20 % when the ditch spacing increases from 20 to 60 m, the corresponding decrease in the mean diameter having a magnitude of 10 %. This was interpreted to be due to the fact that the main part of the superior growth along the margin of the ditch is spent in compensating for the space lost in the area taken up by the ditches.

On the basis of the results obtained it was concluded that the best solution in forest drainage from the economic viewpoint is to employ relatively wide ditch spacings, which lead to a rate of stand development somewhat below the potential.

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Seloste:

SARKALEVEYS KORPI- JA RÄMEMETSIKÖIDEN OJITUKSENJÄLKEISEN KEHITYKSEN SÄÄTELIJÄNÄ

Tämä tutkimus kuuluu osana metsänparannustöiden edullisuusjärjestystä käsittelevään tutkimusprojektiin, jota Valtion Maatalous-metsätieteellinen Toimikunta on tutkimussopimuksen perusteella rahoittanut vuodesta 1967.

Tutkimuksen tarkoituksena on selvittää, miten sarkaleveys vaikuttaa jo luonnontilaisina metsäisten soiden ojituksenjälkeiseen puuston tuotokseen, ja täten luoda pohjaa eri sarkaleveysvaihtoehtojen edullisuusvertailuille.

Tutkimuksen kohteena ovat olleet seuraavat suotyypit: ruoho- ja heinäkorvet, varsinaiset korvet, ruohoiset ja varsinaiset sararämeet, pallosararämeet sekä isovarpuiset ja tupasvillarämeet.

Tutkimuksen aineisto kerättiin vuosina 1967—70 Keskusmetsälautakunta Tapion ja Metsähallituksen 1930-luvulla toteuttamilta ojitushankkeilta. Se käsittää yhteensä 411 koealaa, joiden alueittainen jakaantuminen on esitetty kuvassa 1. Suurin osa koealoista, 237 kappaletta, sijaitsee kohteissa, jotka Heikurainen on aikaisemmin mitannut suometsien tilaa ja kehitystä koskevaa tutkimustaan varten (1959). Loput 174 koealaa ovat yhtäläisin perustein arvottuja täydennuskoeoloja.

Tutkitut metsiköt sijaitsevat ojitusalueilla, joilla käytetty sarkaleveys vaihtelee 70 metristä 90 metriin. Tämän vuoksi sarkaleveyden ja puustotunnusten välisten vuorosuhteiden selvittämiseksi käytettiin seuraavanlaista tutkimusmenetelmää: Suorakaiteen muotoinen koeala sijoitettiin maastoon ojan suunnassa siten, että yksi koealan sivuista kulki keskellä ojaa. Koealan leveys oli ojaan nähden kohtisuorassa suunnassa 30 metriä. Koeala jaettiin viiteen ojan suunnassa kulkevaan kaistaan, joista ojan viereinen mitattiin kymmenen ja seuraavat neljä viiden metrin levyisiksi. Kuvassa 2 on koealan sijoittelun periaate. Laskelmissa on edellytetty, että lähinnä ojaa sijaitseva kaista vastaa olosuhteiltaan todellista 20 metrin sarkaa, se ja seuraava yhdessä 30 metrin sarkaa jne. Olettamuksen paikkansa pitävyyttä on teoreettisesti pohdittu kirjoittajan aikaisemmassa julkaisussa (Seppälä 1969). Tämän lisäksi olettamusta testattiin myös empiirisesti mittaamalla 50 kontrollikoealaa, joiden sijoittelun periaate esitetään kuvassa 3. Kontrollimittausten ja kaistakoealamittausten tulosten välillä ei havaittu selviä systemaattisia eroja, joten kaistoittain suoritetut puustotunnusten ja sarkaleveyden välisiä vuorosuhteita koskevat laskelmat kuvannevat tyydyttävän hyvin myös todellisilla saroilla vallitsevaa tilannetta.

Taulukosta 1 nähdään suhteellisina lukuina, miten saran leventäminen pienentää metsikön kokonaispuumäärää (= nykypuusto + luonnonpoistuma + hakkuupoistuma edellisellä kymmenvuotiskaudella) viljavuudeltaan erilaisilla soilla. Luvut ovat koko aineiston suotyypeittäisiä keskiarvoja. Taulukossa 2 on samalla tavoin esitetty saran leventämisen vaikutus metsikön viimeisen viisivuotiskauden vuotuiseen kuutiokasvuun.

Tulokset osoittavat, että suhteellisina lukuina sekä puumäärä että kasvu pienentyvät sitä jyrkemmin, mitä karummasta kasvupaikasta on kysymys; ruoho- ja heinäkorvissa mainitut tunnukset säilyvät lähes muuttumattomina saran leventyessä 20 metristä 60 metriin, kun taas tupasvillarämeillä puumäärän ja kasvun pienentyminen vastaavalla välillä on 20 prosenttiyksikön suuruusluokkaa.

Aineiston jatkokäsittelyssä havaittiin, että saran leventäminen pienentää eniten suometsiköiden tuotosta Lounais-Lapissa, Oulun tienoilla, Etelä-Pohjanmaalla ja Jyväskylän ympäristössä, vähiten puolestaan Peräpohjolassa, Kainuussa kapealla kaistaleella itärajan tuntumassa, Etelä-Suomessa sekä kapealla kielekkeellä Tampereelta pohjoiseen aina Keski- ja Pohjoispohjanmaan rajoille saakka. Laskelmien perusteella päädyttiin kuvan 4 esittämään aluejakoon. Siinä maa on jaettu kolmeen alueeseen, joista ensimmäisessä saran leventämisen metsikön kehitystä hidastava vaikutus on vähäisin ja kolmannessa voimakkain. Tämän aluejaon puitteissa muodostuvat 60 ja 20 metrin sarkojen puumäärien prosentuaaliset suhteet suotyypeittäin seuraaviksi:

Alue	I	II	III
Suotyyppi	60 m:n saran puumäärä, % 20 m:n saran arvosta		
RhK	104.3	98.5	94.0
VK	101.1	94.6	91.2
RhSR	105.5	95.4	84.3
VSR	97.7	88.7	86.0
PsR	89.3	88.9	82.2
IR	93.6	92.0	78.2
TR	89.9	84.7	76.4

Alueiden väliset erot sarkaleveysvaikutuksen suuruudessa ovat siis huomattavia, I ja III alueen välillä jopa samaa suuruusluokkaa kuin kasvupaikkojen väliset erot alueen sisällä. Korvissa sarkaleveyden vaikutus ensimmäiseltä alueelta kolmannelle jyrkentyy noin kymmenen, rämeillä keskimäärin viisitoista prosenttiyksikköä.

Sarkaleveyden vaikutusta suometsiköiden rakenteeseen tutkittiin sekä koealoittaisten sahapuumäärien että nykypuuston pohjapinta-alalla punnittujen keskiläpimittojen perusteella. Laskelmien tulokset näyttivät osoittavan, että sahapuumäärien suhteet sarkaleveyden muuttuessa muuttuvat jokseenkin samoin kuin kokonaispuumäärienkin. Sen sijaan metsiköiden keskiläpimittaan saran leventyminen vaikuttaa selvästi vähemmän kuin muihin tutkittuihin tunnuksiin. Lisäksi saran leventäminen pienentää keskiläpimittaa kaikilla tutkituilla kasvualustoilla lähes yhtä paljon, välillä 20—60 metriä kaikissa tapauksissa vajaat kymmenen prosenttiyksikköä.

Tutkimuksen tulokset osoittavat siis, että saran leventäminen yleensä alentaa suometsiköiden kasvua ja täten pienentää metsikköön kertyviä puumääriä, samalla kun myös metsikön rakenteen järeytyminen jonkin verran hidastuu. Saran leventämisen metsikön kehitystä heikentävä vaikutus on suhteellisina lukuina sitä selvempää mitä karummasta suosta on kysymys. Sarkaleveyden vaikutuksen voimakkuudessa havaittiin myös selvää alueittaista vaihtelua siten, että pinnanmuodostukseltaan tasaisilla alueilla tarvitaan samaan kuivatustehoon pääsemiseksi tiheämpää ojastoa kuin alueilla, missä maaston keskimääräinen kaltevuus on suurempi.

Kaiken kaikkiaan sarkaleveydellä on tämän tutkimuksen tulosten mukaan yllättävän vähäinen vaikutus yhtä hyvin metsikön puumäärään kuin sen rakenteeseenkin. Sen perusteella voitaneen päätellä, että alunperin metsäisten soiden ojituksessa ei ole tarkoituksenmukaista käyttää kovin kapeaa sarkaa, koska ojituksen tehostaminen nostaa ilmeisesti jyrkemmin hankkeen toteuttamiskustannuksia kuin nopeuttaa suometsiköiden kehittymistä.

leventäminen yleensä alentaa suometsiköiden kasvua ja täten pienentää metsikköön kertyvää puumäärää, samalla kun myös metsikön rakenteen järeytyminen jonkin verran hidastuu. Saran leventämisen metsikön kehitystä heikentävä vaikutus on suhteellisina lukuina sitä selvempää mitä karummasta suosta on kysymys. Sarkaleveyden vaikutuksen voimakkuudessa havaittiin myös selvää alueittaista vaihtelua siten, että pinnanmuodostukseltaan tasaisille alueille tarvitaan samaan kuivatustehoon pääsemiseksi tiheämpää ojitusta kuin alueella, missä maaston keskimääräinen kaltevuus on suurempi.

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Tutkimuksen tulokset osoittavat siis, että saran

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1972. Ditch spacing as a regulator of post-drainage stand development in spruce and in pine swamps. — ACTA FORESTALIA FENNICA 125. 25 p. Helsinki.

Usually, if the distance between ditches is increased in forest drainage, the stand increment decreases. This, in turn, decreases the timber yields produced and retards the development of the stand dimensions. The decrease in stand development is more distinct the poorer the site. The influence of ditch spacing is rather small, however, and therefore there is no reason to employ very narrow ditch spacing in the drainage of originally forest-covered peatland.

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