The forests and forest research in Finnish Lapland

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Figure 11. A view from the Pyhätunturi National Park, Kultakero slope, in Pelkosenniemi, over to vast expanses of forests and bogs of Peräpohjola, central Lapland. In the foreground the Tunturiaapa mire and in the background the Javarus fells. Photo: Erkki Oksanen.

The forests and forest research in Finnish Lapland

The forests in Fennoscandia (Norway, Sweden, Finland, the Kola Peninsula) extend further north than anywhere else in the world. Thanks to the nearness of the Gulf Stream, the conditions for forest growth are reasonable even in Finnish Lapland where one-third of Finland's land area, 16% of the country's timber resource and 10% of its annual increment are to be found.

Forest growth in Lapland is a slow process. Given the equivalent land area, forest growth there amounts to a mere fifth of what it is in southern Finland. Thanks to larger holdings and the marked presence of State forestry in the region, forestry in Lapland has been practised with efficiency.

Forests are of great importance to Lapland. Forestry industry accounts for 50% of the region's industrial production and 70% of its export earnings. Other important forest uses besides traditional forestry are conservation, reindeer husbandry, collecting of wild berries and mushrooms, hunting, and tourism.

The region's forests are also targets of intensive research. Wood production studies have, during the past few decades, been joined by studies emphasising other themes, especially forest health and multi-purpose forestry studies.

The boreal coniferous forest zone and the timber line

Development of Lapland's forest vegetation following the Ice Age

The present-day vegetation of Finland – and of Lapland – is the result of development since the end of the most recent glaciation (i.e. the Würm glacial stage) ca. 10 000 years ago. Birch, a pioneer tree species to this day, was quick to colonise the land revealed by the receding ice. During the boreal stage, ca. 6 800–5 500 B.C., the region's forests developed into mixed woods dominated by Scots pine but with an abundant admixture of broadleaved species. With climates warmer and more humid than the present one, the Atlantic climatic interval prevailed from ca. 5 500 B.C. to 2 000 B.C. In those times, the timber line, for instance, was located as much as 200 m higher up the fell sides than at present and paludification of forest land became more commonplace. Norway spruce arrived in Finnish Lapland from the east as recently as ca. 4 000 years ago and commenced to invade sites from pine.

The climate in Lapland has changed so little during the past 2 000 years that it has not decisively influenced the distribution of tree species. Short-term variation has, however, taken place. Cool summers, the crop-failure years of the 1860s, and especially the exceptionally warm years of the 1930s, when promising results were obtained concerning forest regeneration in the timber-line regions, are all examples of this variability.

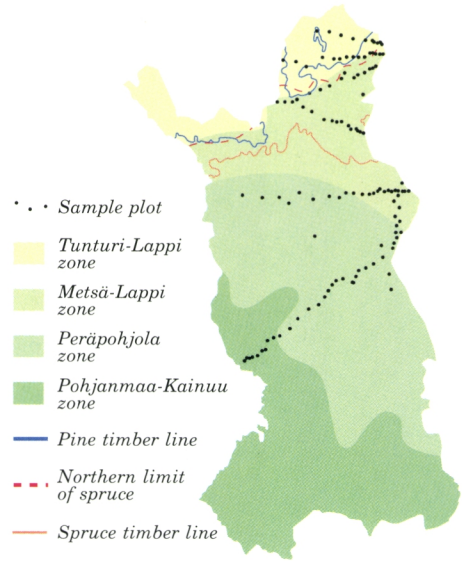

Figure 12. Northern Finland in terms of its vegetational zones and the distribution of conifers as shown in Suomen kartasto (1988) and the Lapland Forest Damage Project's sample plots.

Northern Finland in terms of vegetation zones

Finland falls within the coniferous forest zone encircling the Earth. Part of the coniferous zone lies within the boreal zone. Climatically, this zone corresponds to the cool zone (*Dfc* according to the Köppen-Geiger-Pohl scheme), where the mean temperature of one to three summer months exceeds +10 °C. North of the boreal zone is the Arctic-Alpine region, which belongs to the Earth's tundra vegetation zone. It comprises the tundra north of the timber line and the alpine areas above montane timber lines.

The southern part of Lapland belongs to the hemi-boreal zone, whose northern boundary follows the northern boundary of the Pohjanmaa–Kainuu vegetation region in Finland. Most of Lapland belongs to the northern boreal zone; within Finland, this zone may be subdivided into the vegetation regions of Peräpohjola and Metsä-Lappi (Fig. 12). North of the coniferous timber line lies the subalpine-subarctic birch forest zone. In Finnish Lapland, the two northernmost municipalities, Enontekiö and Utsjoki, cover most of this zone.

The region referred to as Pohjanmaa–Kainuu (or the Province of Oulu) is the transition zone between southern and northern Finland. Southern and northern flora and vegetation types meet here. Of the tree species, alder (*Alnus glutinosa*) is at its northern limit in the northern parts of this region. The southern limit to the abundant occurrence of dwarf birch (*Betula nana*) follows the region's southern boundary.

In the north, the Peräpohjola zone extends to the spruce timber line. Grove-like, lush forests are very rare there. The so-called thick-moss type (*Hylocomium-Myrtillus* type) is the characteristic forest type in Peräpohjola and Norway spruce (*Picea abies*) forms climax stands with an admixture of downy birch (*Betula pubescens*). Such forests have in many places been converted into plantations of Scots pine (*Pinus sylvestris*). There is an abundance of lichen-rich stands of pine.

The main tree species in the Metsä-Lappi (or Forest Lapland) zone is Scots pine. Birch occurs as an admixture among the pine; on more fertile sites, birch may be the main tree species.

Tunturi-Lappi (or Fell Lapland) is a transition zone between the boreal and arctic zones. This is a zone dominated by mountain (fell) birch (*Betula pubescens subsp. czerepanovii*); stands of Scots pine occur only in the larger river valleys. The flora in stands of mountain birch resembles that of the coniferous forest zone. The most extensive treeless fell-top areas are to be found in the Muotka fells (Inari), Pais fells (Utsjoki) and the North-west Arm (Enontekiö) (Fig. 13).

Several of the Lapland Forest Damage Project's sample plot lines cross over two forest vegetation zones. Sample plots along Line #1 fall within the Pohjanmaa–Kainuu and Peräpohjola zones. In the Russian territory the conditions on the sample plots show greater similarity with Metsä-Lappi than Peräpohjola. Due to variation in topography and local pollution sources (the towns of Kemi and Kemijärvi), Line #1 poses some problems. Line #2 is very representative of the east-west gradient. Sample plots on the Finnish side of the border along this line fall mainly within the Peräpohjola zone. Lines #3 and #4 pass through Metsä-Lappi while the northernmost Lines #5 and #6 mainly pass north of the pine timber line within the Tunturi-Lappi birch forest zone.

Pine forms the coniferous timber line in Finland

Contrary to the situation elsewhere in the Northern Hemisphere, it is Scots pine (not spruce or larch) which is the northern timber line species in Fennoscandia (inc. parts of the Kola Peninsula) (Fig. 12). Much

Figure 13. Treeless fell-top areas, main watercourses, the Finnish Forest Research Institute's research stations and areas and the Universities' research stations in Lapland.

favoured explanations for this phenomenon include distribution history of trees and climatic reasons. Edaphic factors have also been put forward.

The spruce timber line passes via Pallas-Ounas fells (in Enontekiö) to Ivalojoki river (Inari) and then on to the Saariselkä fells (Figs. 12, 13 and 14). Single spruces and clumps of spruces may, however, be encountered north of this line.

The pine timber line passes via the Enontekiö fell area to the Muotka fells and then along

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Figure 14. The northern timber line for Norway spruce (Picea abies) on top of Kuusipää, Saariselkä, Inari.

the northern shore of Lake Inarijärvi to Näätämöjoki river (Figs. 12 and 13). North of this line, regular stands of pine are to be found only in the Utsjoki and Kevojoki river valleys, around Lake Pulmankijärvi, and along the shores of fjords on the Arctic Ocean.

Mountain birch occurs almost throughout Tunturi-Lappi. In the fells of the Inari region, as well as in some places to the south, but especially in the North-west Arm region of Finland, the climate becomes so extreme that mountain birch, too, has to give way to the treeless fell-top areas. Aspen (*Populus tremula*) will sometimes grow among the mountain birch. When it does, it often occurs as vegetatively arisen clones, extending into the Utsjoki river valley.

Climate the principal factor in determining the timber line

The present-day distribution of tree species is primarily the result of climatic factors. In addition to the temperature conditions during the growing season, critical temperatures significantly differing from the average temperature and wintertime winds also contribute to the formation of the timber line.

Topography determines the abruptness of the timber line. Conifers and birch appear to use the protection of depressions in creeping up the more gentle slopes. On steep slopes the timber line is very distinct.

The soil also has an influence on where the timber line occurs, especially in the case of spruce. In the northernmost Lapland, the soils are so deficient in nutrients that spruce cannot survive there. On the other hand, it may be that spruce has still not reached the peak of its distribution – after all, it arrived in what is now called Finland considerably later than pine. Biotic factors are also involved at the local level in the formation of the timber line. In 1965–1966, mountain birch over an area of ca. 500 000 ha in northern Norway, Sweden and Finland was damaged to varying degree by an epidemic of autumnal moths (*Oporinia autumnata*). At Kaunispää, in the Saariselkä fells of Finnish Lapland, pine sawflies (*Neodiprion sertifer*) kill pines on upland sites.

Forests under natural forces and the action of man

Wildfires moulded forest structure

Up until the turn of the century, wildfires played a role in the natural tree-species cycle within the boreal coniferous forest zone. Lit by lightning or man, these fires moulded the look of the forests. Spruce was forced to give way; birch, aspen and pine gained more room.

The area of state land annually burnt in the late 1800s has been estimated to have been 0.1–0.5% of the total area of forest land. Studies conducted in northern Sweden have arrived at an estimate of less than 100 years for the average interval at which wildfires have occurred in forests on dry heathland soils. In northern Finland's thick-moss (*Hylocomium-Myrtillus*) type of spruce stands fires have occurred at considerably longer intervals, perhaps every 400–500 years. The most recent major forest fire in Lapland occurred in 1960 when ca. 20 000 ha of forest was burnt in the Tuntsa district of Salla, eastern Lapland. In Russian territory the affected area was even greater.

Early stages of reindeer husbandry and the spread of human settlement

The original Sámi (Lapp) settlement of Lapland was characterised by its sparseness. Reindeer husbandry, hunting and fishing were activities that did not require a great deal of wood. It was mainly firewood and construction timber for shelters and fencing that were consumed in those times. One sign of the impact that reindeer husbandry had on the forest scene was in the so-called *luppo* (beard lichen) swidden sites of the late 1880s: thousands of hectares of lichen-bearing spruce were felled in the winter to provide reindeer with emer-

gency fodder. It is also known that reindeer herders burnt remote pastures in order to make the reindeer stay closer to their camps. Out of envy and spite, too, some would burn the choicest lichen pastures.

The spread of the settlement of the country by Finns was accompanied by intensification of forest use. The swidden (also referred to as shifting cultivation or slash-and-burn) practice in agriculture, very common in southern Finland, was adopted as far north as Rovaniemi in the 1800s. Its common application, however, went no further than Kuusamo (Fig. 15). Farming in Lapland was mainly based on using the natural meadows along the banks of rivers and some clearing of arable land. Wasteful from the viewpoint of forestry, tar distilling was not practised in Lapland. In the Province of Oulu the situation was quite the opposite. There tar distilling was so popular in the 18th and 19th centuries that, in its peak times, the consumption of pine is estimated to have risen to ca. 3/4 of the present-day level in wood consumption. The northernmost tar distilling places were in the Iijoki river valley.

The human influence on the forests of Lapland remained moderate right up to the turn of the century. In southern and central Finland this was not so. The greatest impact was caused by forest fires, although these were usually confined to small areas due to the humid climate and the plentiful occurrence of peatland. To quote Claës W. Gylden, who was invited to make an assessment of Finland's forest resource, Lapland in the 1850s had "more than enough forests".

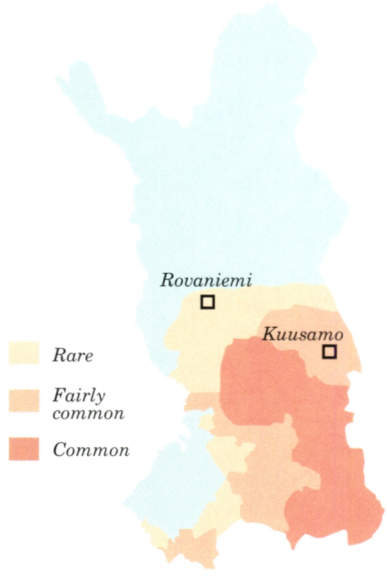

Figure 15. The extent of swidden (also referred to as shifting cultivation or slash-and-burn) agriculture in northern Finland in the 1860s.

Increasing use for wood

Finland's first steam-powered sawmill, the Kestilä sawmill, was granted its charter to begin operating at the mouth of the Iijoki river in 1857. This signalled the beginning of industrial consumption of wood in Lapland. In the course of the "Big Reallocation" of land in the mid-1800s, most of Lapland's forests went to the Crown. The Forest Service, the predecessor of today's Forest and Park Service, was created for the purpose of administering these lands. The mapping and inventorying of Lapland's forest resource began. The annual felling area system was adhered to in government forestry.

The principal felling method applied was diameter-limit felling, or culling for sawtimber. Although attempts were made by the Forest Service in government forestry as early as 1907 to shift over to forest management by stands, diameter-limit felling remained the sole method in public and private forestry right up to the early 1920s. Sawtimber-sized pine was the prime target. Forest regeneration was not practised and consequently the resulting stands became understocked. Exports of sawngoods were at their peak and wood was floated to the mills along the Tornionjoki and Kemijoki rivers. In the 1920s and 1930s, timber floating was also practised in northernmost Lapland, along the Paatsjoki river to the shores of the Arctic Ocean (Fig. 13).

Aimed especially at preventing a southward shift in the timber line and at imposing restrictions on the forestry practised in northernmost Lapland, the Protection Forest Act was passed in 1922. Some three million hectares of forest were set aside to act as a barrier against the tundra. The Private Forestry Act of 1928 provided means of steering and supervising private forestry. These Acts heralded the beginning of an era of systematic forestry in Lapland as well. Up to World War II, the forestry practised was mainly based on the felling of sawtimber-sized trees and confidence in natural forest regeneration.

Era of artificial regeneration in forestry begins

World War II and the subsequent territorial losses, reparations bills, reconstruction and resettlement caused a major change in the way that forestry

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Figure 16. Ploughed pine regeneration site in Naruska, Salla, in August, 1994. The seedlings are infected by the Scleroderris canker fungus (Gremmeniella abietina).

was practised in Lapland as well. Immense logging operations were set up in remote wildernesses and unprecedented amounts of timber were felled. The reparations bills were paid for largely with timber from Lapland.

Expansion in forestry was not possible without some major changes being made regarding the logging methods applied. Diameter-limit felling was discarded in favour of active natural forest regeneration and especially artificial forest regeneration (i.e. renewal by sowing and planting). The primary policy adopted in exploiting the forest resource in Lapland was one of speedy and extensive regeneration of mature forests. This activity focused especially on the region's thick-moss (*Hylocomium-Myrtillus* type) stands of spruce as these were believed to be initially highly productive sites for forest growth. Clear felling and artificial regeneration to pine (initially by sowing following prescribed burning) became the standard solutions when dealing with these old stands of spruce. Site preparation by scarifying was also applied.

Planting of pine and ploughing as an aid in regeneration became popular practices in the 1960s (Fig. 16). This was also the time when mechanisation of forestry work got underway. Chainsaws replaced handsaws, forwarders replaced horses. The labourer with his hoe had to step aside when site preparation machinery, scarifiers and ploughs, drawn by bulldozers and forwarders, were brought to the forest. Drainage of peatlands for forestry became a mechanised operation with ploughs and mechanised diggers replacing manual work. The mechanisation of forestry work was "brought to conclusion" in the early 1990s: multifunction forestry machinery, typically harvesters, now carry out almost all of the timber harvesting in Lapland as well. The motor-manual alternative is employed when carrying out first-thinning, planting and sowing work in stony terrain inaccessible to mechanised systems.

The 1950s and 1960s were the golden era of timber floating (or river driving). In those years the annual roundwood volumes of timber transported by water were in excess of three million cubic metres. Road and rail transportation have subsequently taken over from floating. River driving on the Tornionjoki river ended in 1971 and in 1991 it ended on the Lapland main route of the Kemijoki river.

Forestry industry expands

Up to the 1920s, the consumption of wood by industry in Lapland was based solely on the demand coming from sawmills. Lapland's oldest large-scale forestry industry enterprise, Kemi Oy, was founded in 1893. The company originated from the stock of shares of a large, private company which had started as a sawmilling enterprise. In 1919, Kemi Oy built Lapland's first pulp mill in Kemi. The second such mill went into operation in 1927.

Lapland's biggest forestry industry enterprise, Veitsiluoto Oy, came into being when Parliament, in 1919, approved a bill for the founding of a new sawmill on the coast of the Gulf of Bothnia. The sawmill was built in Kemi in 1922, and the sulphite pulp mill went onstream in 1930. Thus was formed a firm base for the large-scale utilisation of wood in Lapland.

The next significant expansion of forestry industry was the founding of Kemijärvi Oy in 1965. Three years later this cellulose plant was merged with Veitsiluoto Oy. The Kemijärvi plant meant a considerable increase in the demand for timber from north-eastern Lapland.

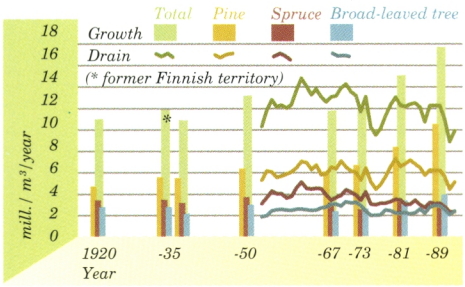
The stages in the development of forestry industry in Lapland are typical for Finland's integrated industry: the water-driven sawmills along the Kemijoki river were replaced by steam-driven mills and these in turn gave way to companies mainly active in the chemical forestry industry sector. Nowadays, forestry industry production emphasises printing and fine paper grades, cartonboard, cellulose, sawngoods and products serving the building industry.

Lapland's forest resource

The first inventories

Prior to the 1920s, estimates concerning Lapland's forest resource were mainly based on calculations made in conjunction with the mapping of government lands. It was not until the 1st national forest inventory (NFI-1), led by Academician Yrjö Ilvessalo and with the field work carried out during the years 1921–1924, that the first reliable information on Lapland's forests became available. The then area of Lapland, demarcated in accordance with the main watersheds, was found to contain a total wood volume of 343 mill. m^3 on forest land; this gave an average per hectare volume of 43 m^3. The proportion of pine-dominated forests of the area of productive forest land was at its greatest within the Arctic Ocean watershed area (76%). The proportion of pine-dominated stands in the areas adjacent to the Tornionjoki, Muonionjoki and the Kemijoki rivers was 53%, whereas within the eastern Tuntsajoki and Oulankajoki watersheds it was only 34% (Fig. 13). The proportion of peatlands was at its maximum within the Kemijoki watershed, namely 47.3% of the total land area. In the then Lapland, the proportion of peatlands averaged at 38%. A mere 24% of these were productive forest land.

Figure 17. Volume increment (o.b.) and total drain (o.b.) of the growing stock in northern Finland during the period 1916–1992. (Source: NFI)



In 1936–1938, just before World War II, Yrjö Ilvessalo supervised the 2nd national forest inventory (NFI-2) over the then territory of Finland. The results of the inventory revealed that the country's forest resource had decreased by ca. 25 mill. m^3. In other words, wood harvesting had clearly exceeded growth.

The results of the NFI-3 (conducted in 1952–1953) showed, to everyone's surprise, that Lapland's forest resource had now increased. The total volume recorded was 310 mill. m^3. This was most probably due to the exceptionally warm climatic period and reduced harvesting during the war years. This contributed to a policy of significantly increased felling of timber in Lapland.

The fourth national forest inventory, the NFI-4 (1962–1963), led by Yrjö Ilvessalo, was the last one based on the method of systematic line survey. The effect of increased felling showed up clearly in the results. The volume of the growing stock had reduced by 40 mill. m^3 in the space of fifteen years. The fall was most marked in the case of pine volumes. Forest growth had also decreased despite the creation of extensive regeneration areas.

The current forest structure

Since the NFI-4, Lapland's forests have been inventoried once every 10 years on average. Professor Kullervo Kuusela supervised the NFI-5 (1969–1970), based on the block method. The NFI-6 (1970, 1974–1976) and the NFI-7 (1978, 1982–1984) of Lapland's forests, developed by Professor Simo Poso, forest engineer Matti Kujala and doctor Eero Mattila, were carried out using combinations of two-phased interpretation of aerial photographs and field measurements. The results obtained from the inventories demonstrated the impact that extensive felling had had on the growing stock. The increase in the proportion of growth contributed by juvenile stands and drained peatlands has increased the total annual forest growth in Lapland from 6.1 mill. m^3 (NFI-5) to 7.55 mill. m^3 (NFI-7). The increase in forest growth has also led to an increase in the total volume of the forest resource since the days of the NFI-5. However, the total volume is still less than it was in the 1950s.

The annual growth of pine, spruce and broadleaved species in northern Finland (i.e. the Province of Lapland and most of the Province of Oulu), a region for which inventory results have been output since the NFI-1, varied between 11 and 13 mill. m^3 in the results provided by the first five inventories (Fig. 17). In the 1980s the increase in growth was vigorous. With felling focusing on mature forests, the annual drain exceeded annual growth up to the 1970s. Felling was at its height in the 1960s. The slump of the mid-

1970s, as well as the 1990s' recession, clearly stand out in the drain figures. For Lapland, too, the 1990s has been a period of surplus growth.

Scots pine is the leading tree species in Lapland. It accounts for 60% of the region's total growing stock volume. In the three northernmost municipalities of Utsjoki, Enontekiö and Inari, pine accounts for 93% of the area of forestland and scrubland combined. Birch dominates the so-called wasteland category of forestry land in the fell areas; these are of little value from the viewpoint of forestry. Elsewhere in Lapland, the proportion of pine falls slightly as one moves eastward. On combining forestland and scrubland in the jurisdiction of the Lapland Forestry Board, pine is the dominant species on 70% of the area. The corresponding figure for the Koillis-Suomi Forestry Board (northeastern Finland) is 65%.

According to the results of the NFI-7, 40.8% of northern Finland's total land area consists of peatlands; i.e. about as much as at the time of the NFI-1 for the corresponding land area. In Pohjanmaa–Kainuu (i.e. the Province of Oulu) roughly half of the peatland area has been drained but in Lapland only 23%. Due to drainage for forestry, the proportion of productive forest land in the total peatland area in northern Finland has risen to 37%. In Lapland this figure is 25%.

The majority of Finland's conservation areas are located in Lapland (Fig. 18). The foremost areas set aside to protect specific forest ecosystems are judicial reserves: strict nature reserves, national parks and wilderness areas. In addition to these, the Forest and Park Service has set aside old-growth forests and nature-management forests through internal decisions. The Service has also placed some upland forests outside the sphere of normal wood production. Forestland and scrubland within the sphere of normal forestry amount to ca. 5.2 mill. ha of Lapland's total of 9.6 mill. ha; the rest comprises scrubland in terms of wood production capacity and areas set aside for conservation. It has been estimated that the growing stock set aside for conservation reasons has reduced the maximum sustainable allowable cut in Lapland by more than 1 mill. m^3 per year.

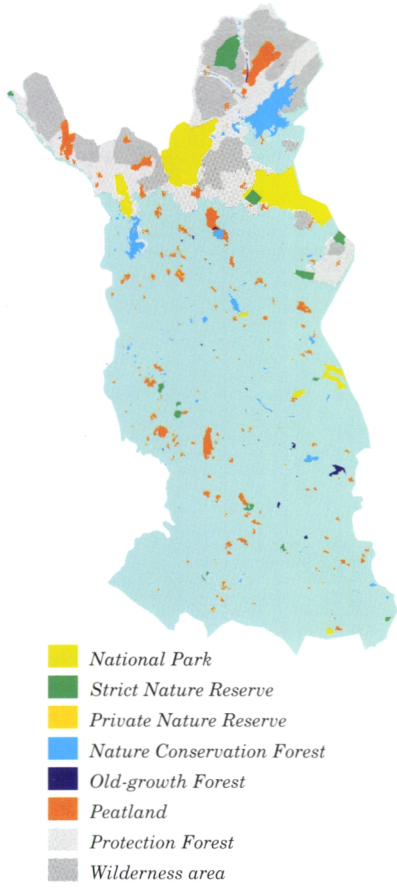


Figure 18. Conservation areas and other protected areas in northern Finland.

The sample plots serving the Lapland Forest Damage Project were established on pine-dominated dryish and dry heathland forest sites. The proportion of these forest types is at its maximum in the northern part of the Lapland Forestry Board's jurisdiction, where they amount to 72% of the area of forestland on mineral soil sites. Elsewhere within the said jurisdiction their proportion is 62%. The corresponding figure for the Koillis-Suomi Forestry Board jurisdiction (eastern northern Finland) is 49%. The majority of these heathland soils carry pine-dominated forests and thus the sample plots represent the most typical forest cover in Lapland in terms of tree-species composition (Fig. 19).

Research – the cornerstone of forest use

Pioneers of forest research in northern Finland

The launching of forest research in Lapland is connected to the Forest Service's (the predecessor of the present-day Forest and Park Service) interest in the forests placed in its care – in their structure, how to manage and regenerate them. August Renvall, the Service's District Forester at Utsjoki, was the author of the first scientific work, his doctoral dissertation, dealing with forest research in Lapland. Published in 1912, his

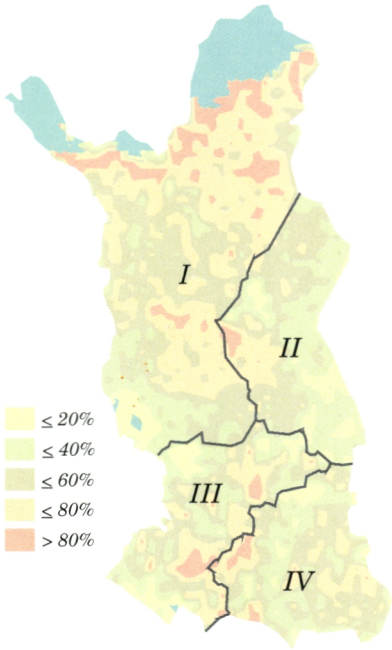


Figure 19. Occurrence of pine-dominated dryish and dry heathland forest soils in northern Finland and the jurisdictions of the forestry boards in northern Finland. I = Forestry Board of Lapland, II = Forestry Board of Koillis-Suomi, III = Forestry Board of Pohjois-Pohjanmaa, IV = Forestry Board of Kainuu. (Source: NFI)

thesis addressed the subject of flowering, cone and seed production of Scots pine "on the polar timber line", a subject which continues to have relevance. Renvall also carried out forest regeneration trials north of the timber line.

Besides Renvall, Professor Olli Heikinheimo, soon to be appointed head of the Experimental Forest Institute (today's METLA for short), deserves a special mention. He published significant studies in the 1910s and 1920s on the forest use in Lapland: on the silviculture to be applied in the northern Finland's spruce forests, the snow-damage areas of Finland and the forests of these areas, and on Finland's timber-line forests and their future use.

Yrjö Ilvessalo, the innovator and leader of national forest inventories in Finland, studied the structure of Lapland's forests in the 1930s in his work titled "*Growth of natural-normal stands in North-Suomi (Finland)*". This work continues to hold its position as a basic study on the development of untouched forests in Lapland.

An extensive network of experimental areas (today's research areas) was set up and placed under the jurisdiction of the then Experimental Forest Institute (predecessor of today's METLA): Kivalo in 1924, Laanila in 1925, Petsamo in 1927, Kilpisjärvi in 1940 and Pallasjärvi in 1945 (Fig. 13). The Kivalo area stands out among these as a place which provided forestry in Lapland with particularly useful information on forest regeneration, the cultivation of exotic tree species, forest fertilisation, and drainage.

From selection felling to forest regeneration studies

In 1950 Professor Risto Sarvas published his study on the regeneration of selection-felling forests in private, non-industrial ownership in Peräpohjola. The results presented in the study had a major impact on the development of methods employed in connection with natural regeneration in Lapland as well. Selection felling was discarded in favour of the seed-tree and shelterwood systems.

The results obtained from the regeneration experiments established by Heikinheimo in the 1920s and 1930s were particularly useful in indicating the good growth achieved with pine on regeneration sites of the spruce-dominated, thick-moss (*Hylocomium-Myrtillus*) type. Professor Gustaf Sirén's doctoral dissertation, published in 1955, is a thorough treatment of the development and ecology of northern Finland's spruce forests on sites classified to be of the thick-moss (*Hylocomium-Myrtillus*) type. Sirén's view was that these forests were deteriorated secondary stands of the *Myrtillus* type, and that artificial regeneration would be the way to make the sites productive once again. Sirén, too, was in favour of prescribed burning and regeneration to pine through sowing.

The 1950s were a period of rapid increase in the adoption of artificial regeneration. A further-training seminar arranged by Finland's Society of Professional Foresters in 1954 provided the setting for the formulation of guidelines for the development of forestry in Lapland. With the participation of respected, leading figures in Finnish forestry, the book published following the seminar, "*Lapin metsien mahdollisuudet*" ("The potential of Lapland's forests"), relying largely on research results, presented a picture of great promise for forestry in the region. The resolution proposed the expansion of forestry industry, increasing the efficiency and effectiveness of forest management, improvement of timber transportation, launching of forestry training courses aimed at the rural population, and the establishing of a specific "Department of Northern Finland"

within the METLA. All these proposals have been realised.

Research stations run by universities

In addition to the contributions of the METLA's research personnel, their colleagues in the service of universities have carried out numerous studies in the fields of biology, including studies connected to the forests of Lapland. The first university to set up a research station in Lapland was the University of Turku, whose Kevo Subarctic Research Station was established at Utsjoki in 1956 (Fig. 13). Initially, the research work done at the station focused on the ecology of birch, especially of mountain (fell) birch, and on matters connected to the timber line. An arboretum comprising all the tree species that occur on the boreal timber line was established there in the 1970s. In recent years, research at Kevo has been directed at experimentally clarifying the impact of the Kola Peninsula emissions. The trials established for this purpose have included mountain birch and pine, and the insects that feed on them.

The University of Helsinki's Kilpisjärvi Biological Station was founded in 1964 (Fig. 13). It is located in Finland's severest climatic conditions. The station's staff conduct eco-physiological research and environmental research. Monitoring series going back to the 1940s have earned the station fame. Forestry-related studies carried out at the station include mountain birch, the timber line, and climate change and its impact on tundra vegetation.

The University of Helsinki's Värriö Research Station was founded in 1967 (Fig. 13). The zoological studies of the early years have been supplemented with studies involving the forestry sciences. Studies focusing on the gas-exchange reactions of Scots pine in extreme boreal conditions have in recent years expanded into the sphere of pollution studies in the Kola Peninsula: sensitive analysis methods are being employed to determine the impact of different concentrations of pollutants on the eco-physiology of Scots pine.

The Finnish Forest Research Institute's research stations

The Finnish Forest Research Institute (METLA) has two research stations in Lapland, in Kolari and Rovaniemi (Fig. 13). The METLA's Kolari Research Station was founded in 1964. The research conducted there is currently mainly connected to forest tree breeding and peatland forestry. Timber line issues are also currently addressed at the Kolari Research Station.

The origins of the METLA's Rovaniemi Research Station are interlinked with the problems encountered in forest regeneration. Extensive failures in artificial forest regeneration took place in Lapland in the late 1960s. The primary cause behind the failures was found to be the Scleroderris canker (*Gremmeniella abietina*) (Fig. 16).

Research work at Rovaniemi began in the spring of 1970 and focused at first on clarifications aimed at ensuring the success of forest regeneration, especially of artificial regeneration. Already in the 1970s, the station's research activities came to include multi-purpose forestry, wood production, forest inventories, business economics of forestry, and forest soil science.

In the late 1980s, forest health studies were commenced at Rovaniemi. This followed the reform in research strategy implemented within the METLA, but most of all it was due to incidents of forest damage observed in Lapland's forests and the involvement of the station in clarifying them. Basic knowledge on the reaction of Lapland's forests to changes brought about by human activity was lacking. Steps to eliminate these gaps in knowledge began to be taken in the late 1980s. In recent years, more than a quarter of the Rovaniemi Research Station's resources have been directed into research delving into the impacts of airborne impurities and other human-related effects.

Environmental research of increasing significance

Finnish Lapland offers a prime natural laboratory for the needs of environmental research: the conditions for growth can be extreme harsh and human activity influences the region's forests right up to the timber line. Areas of extreme forest growth are readily accessible and significant point sources of pollution are close at hand. Finnish Lapland and the environmental research conducted there are also of great interest to researchers abroad.

The character of environmental research has undergone changes. The problems studied are so diverse that wide-ranging

co-operation is required among research institutes – both at home and abroad. The increasing efficiency with which the natural resources of the Barents region will be exploited in the future means that new challenges are in store for this branch of scientific research.

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