INCREASING THE LAND BASE AND YIELD THROUGH DRAINAGE'

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Forest Industry Lecturer

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Forest industry in northwestern Canada is cooperating with Alberta Energy and Natural Resources to provide funds to enrich the Forestry Program of the Faculty of Agriculture and Forestry at the University of Alberta through sponsorship of noteworthy speakers.

The Forest Industry Lecture Series was started during the 1976-77 term as a seminar course. Desmond I. Crossley and Maxwell T. MacLaggan presented the first series of lectures. The contribution of these two noted Canadian foresters is greatly appreciated.

Subsequent speakers in the series have visited for periods of up to a week, with all visits highlighted by a major public address. It has indeed been a pleasure to host such individuals as C. Ross Silversides, W. Gerald Burch, Gustaf Siren, Kenneth F.S. King, F.L.C. Reed, Gene Namkoong, Roger Simmons, Kenneth A. Armson, John J. Munro, Peder Braathe, Norman Johnson, and Vidar J. Nordin. The subjects of their talks are listed at the end of this paper.

This paper contains Dr. Juhani Paivanen's major public address given on 15 March 1984.

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Dr. Juhani Paivanen is the Senior Research Specialist of the Department of Peatland Forestry, Finnish Forest Research Institute, at Helsinki. He has held this position since 1982. In addition, he has been appointed a Docent in Peatland Forestry at the University of Helsinki where he has given lectures and directed graduate students.

He attained academic degrees of B.Sc. in Forestry in 1964, M.Sc. in Forestry in 1966, and Ph.D. in Forestry in 1973, all from the University of Helsinki. He started his research work in the Department of Peatland Forestry at the University of Helsinki in the mid-1960's where he conducted studies in the field of forest hydrology, peat properties and amelioration of peatlands for wood production. He later worked for five years developing silvicultural methods and techniques, particularly with mechanized soil treatment for regeneration and machine planting for Metsateho, the Forest Work Study Section of the Central Association of Finnish Forest Industries.

Dr. Paivanen has published more than 90 scientific and practical papers in the field of forestry. He had been previously invited twice to Newfoundland and once to Alberta as an expert in forest drainage. He has also visited northern Ontario and several States in the United States to advise on silvicultural problems.

1. INTRODUCTION

Peat is an organic soil developing as a consequence of the incomplete decay and decomposition of wetland vegetation under high moisture conditions and a deficiency of oxygen. In the following, the term *peatland* is used to refer in general to a site type supporting a peat-forming vegetation. The synonymous term *mire* is often used in ecological studies in western and northern Europe. Because different countries use different definitions of peat and peatlands, it is difficult to accurately estimate the total area of peatlands in the world. Nevertheless, the total peatland area of the world has been estimated to be about 422 million hectares (Kivinen and Pakarinen 1981).

Peatlands are most extensive in cool, humid climates and occur in temperate, boreal and subarctic zones in the northern hemisphere, but are more limited in area in the southern hemisphere. The enormous area of peatlands has a great potential for forestry. It has been estimated, however, that currently only 9.3 million hectares of this have been drained for forestry (Kivinen 1980). My lecture will give some information about the nature of peatlands and especially about their utilization for forestry purposes in Finland.

2. GENERAL BACKGROUND

Finland is situated between 60° and 70°N latitude. In the southern part of the country the altitude is usually less than 150 m above sea level. The average annual temperature on the southern coast is +5°C and at the polar circle +1°C. The main reason Finland has such moderate weather conditions, even though it lies so far north, is because the warm Gulf Stream creates a sub-maritime climate. Thus, in central Finland the mean temperature in July is + 16°C and the duration of the growing season is 160 days. The annual accumulated temperature sum (degree-days, over +5°C) is on the southern coast is 1300, decreasing to 500 degree days in northern Lapland. Mean annual precipitation in Finland is 500 to 700 mm, but the evapotranspiration is only 300 to 350 mm.

The total land area of Finland is 305,000 km'. According to the national forest inventory, 66% is forest land, 22% waste land (including poorly productive land), 10% agricultural land and 2% built-up areas, roads etc.

Forest ownership is as follows:

	Area %	Increment %
Private	64	76
State	24	12
Companies	8	8
Commune, parishes, etc.	4	4

The number of private forest owners totals more than 300,000 with much of their land being located on better-than-average sites and containing about 80% of the existing logging potential.

The following table gives some information about the forests in Finland compared to those in Alberta:

	Finland	**Alberta**
Productive forest land, mill. ha	19.9	20.1
Growing stock, mill. m' (with bark)		
- coniferous	1337	1022
- hardwood	293	674
Mean volume, m'/ha	80	103
Mean volume increment, m^3/ha	3.2	1.8

Scots pine *(Pines sylvestris)* is the dominant tree species in Finland; its share of the growing stock is 44%. Norway spruce *(Picea abies)* accounts for 38% **and deciduous species (mainly *Betula pendula* and *B.*** *pubescens)* for 18%.

The *forest balance* is the difference between the *allowable* and *total drain* *(i.e.* drain = cut). Due to overcutting the total drain exceeded the allowable drain considerably in the early 1960's. Consequently, several unofficial proposals based on studies were initiated as primary improvement and silvicultural programmes. The forest balance surplus resulting from the recession in the 1970's appears to be only a temporary phenomenon which will not give cause for a reduction in basic improvement work (Figure 1).

The *annual increment* of our forests has been increasing: 55.2 million m'/yr in the 1960's, 57.4 million m'/yr in the 1970's and 64.7 million m'/yr in the 1980's. The climatic condition and the barrenness of the soil found in northern parts of the country make for considerably more unfavorable growth conditions than in the south. The average annual increment there is only 1.4 m'/ha of forest land as opposed to an average of 4.5 in the south. The annual increment for the whole country is 3.2 m'/ha. The increase in mean annual growth has resulted mainly from forest improvement work carried out during the past decades.

Forest industries in Finland are mainly export industries. About 80% of the products are exported. As late as the early 1960's, forest products accounted for 75% of the total export earnings of the country. Since then the share has decreased due to the rapid expansion of other industrial sectors, but forest products still account for over 40% of exports. The relatively high standard of living in Finland is, to a large extent, dependent upon the intensive management of our renewable forest resources and forest industries. Consequently, Finnish society pays great attention to the development of forestry and forest industries.

3. NATURE OF PEATLANDS

In terms of peatland area, Finland is one of the foremost countries in the world. The peatland area in Finland amounts to some 9.7 million ha. To this, another 700,000 hectares of peat soil under agricultural use should be added to arrive at a total figure of 10.4 million ha. Altogether one-third of the country's entire land area is considered to be peatland.

The Finnish peatland classification is based on the composition of the ground vegetation, which is considered to reflect the nutrient status of the site as well as being an indicator of other chemo-physical site factors (Cajander 1913). Quite recently Heikurainen and Pakarinen (1982) outlined a refined

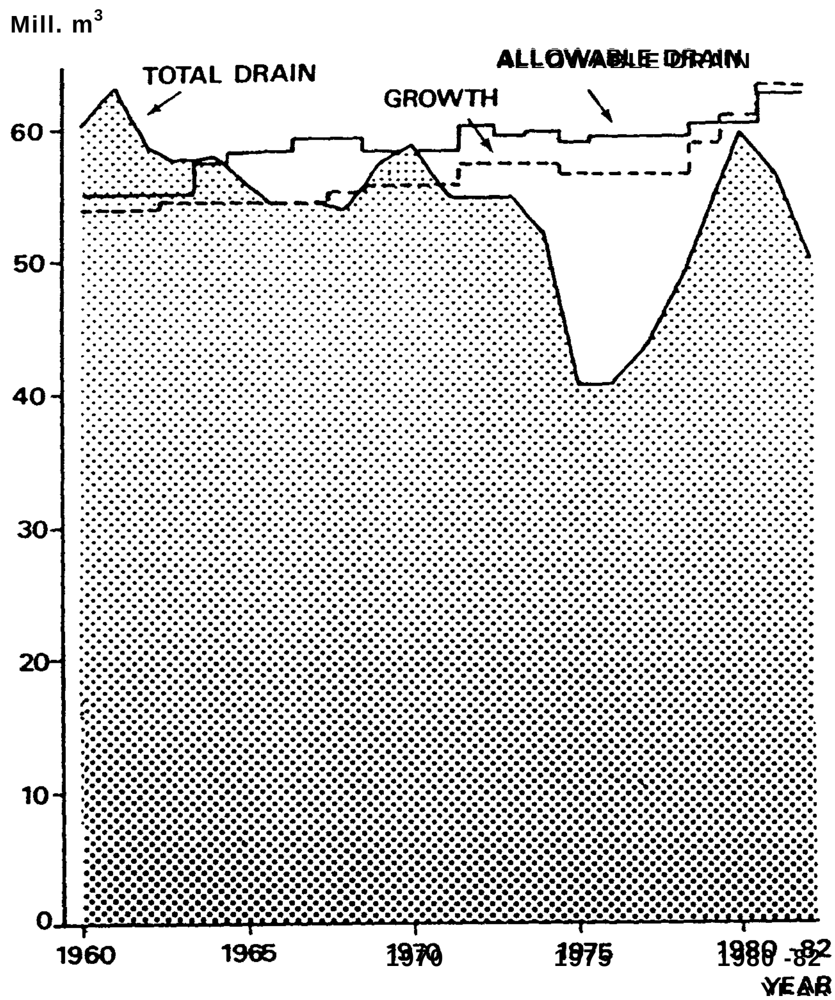

Figure 1 The difference between the allowable and total drain (forest balance), and the annual growth in 1960-82 in Finland.

version of the peatland classification system applicable to the boreal zone of Finland (60-69°N). In this classification a total of 40 site types are grouped into three major categories: hardwood-spruce mires, pine mires, and treeless mires. Norway spruce, a minerotrophic species, characterizes the hardwood-spruce mires, while the less demanding Scots pine is the dominant tree species of pine mires. Birch *(Betula pubescens) is* a common species in spruce mires, but may also be found in certain pine mires. Approximately 25% of the original peatlands were hardwood-spruce mires, 45% pine mires and 30% were treeless (open) peatlands.

At the regional scale two main peatland complexes are recognized in Finland: ombrotrophic mires (raised bogs) and minerotrophic mires (aapa and palsa mires), mainly due to the macroclimate and topographical factors (see Ruuhijarvi 1982a). The raised bogs receive their nutrients mainly from rainfall, whereas the aapa mires are dependent upon the surrounding mineral soil as the source of nutrients.

4. UTILIZATION OF PEATLANDS FOR WOOD PRODUCTION

4.1 Biological bases

In the case of undrained peatlands excessive water in the substrate checks root growth and microbial activity, and may lead to unfavorable biochemical phenomena. One of the most important tasks of draining is therefore to adjust the water content of the soil to a level which ensures sufficient aeration (Paivanen 1973).

It has been found that the plant sociological site classification (Cajander 1913) satisfactorily reflects the average fertility of surface peat in the virgin state (Westman 1981). Several Finnish studies have investigated the response of trees to drainage (e.g. Heikurainen 1959, Heikurainen and Kuusela 1962, Laine and Starr 1979). Also the continuity of post-drainage growth has been studied on naturally tree-covered peatlands (Seppala 1969, Heikurainen and Seppala 1973). Tree growth after drainage seems to increase gradually, even after the initial response period. At least we are sure that growth conditions do not decrease during the first rotation.

Sufficient data have been accumulated to be able to calculate the suitability of various peatlands for forest drainage (Heikurainen 1973). The most important factors used for calculating the profitability of drainage are: the site quality, the volume of the tree stand capable of response at the time of draining, the temperature sum, and the stumpage price.

Much of the drainage in Finland has been on the extensive areas of naturally tree-covered peatlands. The study of peatland afforestation has, therefore, received less attention than the effect of drainage on the growth of tree stands prevailing on the site already at the time of drainage. Nevertheless, afforestation problems have been studied also (e.g. Kaunisto 1975, 1982). In the Finnish Forest Research Institute basic research has developed a forest fertilization practice for peatlands (e.g. Paavilainen 1972, 1980; Karsisto 1974).

Forest drainage also has an effect on the runoff leaving the ditching area (Starr and Paivanen 1981) and the silvicultural treatments have an effect on the hydrology in the drained area (Heikurainen and Paivanen 1970, Paivanen 1982). Providing proper measures to ameliorate peatlands for forestry are taken, conditions can be created suited to timber production.

4.2 Peatland drainage - past and present

The oldest areas drained for forestry are about 110 years old. Ditches were dug during famine years to decrease unemployment. More systematic forest drainage activity started on State-owned lands in 1908 and on privately-owned lands in 1928. By World War II the drained peatland area was about 700,000 hectares.

In the post-war years drainage work picked up again from about 1950. But it was not until the 1960's that forest drainage activity **developed** into a nation-wide campaign to increase the forest growth. Figure 2 shows the development of forest drainage activity during the last three decades. The annual drainage area increased steadily to 1969, when a maximum of 295,000 ha was drained. The annual drainage area has since decreased and is now below 100,000 ha. The total area drained for forestry is about 5.5 million ha, the bulk of which is comprised of peatlands, **although** about 1 million hectares of land classified as paludified mineral soil are included in this figure. The objective is to drain approximately 6.5 million hectares in all.

Most of the drainage has taken place on private forests (Figure 2). Forest amelioration activity on private forests is entrusted to the Central Forestry Board Tapio, an organization promoting private forestry. Drainage operations on private land are co-operatively performed projects. The Government subsidizes forest drainage on private forests by paying about 60% of the total drainage costs; partly as grants, and partly in the form of low-interest loans.

4.3 Drainage requirements

The *ditch depth* used varies for different peatland sites, ranging from 65 cm for shallow peats to about 90 cm for deep peats. Deeper ditches are necessary in wet, deep peats because of increased peat subsidence. The optimal ditch depth, however, is dependent on the *ditch spacing.* The drainage norm achieved with different combinations of ditch depth and spacing is furthermore dependent on such factors as climate, topography, hydraulic conductivity of peat and vegetation (Meshechok 1969, Braekke 1983).

The *economically optimal ditch spacing is* always wider than the corresponding *biological* one. It is affected by the digging costs and the discounted return due to drainage (Keltikangas 1971). On naturally tree-covered peatlands the volume of the tree stand is reduced due to the cleared ditch lines. This reduction in tree volume increases as the ditch spacing decreases (Seppala 1972). The ditch depth and spacing recommendations presently used for *contour ditches* in Finland are presented in Table 1. For further details concerning the design of drainage systems see Paivanen and Wells (1977).

Ordinary open ditches remove water more effectively than plastic pipe drains (Paivanen 1976), and the former type of contour ditches are almost exclusively used in practice.

On open peatlands water furrows also are used. The drainage ditches are spaced 30 to 40 m apart, and the furrows are placed perpendicularly to them at 3 to 5 m spacings. The water furrows are 25 to 50 cm deep and are made by rotary ditchers or site preparation plows. The water furrows shorten the period of high ground water and contribute to the lowering of the water table, particularly in the case of wide drainage-ditch spacing (Paivanen 1974). Simultaneously, furrowing acts as a form of site preparation for afforestation.

FOREST DRAINAGE AREA IN 1950-80
BY FOREST OWNER GROUPS

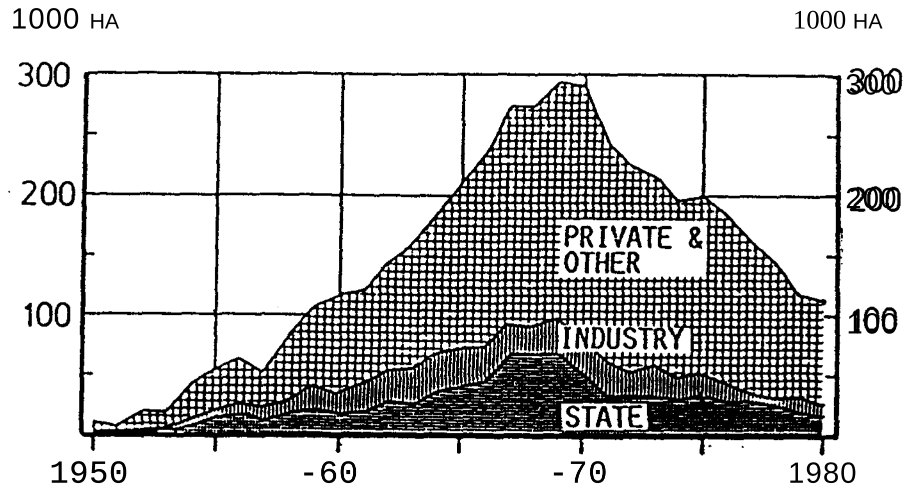

Figure 2. Forest **drainage** in 1950-80 by **forest owner groups in Finland.**

Table I. Ditch depth and spacing recommendations presently used for different sites in Finland.

Sites	Drainage ditch Spacing (m)	Density (m/ha)	Depth (m)	Size (m'/m)
Tre -enyt red pea Hands				
Shallow peat soils (and wet mineral soils)	50	200	0.65	0.55
Deep peat soils of good quality	40	250	0.75	0.70
Deep peat soils of poor quality	30	333	0.75	0.70
Open pentlands				
Fens	30	333	0.80	0.75
Bogs	25	400	0.80	0.75

Trap ditches collect surface and subsurface water entering the drainage area. These ditches are dug along the border between the peat-covered sites and the surrounding mineral soils.

The design of a *main ditch is* dependent mainly on its capacity to lead water away from the site. The water in the main ditch should not rise above a level that would prevent the drainage ditches from discharging. In bigger drainage areas the dimensions of the main ditch are calculated on the basis of the average peak flow (MHq)' which takes into consideration the influx of spring snowmelt.

4.4 Drainage equipment and costs

Until the early 1950's, forest ditches in Finland were dug manually. Mechanized forest drainage commenced in 1953 with the introduction of forest ditch plows (Huikari 1958). Optimal conditions for plowing are found in the large homogeneous peatland areas of northern and eastern Finland.

The forest ditch plows have a weight of 5,000 to 6,000 kgs and require heavy tractors (14-18 tons) with a surface pressure not exceeding 30 kPa. In making the ditch the plow is pulled by means of a winch, the hauling resistance reaching 100 to 120 kN-force. A standard ditch may be plowed into firm peat soil at a rate of 500 to 600 in per hour.

The amount of ditches made by plowing has decreased during the last decade (Figure 3). The most common machine used now is a tractor digger or backhoe. These are units consisting of a prime mover and hydraulic excavating equipment. The prime mover is usually a light-track tractor with a 45 to 75 kW engine. Forest ditches are dug longitudinally with a bucket scoop, and the cross-section measurements conform to the standard forest ditch dimensions. The equipment should have a loosening force of 60 kN and a lifting force of 20 kN. A long reach is also important; it should be possible to dig at least 4 in of forest ditch from one position. The operator must be able to operate both the excavating equipment and the power machine from the same place. In the field, the unit is steered by means of the brakes and the hydraulic excavating equipment. The work output of a tractor digger is 70 to 90 m of forest ditch per hour. At present about 80% of all forest ditches are dug with tractor

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'MHq = mean maximum flow m'/sec/km'

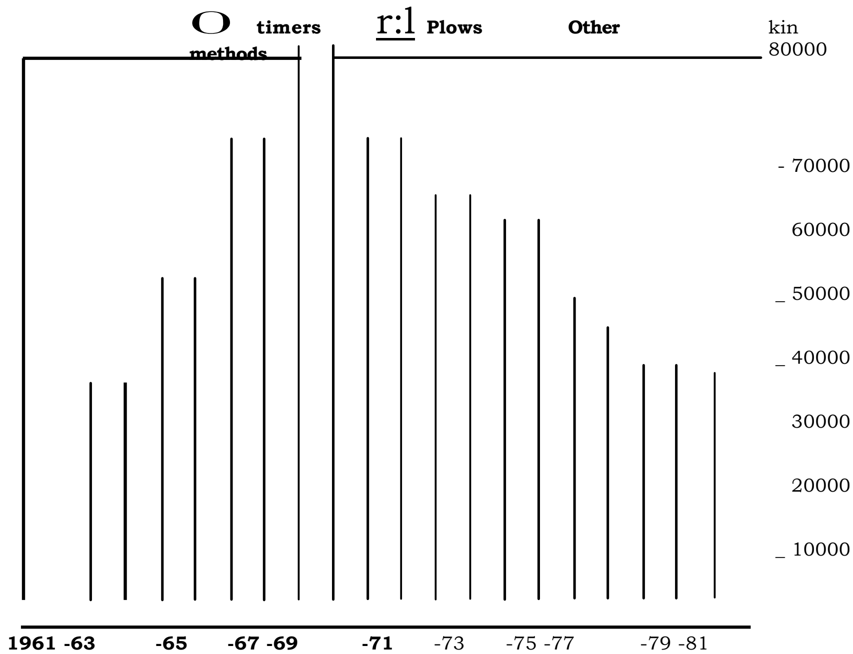

Figure 3. **Forest drainage in 1961-81** by digging methods in Finland.

diggers, and the total number of units of this kind number in the hundreds.

During the past few years rotary ditchers have also been used, mainly for furrowing and site preparation for afforestation. Some of them are capable of making either vertical walled, narrow ditches or ordinary open ditches. Rotary ditchers cannot, however, be used as general ditching machines because their use is restricted to deep peat soils. In the case of open peatlands standard forest ditches can be dug by rotary ditchers at a rate of 60 to 200 m/hour.

Tractor diggers are the most commonly used equipment in forest drainage because they have the following advantages in comparison with forest ditch plowing:

a. Easier to move from one drainage site to another. The tracks can be taken off and the unit can be driven along paved roads. The heavy plowing units have to be transported on big trucks.

b. A great mobility in the field. This means that the drainage ditches can be placed solely on the basis of hydrological requirements. For efficient plowing, the ditches ought to be long and, consequently, they may not always be the best hydrologically.

c. Smaller dimensions. On tree-covered peatlands less damage is caused to the standing trees.

d. Possible to dig according to a ditch profile. This makes it possible to use the same machine for digging both drainage and main ditches.

e. The ditches are more durable, keeping their form and repair better than plowed ditches. In plowing, the peat soil is both pressed to the side and lifted up from the ditch. With a tractor digger all the soil is extracted.

f. If necessary, the removed soil can be put on one side of the ditch. This may be an advantage when making trap ditches or when a road is going to be made along the ditch.

g. Water outlets for surface runoff can be left where there are depressions in the ground. The overturned peat on both sides of a plowed ditch may slow down surface runoff.

h. No need for manual work. When using a forest ditch plow it is necessary to open ditch ends with a spade.

Most ditch digging is performed by private contractors. Work studies to determine expected production rates as a basis for payment are performed by research organizations. The main aim of work studies is to determine the performance level of digging units for different kind of conditions. The cost level per hour and the digging costs per m' in different digging difficulty classes are agreed upon annually between the associations of contractors and employers.

The digging cost for a standard size forest ditch (0.70 m'/m) varies from 1.2 to 2.8 FIM/m) the total cost amounts to about 600 FIM/ha. When the expenses of the drainage planning and main ditches are added, the total may reach about 800 FIM/ha.

4.5 Fertilization and other silvicultural measures

More than two million hectares forest land have been fertilized, which is more than 10 percent of the total productive forest land. Half of the fertilized area is peatland.

Fertilization recommendations for tree-covered drained peatlands vary according to the quality of the site type, stage of development of the tree stand, etc. On fertile and medium quality sites PK fertilizer is applied in quantities corresponding to 30-50 kg/ha and 40-80 kg/ha of P and K, respectively. Poor sites require an additional 50-100 kg/ha of N. The duration of fertilizing influence for phosphorus and potassium is 10-15 years, and for nitrogen 5-7 years.

First commercial thinning is regarded as a highly important silvicultural measure in Finland. In addition to determination of the growing density and the species composition of the stand it is still possible in this phase to influence the quality of the residual growing stock. However, from the viewpoint of tree growth, intensive intermediate cuttings that cause a rise of the **ground** water table ought to be avoided on drained peatlands. The biological **drainage** effect of the tree stand in itself (evapotranspiration) is of great importance, particularly on old drainage areas where the ditches may have collapsed (Paivanen 1982). The mechanization of ditch cleaning work is still under progress. Only one excavator specially developed for the maintenance of

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old ditches at present has been evaluated (Vuollekoski 1983). **4.6**

Yields and benefits of forest drainage

The **profitability** of draining peatlands is dependent on the fertility of the site, on the state of the existing growing stock and, thirdly, on the **geographical** location of the site. These factors have a bearing on the growth on the trees **subsequent** to **drainage** of the site. As a generalization, it may be said that drainage becomes more profitable with increasingly fertile sites, the more timber there is on the site, and the further south the site is located.

One of the major factors influencing postdrainage growth and development of tree stands is macroclimate. Figure 4 demonstrates the effect of climate and site type on tree growth after drainage. To obtain the growth increase resulting from drainage the average growth of the tree stands in virgin condition has to be subtracted from post drainage growth. This subtraction in southern Finland for some representative sites is as follows:

	m'/ha/a
Herb-rich spruce mire and *V. myrtillus* spruce mire	4.0
Ordinary sedge pine mire	0.3
Dwarf shrub pine bog	0.5

Heikurainen (1982) gave the following estimate of the increase in forest growth due to forest drainage: "The magnitude of this increase in growth and subsequent removal will naturally depend on the range of stand maintenance and, more especially, on the extent to which fertilizer application will be performed in the country. If we assume that the drained area will reach a figure *of 6.5* million hectares, and if only the poorest sites are fertilized, the annual increase in stand increment will be approximately 13 million cubic meters. If, on the other hand, the application of fertilizers is extended to all peatlands where it is practically possible and economical, the corresponding increase in growth will approximate 17 million cubic meters. The true figure will **probably** actuate something in between these two estimates, commonly thought to be around 15 million cubic meters."

The estimate (Heikurainen 1982) also predicts when the above-mentioned increases can be expected (Figure 5). Based on the results of

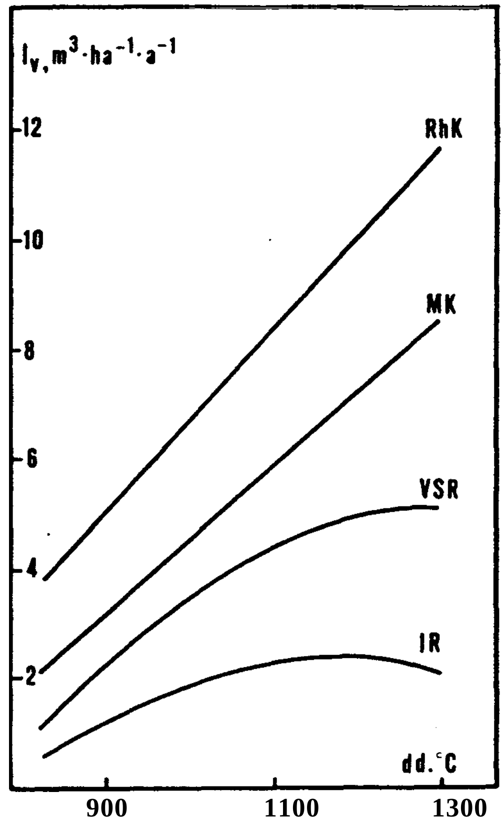

Figure 4. The effect of accumulated temperature sum (dd °C) on the volume increment on certain peatland site types (RhK= herb-rich spruce mire, VK= V. *myrtillus* spruce mire, VSR=ordinary sedge pine mire, IR=dwarf shrub pine bog) (According to Laine and Starr 1979).

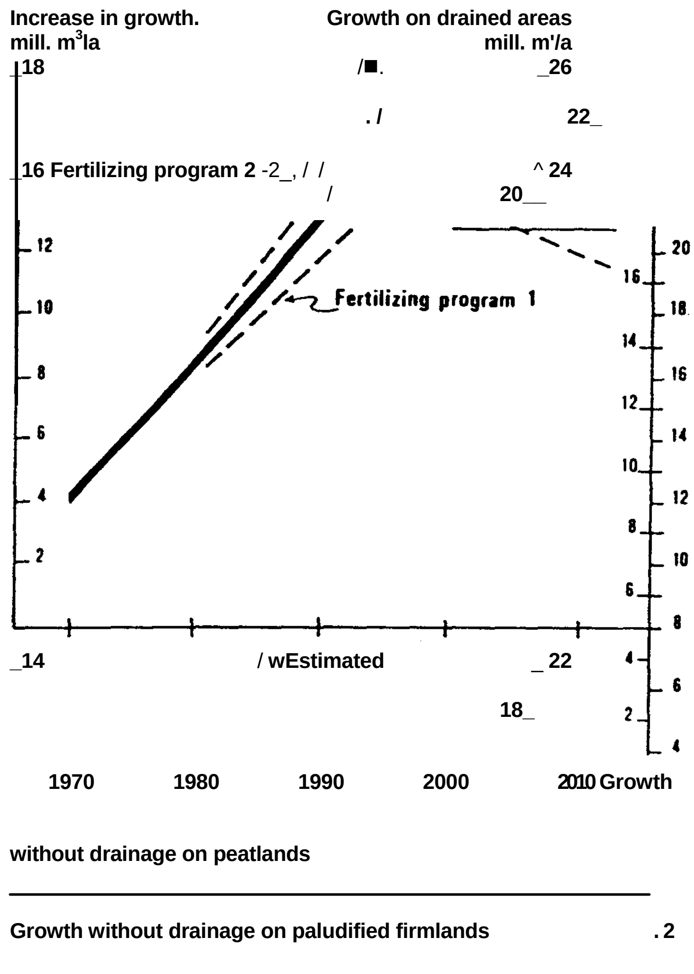

Figure 5. The increase in growth due to forest drainage

and the future growth on drained areas in Finland
(According to Heikurainen 1982).

the National Forest Inventories the effect of peatland forest drainage and amelioration on the annual volume increment at present is at least 7 million m' (Paavilainen and Tiihonen 1984). This means that the two different approaches are in close agreement.

An attempt has also been made to estimate the profitability of forest drainage by calculating the inputs (all cost factors) and outputs (the increase in allowable cut evaluated with stumpage prices). Accordingly, the internal profitability percentage in the Finnish forest drainage activity would lie somewhat above 5% (Heikurainen 1980). The indirect effects (employment, balance of payments, etc.) are not included in this estimate.

5. UTILIZATION OF PEATLANDS FOR OTHER PURPOSES

As a source of ***wild berries*** (the most **valued** are cloudberry, ***Rubus*** *chamaemorus,* and cranberry, *Vaccinium oxycoccos)* the significance of peatlands is high. In northern Finland the local people in the rural areas are dependent on the cloudberry for a sizeable share of their annual income. The State encourages this manner of utilization by making income from wild berries tax-free.

Agricultural use of peatlands began with harvesting of fodder for cattle in the form of wild grasses. This was followed by a form of shifting cultivation. At present, the peat-based area under cultivation amounts to 700,000 hectares which represents nearly 30% of our arable land. This percentage is bigger in the northern region of Finland; in places, over 50% of the present arable land has at one time been virgin peatland. In southern Finland the most fertile sites have been favored for converting peatlands to arable land.

Peat itself has two main uses; as *fuel* and *horticultural peat* (substrate). The bulk of the peat harvested is used as fuel. In 1982 fuel peat production reached the level of 17.7 million m' (Table 2). Fuel peat amounts to about 2% of Finland's total energy consumption, equaling 25 Mtoe'. The total peatland area under production in 1982 was 38,000 ha. About 100,000 hectares

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Mtoe = 1.128.10'MWh = 4.061.10'GJ

Table 2. Fuel peat harvesting (1000 m') in Finland (According to Harme 1982).

Method	1979	1980	**1981**	**1982**
Milled peat	4,300	8,300	3,300	16,100
Sod peat	320	880	590	1,600
Total	4,620	9,180	3,890	17,700

of peatlands will be reserved for peat harvesting. This is, however, a relatively small fraction of the total peatland area of the country (Harme 1982).

Peatland areas have also been used for *reservoirs* in hydroelectricity production, which is an extreme example of their utilization. In Finnish Lapland there are two vast reservoirs, the total area of them being 63,000 hectares. One of the two is situated on what was Finland's biggest single peatland complex.

The flora and fauna of the various peatland complexes and peatland site types should be **preserved to** a **sufficient** degree. A nation-wide ***conservation plan*** *for* ***peatlands*** **covering 498,000** ha has been worked out. Thus, the proposed area to be preserved comprises approximately 5% of the original peatland area of the country. Additionally, there are about 200,000 ha of peatlands in the National Parks or other conservation areas of the National Board of Forestry (Ruuhijarvi 1982b). Including the poorer site types, which have little value for forestry, the peatland area to be preserved in a natural state will be about 2.5 million ha. However, the planned preservation of privately-owned land, about 154,000 ha, is difficult to realize as funds for purchasing the areas in question are limited.

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