

**THE NATURAL REGENERATION  
OF FORESTS IN FINLAND AND  
RUSSIAN KARELIA**

**ЕСТЕСТВЕННОЕ  
ВОЗОБНОВЛЕНИЕ ЛЕСОВ В  
ФИНЛЯНДИИ И В РОССИЙСКОЙ  
КАРЕЛИИ**

**Jukka Valtanen (Ed.)  
Юкка Валтанен (Ред.)**



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METSÄNTUTKIMUSLAITOS  
Kirjasto

*Cover photo: Seed crop measuring with funnels in a pine forest in Kuhmo near the boundary line of Finland and Russian Karelia. Photo Jukka Valtanen.*

*Фото на обложке: Измерение урожая семян опадоуловителем в сосновом лесу Кухмо, около границы Финляндии и Российской Карелии. Фото Юкка Валтанена.*

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Forest regeneration is the most difficult part of silviculture. After a stand has been established with seedlings reaching half a meter in height, it is usually easy for it to grow to maturity. Therefore, regeneration should be carried out fast with the least delay possible.

Finland and Russian Karelia belong to the boreal coniferous zone and within that to the southern, central and northern sub-zones. In southern regions grass, herbs and drought are the worst drawbacks. In the north the pine and the spruce seldom produce seeds and its ability to germinate is low. A lot of seedlings are damaged by disease, insects or browsing by larger animals. Sometimes forest regeneration fails totally.

A forester has two methods in his possession: either the natural method or the artificial method, the latter meaning seeding or planting. Mechanical soil preparation is usually necessary with both methods, since a seed does not grow into a seedling and the transplanted seedling does not survive in the humus layer. The natural method is slower and cheaper than the artificial way, especially planting, which is far more expensive, but much quicker.

The climate and the qualities of the soil define the tree species choice and the regeneration method. Usually, however, there are several possibilities or combinations. The manager — forest owner or professional forester — should know how to choose the right method. We have acquired more knowledge in research in the last few years, and the operational choice is now far greater.

In the eastern part of Fennoscandia (in Finland and Russian Karelia) the climate, the soil and the other natural surroundings are mainly very similar. Consequently, we can act on both sides of the border in the same way. Because of this, forest researchers of these countries had gathered together in 1994 to discuss research problems and especially the natural regeneration of forests. In this book there are gathered the nine lectures which were given in the seminar, they deal with both the ecological aspects of forest regeneration and the techniques of regeneration, both areas where these two neighbouring countries can learn from each other's knowledge and experiences.

Keywords: Natural regeneration, pine, spruce, silver birch, pubescent birch, Finland, Russian Karelia.

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Восстановление лесов-самая трудная часть лесоводства. Тем не менее, восстановление лесов можно провести быстро. После того как лесовозобновление достигло 0.5 м в высоту, обычно легко вырастить лес до спелого состояния. Финляндия и Российская Карелия располагаются в зоне бореальных лесов в пределах северной, средней и южной подзон. Плодоношение сосны и ели редкое, а всхожесть семян низкая. Большое количество всходов погибает от болезней, вредителей и повреждения животными. Иногда лесовосстановление совсем не удаётся. Лесовод может использовать два метода: естественное лесовосстановление и искусственное (посевом и посадкой). Механическая обработка почвы обычно необходима в любом случае, поскольку условия для прорастания семян и роста саженцев или самосева неблагоприятны на поверхности лесной подстилки. Метод естественного возобновления дешевле, но медленнее, чем искусственного. Последний более надёжный, особенно посадкой. Климатические и почвенные условия определяют выбор древесной породы и метод лесовосстановления. Однако обычно есть несколько возможностей или комбинаций. Менеджер-собственник леса или профессиональный лесничий должен знать, как выбрать правильный метод. В последние годы в результате исследований накоплена значительная информация. Поэтому реальнее стала возможность правильного выбора. В восточной части Фенноскандии (в Финляндии и Российской Карелии) климатические, почвенные и другие природные условия, в основном, очень близки. Следовательно, практика лесного хозяйства по обе стороны границы схожа. Поэтому исследователи леса из этих стран собрались вместе в 1994 году для того, чтобы обсудить исследовательские проблемы, особенно, естественного восстановления лесов. Вданной книге собраны 9 докладов семинара, которые касаются как экологических, так и технологических аспектов восстановления лесов.

Ключевые слова: Возобновление леса, сосна, ель, берёза бородавчатая, берёза пушйстая, Финляндия, Российская Карелия.

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## For the Reader

A joint symposium between the Muhos Research Station of the Forest Research Institute of Finland and the Forest Institute of the Karelian Research Centre was arranged at Muhos Research Station between the 17th and 20th of January 1994. At the same time there was scheduled a more in depth meeting on the subject, a seminar, which was held on the 27th to 30th of June 1994. The program of the seminar included lectures and excursions in Muhos and eastwards as far as the forests in the area of Kostomuksha. The lectures have been collected into this publication in English, with the abstracts also in Russian.

The natural conditions of the coniferous zone of eastern Fennoscandia, that is of Finland and Karelia, are in the point of view of silviculture mainly very similar. The climate (precipitation, temperature, the change of seasons) and the soil (mineral soils and marshes) are in the same way suitable for the most important tree species of forestry, pine, spruce, silver birch and pubescent birch. The topographical features of the terrain are also similar. Because of this forestry in Finland and Karelia can utilize the experiences which have been obtained on both sides of the border and also the knowledge which has accumulated in common research and practical work. This holds true especially in the northern parts of the area, where there are more constraints on forestry compared to the more southern areas and where the need of research data is greater. This opinion was unanimous in our seminars.

The manager of the Forest Institute of Petroskoi, Sergei Zybchenko participated in both seminars. We could not foresee (perhaps he did not foresee it either) that he would become seriously ill. Already in July he had to go to the hospital, from where he could not continue his work. He died on the 12th of September 1994. Before that he put the finishing touch on his lecture which is the third in this publication. This became his last written product. Sergei Zybchenko was a central person in our long-term cooperation, and we hold deep respect for his memory.

I wish to thank Miss Hannele Mäki for translating the Finnish texts into English, Mr. William Fasse and Mr. Robert Mann for revising the English of the manuscript and Mr. Uno Ridal for translating the majority of Russian texts.

Jukka Valtanen  
MML, editor

## К читателю

Мухосская исследовательская станция Финского Лесного Научно-исследовательского института и Институт леса Карельского Центра РАН организовали совместный симпозиум по проблеме естественного возобновления лесов 17—20.1.1994 на исследовательской станции Мухоса. В то же время готовили более основательное совещание, семинар, который провели 27—30.6.1994. В программе семинара были доклады и полевые экскурсии в лесных массивах в окрестностях Мухоса и Костомукши. Доклады этих дней собраны в предлагаемом читателю издании на английском языке, рефераты написаны и на русском.

Природные условия в полосе хвойных лесов в восточной Фенноскандии или в Финляндии и Карелии с точки зрения лесоводства очень близки. Климат и почвы подходят для произрастания важнейших для лесного хозяйства древесных пород: сосны, ели, берёзы бородавчатой берёзы пушистой. Также сходны и топографические черты местности. Поэтому лесоводство в Финляндии и Карелии может использовать опыт, который получен по обе стороны границы, а также знания, аккумулированные в результате проведения совместных научных исследований. Особенно это касается северных территорий, где условия для лесоводства значительно труднее и поэтому потребность в научных результатах выше. К этому мнению пришли все участники семинара.

Руководитель Института Леса Карельского Научного Центра Сергей Зябченко участвовал в работе обоих семинаров. Мы не предполагали, может быть и он сам не знал, что серьёзно болен. В июле он попал в больницу и не смог больше продолжать работу. Он умер 12.9.1994. До этого он написал свой доклад, третий в этом издании, который стал последней его письменной работой. Руководитель Сергей Зябченко был одним из инициаторов длительного сотрудничества двух лесных институтов. Почтим его память.

Хочу поблагодарить: Ханнеле Мяке за переводы с финского на английский Виллиама Фассе и Роберта Манна за проверку английских текстов и Уно Ридаля, который переводил большинство русских текстов.

Юкка Валтанен  
ММЛ, редактор

**Alfred Colpaert**

## **Application of GIS in Cross-Border Research Projects**

**Альфред Кольперт**

### **Использование географических информационных систем (GIS) в трансграничных исследовательских проектах**

#### **Abstract**

Computer systems designed to handle spatial data are usually referred to as Geographical Information Systems (GIS). Geographical information is co-ordinate based data related to the earth surface. GIS systems can be divided into vector and raster based systems, hybrid systems integrate both spatial data models.

International research projects often create large amounts of shareable data. GIS systems can play an important role in storing and maintaining data produced by research groups in different countries. The use of GIS in this context stresses the need for standardisation of data collection and representation of results.

#### **Реферат**

Вычислительные системы, предназначенные для обработки пространственной информации, обычно называются Географическими информационными системами (GIS). Географическая информация представляет собой базированные на координатах данные о поверхности Земли. Географические информационные системы можно разделить на векторные и растровые системы. Гибридные системы объединяют оба типа систем.

В рамках международных научно-исследовательских проектов часто создается большое количество совместно и используемых данных. Географическая информационная система может играть важную роль в хранении и сопровождении данных,

полученных коллективами ученых в разных странах. Использование географической информационной системы в таких целях подчеркивает значение стандартизации сбора, хранения и визуализации данных.

## **GIS**

Geographic Information Systems (GIS) can be defined as computerised systems designed and maintained to process spatial data. Spatial means that the data is related to a physical object with given co-ordinates on the earth's surface. Usually GIS systems resolve complex physical objects into three basic spatial items, points, lines and polygons. These systems are called vector based in contrast to raster based systems that have only one basic spatial item, the grid cell (Fig 1). Usually GIS software incorporates both systems and are able to process raster and vector format data. Functionally GIS programs consist of five major modules, the input, output, data storage, analytic and the manipulation module. The GIS and the user communicate through a user interface that is designed to give easy and efficient access to these modules (Fig 2).

GIS differs from traditional database management systems in that data can be accessed and analysed using geographical techniques. Data can be selected on the basis of some non spatial attribute and displayed to reveal the presence or absence of spatial relations. Data can also be selected using spatial queries, for example, we can retrieve the information available for a location. For a detailed description of GIS see Aronoff (1989) and Maguire, Goodchild and Rhind (1991).

## **GIS Applications**

Although it can be said that GIS is used to process spatial data, there is a wide variety of possible applications. It depends upon the nature and the goals of a project which type of GIS is needed. In some instances GIS is used for mapping and map production, in others the main use is the storing of large spatial databases. It is therefore that there is not one generic GIS, but there are many different GIS systems that are specialised in certain directions of the GIS field. The platforms on which GIS programs run vary from personal computers (PC) to UNIX workstations and mainframes. Workstations can be linked via a network to give access to

large shared spatial databases. These different demands and needs have led to several distinct GIS implementations.

Several different GIS variants can be mentioned:

- LIS            Land use Information System
- AM/FM        Automated Mapping and Facility Management
- NET           Network analysing and Route optimising
- RS            Remote Sensing
- ARE           Academic Research and Education
- DM            Desktop Mapping

### **Cross-Border Research Projects**

Research projects involving organisations from different countries have often problems comparing data and results. Is it possible to use the power of GIS to resolve these problems? The ability to capture and manipulate geographical information makes a GIS very suitable to store research data with different formats and / or co-ordinate systems. Usually map systems from neighbouring countries have different co-ordinate systems, making it difficult to share geographical data. GIS programs change co-ordinate systems from one projection to another. This feature enables us to reformat all data into one co-ordinate system, for example the Universal Transverse Mercator projection. For some areas map material might not be available at all. Using satellite images and remote sensing techniques we can capture missing geographical data for input in the spatial database.

To ensure the availability of all attribute data (related non-spatial data), the field measurements and inventories have to be associated with co-ordinates of the location. These co-ordinates might be obtained from a detailed topographical map, but better results are obtained using hand held GPS (Global Positioning System) devices, measuring the geographical position with an accuracy between 30 and 100 meter. Using differential GPS the accuracy of the measurements increases to about 1 meter.

When the research efforts of two or more organisations are to be stored in a GIS we can envisage various approaches. The most advanced solution would be the use of a common shared spatial database. This is however often impossible due to differences in software and / or hardware. Remote access of geographical data makes high demands upon the computer network. At present computer network links between count-

ries are not fast enough to accommodate fast, error free transfer of large amounts of data. A second solution is what we could call the mirror solution, in this approach both organisations receive all information and maintain separate mirror copies of the databases. The latter method is also robust because in case of hardware failure or loss of data at least one copy of the data remains. When the number of participating organisations becomes large the volume of data to be exchanged will grow exponentially and thereby limits the number of organisations.

Research projects crossing international borders and GIS applications related with these demand a high degree of standardisation. Standardisation of measurement techniques and inventory methods for the field data collection is of course obvious. A GIS however implies its own demands for standardisation of data collection, co-ordinate system, data model to be used, storage formats etc. Before any database can be constructed all details concerning the data have to be reviewed and fitted into a common data model to provide a homogeneous, error free and accurate database.

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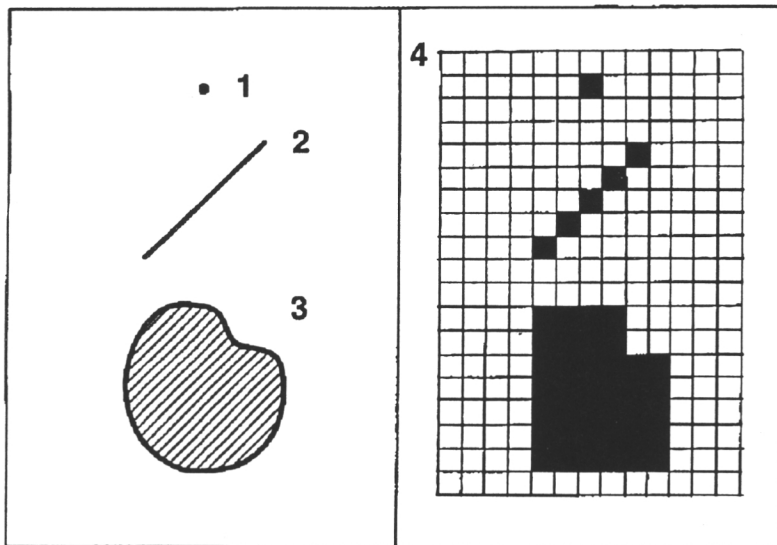
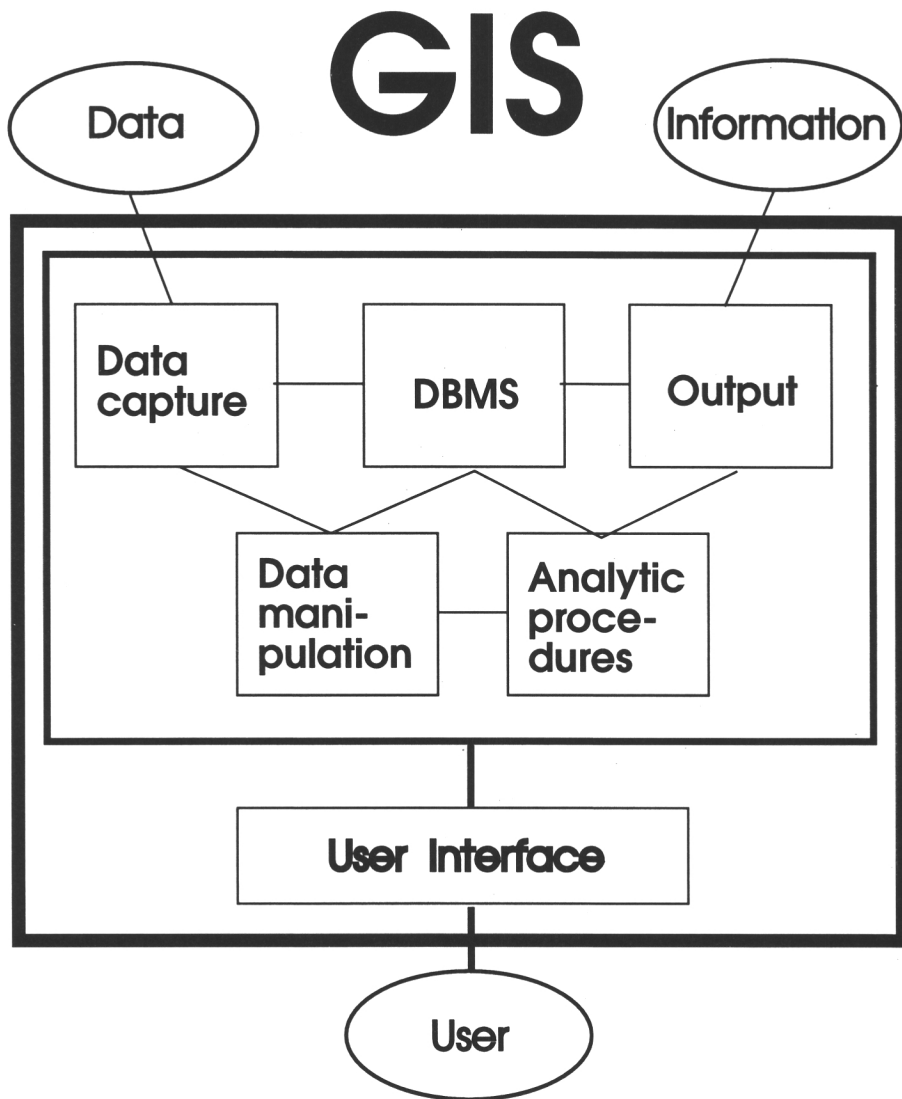


Figure 1. Point (1), line (2), polygon (3) and raster (4) data models.



*Figure 2. Functional description of a Geographical Information System.*

**Matti Oikarinen**

**Forest Regeneration in Finland and the Use of  
Dielectricity Measurements and GIS-System in the  
Choice of Regeneration Procedure**

**Матти Ойкаринен**

**Возобновление леса в Финляндии и использование  
измерения диэлектрических характеристик и  
географической информационной системы при  
выборе методов возобновления**

**Abstract**

During the 1950's the cuttings exceeded the annual growth in Finnish forests. Finland prevented a threatened shortage of wood in good time by taking actions to increase wood production, like more efficient artificial regeneration. The expectations on these methods were, in the light of later research, often too optimistic, so that targets must be reduced. This together with the fall in the price of wood at the beginning of the 90's has increased interest towards natural regeneration. At the same time there has been developments in soil research enabling us to define the suitable areas for different methods of regeneration easier than previously. When these methods are included with the GIS-system we will obtain a promising high technology tool, for the planning of forest regeneration.

**Реферат**

В Финляндии рубки леса превысили прирост в 1950-х годах. В целях предотвращения угрожающего дефицита по древесине интенсифицировали меры, направленные на увеличение производительности леса, в том числе искусственное лесоразведение. Результаты исследований показали, что ожидания по результатам лесоразведения были слишком оптимистичны и так, поставленные цели пришлось пересмотреть. Этот фактор вместе с резким падением цены на древесину увеличили интерес к ес-

тественному возобновлению леса. В то же самое время в области исследования грунта разрабатывали методы, которые облегчают, в том числе, определение участков, на которых могут применяться разные методы возобновления. Когда эти методы комбинируются с географической информационной системой, результатом является инструмент, который представляет высшую технологию - перспективный метод планирования лесовозобновления.

## **1. The Strategies of Forest Regeneration in Finland in 1950—90**

After the Second World War The Finnish economy was rebuilt on its forests. The annual cutting and production was raised from 38 million m<sup>3</sup> in 1943 to 63.3 million m<sup>3</sup> in 1961, which exceeded by 26.6 % the estimated increase at the time. During this period the structure of the use of wood changed so that non-industrial use (household use, heating, transportation) decreased drastically while industrial use increased. Combined with the rapid rise in the processing level of the forest industry, the result was a powerful improvement in the efficiency of the social economics in the forest sector (Sevola 1988, Metsätaloustilastolliset vuosikirjat 1975—1991).

Thanks to the accurate inventory of the country's forests, the forest resources of Finland were reliably known. On the basis of these statistics it was possible to anticipate the situation at the beginning of the 60's, when the drain exceeded the growth of the forests and seriously threatened forestry production on a sustained yield basis. Extensive measures were adopted from the beginning of the 50's onwards to prevent the threatening shortage of wood by increasing the investments in maximising the potential growth of the forests. The most important actions which aimed at increasing wood production were to increase forest ditching, fertilization, cultivation and to improve the management of saplings. Because forest cultivation touches on our subject, we will examine this.

The old forest stands, which often contained tree species of little value and poor growth, were under-productive, having within them uncultivated fields, and other open areas. These were, with the help of forest cultivation, to be converted into young, fast growing stands. It was believed that cultivation would give a 10—20 years' gain in time compared to natural regeneration, also even on such areas where natural regeneration was in principle possible (e.g. Holopainen 1967). There was a general optimism in relation to cultivation, site preparation and to the proportio-

nal distribution of tree species. (Lapin metsien ... 1955). When to this was added the benefit gained by using improved seeds (Sirén 1958, Tigerstedt 1978, Tigerstedt and Malmivaara 1970) and a strong belief in the fact that cultivated forests grow in any case better than the naturally regenerated ones (e.g. Kuusela 1969), it is understandable that the cultivated area increased from 30 000 hectares at the beginning of the 50's to 145 000 hectares in 1971, about the level we have continued at until recent years. The proportion of natural regeneration consequently decreased. At first cultivation was 85 % sowing, this proportion was reduced to 20—25 % by planting during the beginning of the 70's, after which the percentages have remained the same (Metsätalastolliset vuosikirjat 1975—1991).

The practical experience obtained in forest cultivation have not, unfortunately, fulfilled all the expectations. Forest cultivation, especially in the form of planting, is quite an expensive operation. Cultivation has had major setbacks especially in northern Finland, where in large areas these artificial methods, have encountered great difficulties (Oikarinen & Norokorpi 1986, Mäkitalo 1983, 1990, Valtanen 1988, Valkonen 1992). Earlier research indicates that cultivation as such does not have beneficial effect on a stand's growth (Vuokila & Väliaho 1980). Man has also become more cautious as to the benefits produced by forest genetics, and there are also no improved seeds available in northern Finland (Venäläinen 1990, Venäläinen *et al.* 1994, Metsänjalostussäätiö 1993). At first it was believed that by using seeds of southern origin the growth of forests could be improved quickly. This idea was found to be lacking after it became clear that long transport of seed from south to north undermines the success of cultivation (Koski 1989). The gain in time obtained by cultivation diminished, after mechanical soil preparation became more general as a preliminary method for natural regeneration (Kinnunen 1993). In addition, cultivation seems to produce wood of poor quality, the value of which as saw timber is low (Persson 1976, Uusvaara 1985).

Because of these factors natural regeneration has retained a strong position among the methods of forest establishment, although the most eager supporters of cultivation have predicted its end. In recent years the views which emphasize conservation and the greater diversity of nature have obtained more favor, to which view natural regeneration suits well. But above all, the fall of the price of wood as a result of the recession in the early 90's, has increased the interest in natural regeneration as a natural potential which one cannot afford to ignore.



*Figure 1. An old spruce forest after a heavy thinning 50 years ago. The humus layer is 10 to 15 cm. The soil is cool and poorly airated. Only one spruce sapling has come up in 50 years. Photo Jukka Valtanen.*

## **2. Reasons for Regeneration Difficulties**

One of the reasons for the difficulties in regeneration has proved to be the southern origin of the seeds (Mononen 1987, Ruotsalainen 1987). The instructions concerning the origin of the cultivation seed have been revised and since the 70's it has been in this respect flawless. In much research climatic factors have been noticed to have an impact on the success of regeneration. Drought, excess water, frost, and sub zero temperatures etc. may cause considerable damage on regenerated areas. Some of these problems can be avoided by the choice of the tree species and the regeneration method, while others are completely outside the influence of man. Also the soil's physical and chemical qualities can make regeneration more difficult. The particle structure of soil, the soil's aeration and the water permeability are probably in this respect decisive, although their precise influences are still uncertain (Lähde 1974, Pohtila 1977). The portion of the soil's fine particles is evidently important, but their shape, the climate, topography and the depth of the soil and its stratification play their own roles which are difficult to understand. In addition are the biotic factors from animals and insects to fungal diseases.

Of these factors which hamper regeneration, most concern all types of forest establishment, whether it be a question of planting, sowing or natural regeneration. However, the different damaging factors have a very different emphasis as to the method of regeneration. Here the dielectricity of soil makes it easier to choose the workable regeneration methods in varying natural circumstances.

### **3. The Dielectricity of Soil as a Factor which Influences Regeneration**

Natural gamma radiation, electrical characteristics, dielectricity and conductivity of soil offer new possibilities to obtain important knowledge as to the trees' requirements from their growing sites. The conductivity of soil depends on its water and electrolyte content, whereas dielectricity depends directly on its water content (Sutinen 1992). Nature's gamma radiation decreases according to the water contents of soil (Zotimov 1971), and thus correlates strongly with the dielectric characteristics (Mäkitalo *et al.* 1993). Dielectricity can be measured in the terrain with ECP (= electrical capacitance probing), ADR (= time domain reflectometry) or RSAD (= radar surface arrival detection) methods (Sutinen & Hänninen 1991). The two first apparatus are suitable for measuring on site and the latter for measuring by a moving vehicle or by an aeroplane. Capacitance measuring is based on the use of electricity and the two others are based on radar. The measuring of gamma radiation has traditionally been used in geological surveys made by aeroplane of large parts of Finland, so there is plenty of ready research material.

With these methods we can get information on the qualities of the soil, the water content of which is one of the most important. It depends on particle structure, their shape and weathering, on climate, topography, the stratification of the soil and the distance of the bedrock from the surface. It is very difficult and expensive to obtain corresponding information with any other method.

The methods have been tested on the area of Pomokaira in Lapland, where there are diversified regeneration experiments, practical regeneration areas and naturally virgin forest. Poksaselkä in Pomokaira has become well-known as an area where the soil types are fine, spruce is the dominating conifer species, and where the regeneration of pine has proved to be very problematic. With the help of geological gamma flight measurement it was possible to mark relatively well the natural pine forest areas and to distinguish them from spruce areas (Mäkitalo *et al.* 1993). In the regeneration experiments of Poksaselkä pine seedlings perished

most quickly in those areas where, according to dielectricity measurements, the water content of the soil was greatest. The water content of the whole spruce growing area was, for its part, clearly higher than on the comparison area where pine grew naturally.

#### **4. GIS-System as an Aid in Planning Forest Regeneration**

With the help of GIS (Geographic Information System) -method the diverse information concerning the soil, can be transferred as a part of the forest data. This can be supplemented and specified by further surface or flight measurements if needed. The dielectricity signs can be used e.g. together with information concerning the climate, topography and nutrient content to make the choices easier, between the tree species and regeneration methods. The research may produce in the future more precise models about the success of regeneration, wood production, and economic results. This makes it possible to use different calculations flexibly and efficiently in a large scale.

Although the research of this field is taking its first steps, its future prospects are promising. The secrets of forest land may be exposed more deeply, which makes e.g. a better and more appropriate regeneration system possible in the forests. Through the combination of the different branches of science and combined application methods we can reach important synergetic benefits for science, technology and practice very economically. We can also probably find wide-ranging and important uses for the dielectric signs in the future among forestry, geology and in planning the use of general natural resources. Modern data technology in the form of GIS-system offers a possibility for a full-scale utilisation of these possibilities.

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**Sergei S. Zyabchenko**

**Methods of Regenerating Pine Forests in Russian  
Karelia**

**С. С. Зябченко**

**Пути возобновления сосновых лесов Карелии**

**Abstract**

Pine forest dominates the territories of Karelia and the Kola Peninsula. The regeneration processes under the forest canopy as well as on clearcut areas are analyzed. Peculiarities of seedling formation are studied and the optimal combination of forest regeneration methods is suggested.

**Реферат**

Сосновые леса преобладают в пределах Карелии и Кольского полуострова. Анализируются возобновительные процессы под пологом и на вырубках этих лесов. Рассматриваются особенности производства лесных культур и предлагается оптимальное соотношение способов лесовосстановления.

**Introduction**

The forests of Karelia and the Kola Peninsula form the Karelian area of pine forests that occupy more than 50 % of the forested land. Pine occurs on most varied biotopes thus forming pure or mixed stands. The choice of optimal methods for pine forest regenerating after cutting is of primary importance in the regional system of management.

## Results and Discussion

Pine forests are represented mainly by natural stands, with old forests occupying more than 1/3 of the total area. The presence of young trees (understorey) beneath the canopy of mature taiga forests is their innate biological feature that determines their long life (Table 1).

*Table 1. Regeneration under the canopy of mature and overmature stands in Karelia, hectares and percentages.*

Domi- nant species	Total area of surveyed stands, ha	Stands without understorey	Stands with coniferous understorey		
			pine	spruce	total
Pine	929.5	152.3	303.2	414.0	777.2
	100	16.4	46.7	53.3	100
Spruce	672.6	48.6	6.2	617.8	624.0
	100	7.2	1.0	99.0	100
Birch	161.4	30.9	3.5	127.0	130.5
	100	19.1	2.7	97.3	100
Total	1763.5	231.8	372.9	1158.8	1531.7
	100	13.1	24.3	75.7	100

The understorey density, its natural composition and health are greatly affected by natural geographic conditions and their parent stand quality. Spruce regenerates actively under pine stand canopy and dominates here on the half of the area. The most active process takes place in the south of the region. Average coniferous forest stock fluctuates between 1 thousand trees (*Vaccinium* and *Myrtillus* type forests) and 15 thousand trees in *Cladonia*-pine stands. 20—30-year old trees prevail, individual species grow to the age of approximately 80 years.

Spruce undergrowth prevailing under pine stand canopies might have led to their change in the process of endogenic development but this does not take place due to such ecological factor as forest fire.

Long-term pine dominance on the territory of Karelia, the Kola Peninsula and Finland is convincingly supported by the data on pollen-spore complexes of the Pleistocene and Holocene periods (Елина 1980).

In the established practices of Russian silviculture attention is paid to the forming of future forest on the base of young generation retained during the cutting process.

There exist worked-out systems and forest technology requirements on conserving coniferous young trees while timber harvesting. But this practice was not justified, although, it had a certain silvicultural effect. Real figures of the volume and quality of work were far from those given in the reports. Our studies undertaken in 102 clear-cut areas with a total area 3948 ha where young trees were left have shown that only 1/3 of the area has regenerated successfully as a result of this practice.

In clearcut regeneration, a noticeable role is played by after-cutting natural seeding of coniferous as well as deciduous species. The natural regeneration of open areas in the region (clearcuts, burned areas, excavation) is effective (Table 2). In 10 years after cutting in the northern Karelian taiga 79 %, and in the midtaiga 86 % of all areas respectively are successfully regenerated. But the share of areas regenerated with coniferous species during 3 years after cutting is far lower at 19 %. Such coniferous young stands are usually represented by young growth left after cutting.

*Table 2. The percentage of successfully regenerated clearcut areas in Karelia. a = all tree species included. b = coniferous tree only.*

Age of a clearcut area, years	North taiga		Mid-taiga		Total		Amount of total consisting of understorey
	a	b	a	b	a	b	
3	24	21	10	4	17	19	7
6	44	31	49	20	46	25	9
10	79	59	86	42	81	45	12
15	87	72	100	50	91	61	10

In the course of time, the number of areas covered with young coniferous stands grow due to regeneration that follows and in 10 years after cutting such areas account for 45%.

Natural regeneration of tree species is paid more and more attention to in the countries of Central Europe and Scandinavia. Thus, in northern Finland successful natural regeneration takes place on 25 % of clearcut areas (Lehto 1970), in Sweden, 40—45 % of forested areas are regenerated naturally (Bärring 1974). The share of natural regeneration in Eu-

ropean countries makes up 10—25 % of forest areas being created (Wolfgang 1978). The reason is that natural forests are stable, their gene pool and biodiversity being preserved. Also the natural way of forest regeneration is considerably less expensive. Although, in inaccessible sites difficult for soil preparation (steep slope gradient, rocky soils) such a way is thought to be useless.

We also accept man-made means of taiga forest regeneration. The analyses of forest inventory data, survey of clearcuts made during recent years and experiments conducted over a long period, suggest that the following methods of pine regeneration should be used in Karelia (Table 3).

*Table 3. Percentage of forest regeneration methods on felled areas.*

Forest regeneration methods	Pine forest	Spruce forest	Deciduous forest	Total
Artificial regeneration	27.5	20.8	27.5	26.1
Natural regeneration				
— Regen. from understorey	22.5	36.2	55.1	26.8
— Regen. from seed	50.4	43.0	17.3	47.1

On 27 % of the area of pine forest, regeneration is successfully achieved using artificial methods, though this figure varies depending on forest vegetation. Eutrophic biotypes seem the best for artificial regeneration.

Peculiarities of artificial stand regeneration in different forest types:

In Cladonia- and Calluna-pine stands. Young stands are formed by seeding or planting. Crop density is 4—4.5 thousand trees, or seedling spots. The distance between seed strips, or spots, is 2—2.5 m, in a strip 1—1.2 m. 15—20 seeds are broadcast in each spot, the total number of seeds is 0.5 kg/ha. The seedlings are tended until they are higher than the level of snow cover (some 0.6 m).

In Vaccinium-pine stands. Seedlings stands are formed by seeding and planting 3500—4000 trees, or seedling spots. The number of seeds required is 0.5 kg/ha. The distance between strips or furrows is 2.2—3.0 in a strip 1.2—1.4 m. Tending is required during a 5-year period.

In Myrtillus-pine stands. Young stands are formed by seeding and planting. Stand density is 3.0—3.5 thousand trees, or seedling spots. The

number of seeds required is 0.5 kg/ha. The distance between strips is 3.0—3.5 m, in a strip 1.0—1.2 m. Species include: pine, spruce, larch, cembra, Karelian birch.

The soil is treated with herbicides (Dalapone, THA) while planting.

In long-moss, herb rich and related types of forest. Furrow ploughs are used in combination with forest peatland drainage. The distance between furrows is 5.0—6.0 m, seedling stock is 3.0—3.5 thousand trees. Only planting is used. Tending is done during the first 5 years.

Real forest regeneration volume is a topic of interest today. Its lowering has been caused by decreasing the volume of clearcutting as well as by reorganizing the forest management system in the republic.



*Figure 1. The growth of the spruce is during the first 10 to 20 years very slow. Here there are natural seedlings of spruce and pine. Both are 6 years old. The heights are 15 and 85 cm. Photo Jukka Valtanen.*

## Conclusion

To conclude, we would like to share our thoughts about the discussion of the pros and cons of natural and artificial ways of forest regeneration taking place in Russian as well as foreign publications. In our opinion, none of them should be neglected.

The choice of way or method of forest regeneration should depend on:

- specific biological conditions;
- natural-geographic conditions and within the limits of natural zones, or local biotype peculiarities of forest vegetation;
- functional role of forest (commercial, recreational, environmental, etc.);
- economic and technological factors.

Reasonable combination of forest regeneration methods with applying ecologically sound technologies is to ensure conservation of gene pool and biodiversity in boreal forests.

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**Natalya G. Fedorets**

## **Soil Conditions in Clearcut Areas of Karelia**

**Н. Г. Федорец**

### **Почвенные условия вырубок Карелии**

#### **Abstract**

The paper contains characteristics of the most widespread soils in the clearcuts of north- and mid-taiga subzones in Karelia with respect to their regenerating with woody plants.

#### **Реферат**

В статье дана характеристика наиболее распространенных почв на вырубках северо- и среднетаежной подзон Карелии в связи с возобновлением на них древесной растительности.

#### **Introduction**

Studies were undertaken in clearcut-areas of both north-taiga (Loukhi, Kalevala regions) and mid-taiga (Pryazha, Kondopoga regions) subzones in Karelia. The clearcut areas investigated dominate the forest resource in Karelia. Types of clearcuts are given according to the classification by В.С. Воронова (1962) specified and completed by Н.И. Ронконен (1975).

#### **Material and Methods**

Soil cover was studied by cutting soil sections to the profile depth in clearcut areas of different types. Morphological description of the profile was made and soil samples were taken from each genetic horizon. Mechanical composition and chemical properties of soils were analyzed

(Агрофизические методы... 1966, Агрохимические методы... 1975).

## Results and Discussion

Each soil type is characterized by its own number of soils (Table 1, 2).

### North-Taiga Subzone

In lichen and lichen-heath (being an analogue of the former but affected by fire) clearcut areas the soils are sandy surface podzolic and sandy iron-illuvial podzol, dry, poor in nutrition elements. Woody vegetation may suffer from lack of moisture here. Parent soils are sand deposits.

In *Calluna vulgaris*—*Polytrichum commune* burned over clearcuts the soils are found to be iron-illuvial podzol. There might occur also surface-podzolic soils. The soil is covered with a compact aggregated crust regenerating very slowly, mainly with *Calluna vulgaris*. Podzolic soil horizon contains coals. Destroyed by fire litter aggregates water regime, soil moisture being sharply lowered. The soil gets over-heated, with the day temperature liable to great fluctuations. The large quantity of calcium and potassium formed while destroying forest litter by fire is easily washed-out. Burning out litter results in soil impoverishment in humus, phosphorus and nitrogen.

Table 1. Soil types in Clearcut Areas. North-taiga.

Forest type before cutting	Type of clearcut area (dominant vegetation)	Surface podzolic soil	Soils Podzol				gleyic- humus- iron
			iron- illuvial (ferric)	humus- iron- illuvial	iron- humus- illuvial	humus- illuvial	
<i>Pinetum cladinosum</i>	<i>Cladonia rangiferjna</i>	++	+				
<i>P. empetroso - callunosum</i>	<i>Empetrum nigrum</i>	++	+				
<i>P. empetroso - vaccinosum</i>	<i>Calluna vulgaris</i>	+	++				
<i>P. empetroso - vaccinosum (myrtillosum)</i>	<i>Polytrichum commune</i>						
	<i>Empetrum nigrum</i>						
	<i>Vaccinium vitis-idea</i>						
	<i>Vaccinium myrtillus</i>	+	+	++	+		
	<i>Pleurozium Schreberi</i>						
	<i>Hilocomium Speendens</i>						
	<i>Dicranum rugosum</i>						
<i>P. empetroso - myrtillosum</i>	<i>Deschampsia flexuosa</i>						
<i>Piceetum empetroso- myrtillosum</i>	<i>Vaccinium myrtillus</i>			++	+	+	+

Table 2. Soil types in clearcut areas. Mid-taiga subzone.

Forest type before cutting	Type of clearcut area (dominant vegetation)	Soils					
		Surface podzolic	Sod-podzolic	iron-illuvial (ferric)	humus-iron-illuvial	Podzol iron-humus-illuvial	gleyic-humus-iron
<i>Pinetum cladinosum</i>	<i>Calluna vulgaris</i> <i>Polytrichum commune</i>	+	+				
<i>Pinecetum (Pinetum) myrtillosum</i>	<i>Calamagrostis arundinacea</i>			+		++	
<i>Piceetum myrtillosum</i>	<i>Deschampsia flexuosa</i>					++	
<i>Piceetum myrtillosum</i>							
<i>Piceetum oxalidosum</i>	<i>Calamagrostis arundinacea</i> <i>Carex digitata</i> <i>Gumnocarcarpium dryopteris</i> <i>Melampyrum silvaticum</i> <i>Geranium silvaticum</i>		++			+	

In North taiga, dwarf bush—green moss clearcut areas appear to be the most widespread. In mid-taiga they are found but rare. A range of soils is rather wide: in drier habitats on the tops of morain hills they are surface-podzolic, on the slopes — humus-iron-illuvial podzols (humus content in B1 — 1.5—3.0 %), at the base of such hills — iron-humus-illuvial (humus content in B1 is 3.0—5.0 %). All soils are stony.

Dwarf bush—*Polytrichum commune* burned-over clearcuts are considered to be one of the pyrogenic variants in this category. A number of soil types are repeated. The parent soil is moraine.

*Deschampsia flexuosa*—dwarf shrub clearcut areas represent northern variant of *Deschampsia flexuosa* clearcuts in mid-taiga subzone. Sandy-loam morain is the parent soil here. Groundwater level is often high (60—70 cm). Soils may differ depending on their relief position. The most common soils are humus-iron-illuvial. In sites with high groundwater level one may find humus illuvial podzols with humus content in the horizon B1 being 5 %, and iron-illuvial gley. Their gleying connected with groundwater stagnation conditioned by stratiform structure of parent soils.

### Mid-Taiga Subzone

The most widespread type of clearcuts is thought to be that of *Calamagrostis arundinacea*. Parent soil is moraine with sandy, sandy loam and light-loam mechanical composition. The soils are humus-iron-illuvial podzols but one may find also iron-illuvial podzols. The soils are formed under normal moistening conditions. Here they are richer in nutrient elements than in *Calluna vulgaris*—*Polytrichum* commune clearcuts. But it was noted that *Calamagrostis arundinacea* cover negatively affects the process of forest regeneration by forming the durn cover, increasing soil density and decreasing its total porousness.

*Deschampsia flexuosa* clearcut areas occur as small patches in shallow ridge-hilly landscape. Here, the conditions are more moist than those of *Calamagrostis arundinacea* clearcuts. Parent soils are sandy loam and loam moraine. The soils are represented by humus-iron-illuvial, occasionally — by iron-pans.

In 5—6-year old clearcuts one can see the process of sod. *Deschampsia flexuosa* forms dense sod cover thus preventing from forest regeneration.

*Calamagrostis arundinacea*—herbaceous clearcuts occur mainly in southern Karelia. They may occupy various relief elements. Parent soil is moraine with different mechanical composition. Soils are mostly secondary sod-podzolic but podzols may be found as well. The formation of secondary sod soils is associated with durn development in clearcut areas rich in herbs. Typical is formation of A1A2 horizon close to humus, its humus content being 4.5 %.

Mechanical soil composition is considered to be one of the features of soil fertility (Fig.1). Knowing the mechanical composition one can judge of the soil moistening conditions. Moistening is especially important for lichen pine burned-over areas.

Burned-over areas both in north-taiga and mid-taiga subzones are present on soils with sandy mechanical composition, that is coarse- and fine-granulated soils. Fine sand mechanical composition is responsible for slow rainfall infiltration thus increasing soil moisture content. Presence of heavier mechanical strata raises moisture content in the above-lying horizons.

The Figure shows the most typical mechanical composition of soil in clearcut areas of mid-taiga subzone.

Grassy clearcut areas are formed on soils with sandy loam and loamy mechanical composition. One may find also a two-layered profile structure — sandy loam underlain by loam. Their moistening is much higher than that of sandy soils in lichen *Calluna vulgaris* clearcut areas.

*Calamagrostis arundinacea*—herbaceous clearcuts are formed on sandy loam or two-layered soils (sandy loam is underlain by loam) with high content of silty particles. The content of fine-dispersed fractions characterizing soil water permeability and its richness in nutrients accessible for plants is higher in grassy and *Calamagrostis arundinacea*—herbaceous clearcuts.

Typology of clearcuts reflects composition and properties of their litters (Table 3). In north-taiga subzone the depth of litter grows 1.5 (2.0) to 4.0 cm from lichen to *Deschampsia flexuosa*—dwarf shrub clearcuts with an increase of habitat moistening. In mid-taiga subzone litters are noted for their greater depth, 4—7 cm, without regard to burned-over areas (0.5—2.0 cm). Litters differ for their high acidity (pH equalling 3.1—3.3 in the north and 3.3—4.1 in the south).

An unfavourable ratio exists between absorbed base and H<sup>+</sup> (hydrogen) cations apart from the soils of *Calamagrostis arundinacea* clearcut areas.

Soils in all clearcut areas are characterized by low total content of nitrogen in litters (0.67—0.80 %) of north-taiga subzone and (0.77—1.07 %) of mid-taiga subzone. In burned-over areas this index is 2 times lower. Nitrogen content is a little higher in litters of secondary sod soils.

Wide ratio (49—61) in north-taiga subzone speaks for weak production of mineral nutrition elements.

In mid-taiga subzone (23—25), here better conditions for mineralizing the organic matter are created.

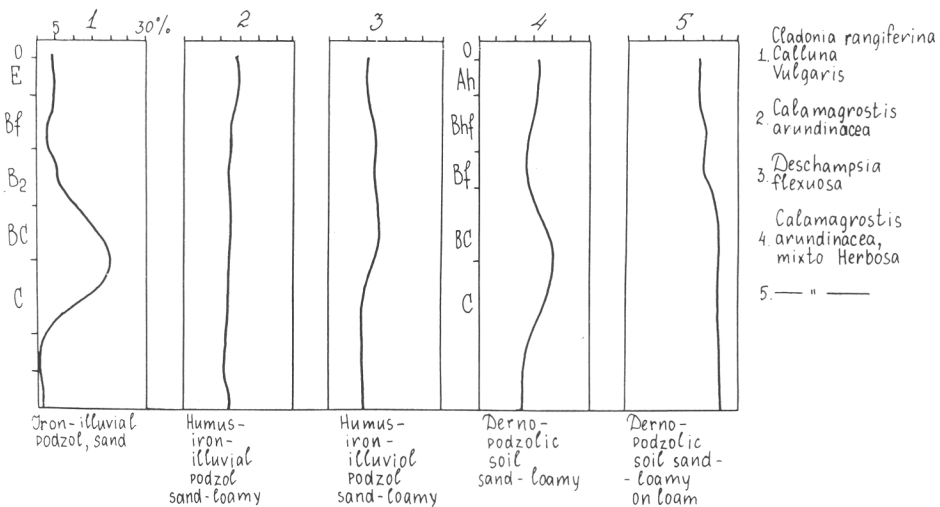


Figure 1. Content of physical clay (<0.01 mm) in soils of clearcut areas, %.

The stock of main nutrition elements and organic matter in litters and 50 cm soil layer (Table 4) increases from dry habitats to more humid. Zonal location of burned-over areas is of no importance for the stock volume of nutrient elements in soil.

Table 3. Chemical properties of forest litters in clearcut areas.

Type of clearcut area (dominant vegetation, soil)	Depth of litter, cm	pH KCl	N, %	C, %	C:N
<b>North - taiga subzone</b>					
1. <i>Calluna vulgaris</i> <i>Polytrichum commune</i> iron-illuvial podzol sand	0.5 (2)	3.1	0.44	32.9	75
2. <i>Empetrum nigrum</i> <i>Vaccinium vitis-idea</i> <i>Vaccinium myrtillus</i> <i>Pleurozium schreberi</i> <i>Hilocomium splendens</i> <i>Dicranum rugosum</i> humus-iron-illuvial podzol loamy	4.0	3.3	0.67	40.7	61
3. <i>Deschampsia flexuosa</i> <i>Empetrum nigrum</i> <i>Vaccinium myrtillus</i> humus-iron-illuvial podzol loamy	4.0	3.2	0.80	39.3	49
<b>Mid- taiga subzone</b>					
4. <i>Calluna vulgaris</i> <i>Polytrichum commune</i> iron-illuvial podzol sand	2 (3)	4.0	0.44	24.4	55
5. <i>Calamagrostis arundinacea</i> humus-iron-illuvial podzol loamy	4	3.4	0.77	27.2	35
6. <i>Deschampsia flexuosa</i> humus-iron-illuvial podzol loamy	4 (5)	3.4	1.07	35.2	33
7. <i>Calamagrostis arundinacea</i> <i>Canex digitata</i> <i>Gumnocarpium dryopteris</i> <i>Melampyrum silvaticum</i> <i>Geranium silvaticum</i> sod-podzolic soil loamy	5	4.1	1.60	37.0	23

Comparing the stock of organic matter in litters of *Deschampsia flexuosa* — dwarf shrub and *Deschampsia flexuosa* clearcut areas being analogues in north- and mid-taiga subzones, greater accumulation of organic remains should be noted in north-taiga subzone. But, litters of *Deschampsia flexuosa* clearcut areas in mid-taiga subzone contain larger amounts of mineral nutrition elements.

Table 4. The stock of soil nutrition elements in clearcut areas.

Type of clearcut area, Soils	P <sub>2</sub> O <sub>5</sub> , kg/ha			K <sub>2</sub> O, kg/ha			C+/ha		
	litter	mineral	0-50 cm depth	litter	mineral	0-50 cm depth	litter	mineral	0-50 cm depth
<b>North-taiga subzone</b>									
1. <i>Calluna vulgaris</i> <i>Polytrichum commune</i> iron-illuvial podzol sand	0.92	678	678.9	12.0	70.0	82.0	13.2	20.2	33.4
2. <i>Empetrum nigrum</i> <i>Vaccinium vitis-idea</i> <i>Vaccinium myrtillus</i> <i>Pleurozium schrebezi</i> <i>Hilocomium splendens</i> <i>Dicranum rugosum</i> humus-iron-illuvial podzol loamy	8.4	1085	1093.4	25.6	97.0	122.6	26.1	25.8	51.9
3. <i>Deschampsia flexuosa</i> <i>Empetrum nigrum</i> <i>Vaccinium myrtillus</i> humus-iron-illuvial podzol loamy	14.2	849	863.2	28.9	159	187.9	29.8	26.4	56.2
<b>Mid-taiga subzone</b>									
4. <i>Calluna vulgaris</i> <i>Polytrichum commune</i> iron-illuvial podzol sand	0.91	685	685.9	8.2	68	76.2	19.5	11.8	31.3
5. <i>Calamagrostis arundinacea</i> humus-iron-illuvial podzol loamy	2.5	434	436.5	15.3	193	34.6	9.8	40.6	50.4
6. <i>Deschampsia flexuosa</i> humus-iron-illuvial podzol loamy	7.2	156	163.2	37.5	221	258.5	23.8	31.0	54.8
7. <i>Calamagrostis arundinacea</i> <i>Carex digitata</i> <i>Gymnocarpium dryopteris</i> <i>Melampyrum silvaticum</i> <i>Geranium silvaticum</i> sod-podzolic soil loamy	7.7	530	537.7	71.0	329	400.0	29.6	59.5	88.1

## Conclusion

Thus, the study undertaken has shown that in clearcut areas with forest vegetation conditions favourable for *Calluna vulgaris* — lichen pine stands a shortage of moisture and mineral nutrition elements are reported. To accumulate moisture it is necessary to preserve forest litter and undergrowth and to mineralize soils before planting crops.

In spruce and blueberry — pine clearcut areas the initial stages of sod are observed. But soil fertility is not realized here, i.e. the rate of natural regeneration in grassy clearcuts is slowed down due to the impact of grass vegetation.

It is necessary to undertake more detailed investigation on how soil conditions and woody plant regeneration interrelate in clearcut areas.

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**Jukka Valtanen**

**The Natural Regeneration of Pine, Spruce, Silver Birch  
and Pubescent Birch**

**Юкка Валтанен**

**Естественное возобновление сосны, ели, повислой и  
пушистой берёзы**

**Abstract**

The most common tree species in the forest management area of Fennoscandia are pine (*Pinus sylvestris*), spruce (*Picea abies*), silver birch (*Betula pendula*) and pubescent birch (*Betula pubescens*). Of these pine and both birch species are fairly easy to regenerate naturally, but the natural regeneration of spruce is, when the economical aims of forestry are taken into consideration, on average too slow a method.

The natural regeneration of pine with the seed tree method is already a 100 years old. The prerequisite for its regeneration is that the surface of the soil is broken so that 20—30 % of the mineral soil surface is exposed. The more difficult the conditions are, the more mineral soil must be exposed. The prerequisite for good natural regeneration and the seedling stand becoming established is the removal of the seed trees 3—5 years after preparation, in moist places taking care of ditching and fighting against the taller thicket of sprouts.

Silver birch can be regenerated in the same way as pine with the help of seed trees. The seed trees need only be 5—10 stems/ha, while for pine it is recommended to have 50—80 stems. Soil preparation is generally necessary. Pubescent birch is usually not regenerated but it becomes regenerated by itself from a neighbouring forest even 100—200 metres away. This also regenerates well in bared mineral soil but also in wet untouched natural surface.

The natural regeneration of forests has become more common with developments in soil preparation methods and because of the high human labour costs which is involved in cultivation. In addition, the cultivated seedlings have proved to be on an average more prone to damages than the naturally born seedlings. In the planted forests of pine it is often

difficult to solve the problem of quality, but because the natural seedling stands usually contain plenty of genetically individual seedlings, a good technical quality is easier to obtain.

When natural regeneration is used the area usually receives a mixed seedling stand with many species and a high stocking level. With the nursing of the seedling stand and the choice of individual trees when thinning we can form a desired forest, a pure coniferous forest, a mixed forest or a pure deciduous forest and at the same time grow a tree stand which has a technically flawless quality.

## Реферат

В лесохозяйственной зоне Фенноскандинавии наиболее распространёнными породами являются сосна (*Pinus sylvestris*), ель (*Picea abies*), берёза повислая (*Betula pendula*) и берёза пушистая (*Betula pubescens*). Из них сосна и оба вида берёзы возобновляются достаточно легко естественным путем, но что касается ели, её естественное возобновление является, как правило, слишком медленным методом с точки зрения получения экономических результатов в лесном хозяйстве.

Метод естественного возобновления сосны с использованием метода семенных деревьев применяется уже в течение более 100 лет. Предпосылкой развития всходов является рыхление поверхности почвы так, что обнажается 20—30 % минеральной почвы. Чем более тяжёлые условия, тем больше минеральной почвы должно быть обнажено. Условием успешного облесения и становления подростка является удаление семенных деревьев через 3—5 лет после рыхления, осушение влажных грунтов и борьба с развитием подлеска.

Берёза повислая может возобновляться аналогично сосне методом семенных деревьев. Требуемое количество семенных деревьев — 5—10 шт/га, причём для сосны рекомендуется цифра 50—80 деревьев. Как правило, рыхление грунта является необходимой предпосылкой. Берёзу пушистую обычно не возобновляют, а она возобновляется сама даже до расстояния 100—200 м от опушечного леса. Подрост развивается хорошо не только на обнаженной минеральной почве, но и на мокрой поверхности грунта, находящейся в естественном состоянии.

Естественное возобновление леса стало распространяться благодаря усовершенствованию методов рыхления грунта и из-за

высокой стоимости человеческого труда, необходимого при лесоразведении. Кроме того, культурные саженцы оказались в среднем более склонными к повреждению чем естественные саженцы. В сосновых плантациях проблемы с качеством часто трудно решать, но благодаря большой густоте естественного подроста, там легче добиваться лучших результатов по техническому качеству.

При естественном возобновлении леса обычно формируется смешанный подрост из разных пород с большим количеством молодых деревьев. Меры по уходу и выбор отдельных деревьев при рубках ухода дают в результате чисто хвойный, смешанный или чисто лиственный лес и позволяют выращивать безупречный по своим техническим качествам древостой.

## 1. Comparison of Tree Species

Tree species have adjusted themselves to the climate and soil of their growing area. In both cases the trees allow more or less versatility. Pine is a typical example of a tree species whose site versatility is wide. It grows from the poorest gravelly soils to groves, and from skeletal soils to wet open bogs. In forestry, where there is an economical goal, it is worth limiting the cultivation of both pine and other tree species. However, it is important that they are not grown there where an other tree species is economically more profitable.

Pine, spruce, silver birch and pubescent birch fill in the boreal coniferous forest belt in the Fennoscandian area, that is e.g. in Karelia and Finland, all sites economically profitably or at least in an approved way. "In an approved way" means e.g. that none of these tree species is wholly able to utilize the great fertility of very fine-textured soil because they need better ventilation for their roots, including pubescent birch. Excess wetness is an obstacle for their growth, too. There are tree species in the world which can grow in compact soil and others which grow in wet soil but none of them are accustomed to the northern climate. Consequently we must make do with our own tree species. Only some larch species may be a necessary supplement to our species. It is beneficial for forestry that there are only a few tree species.

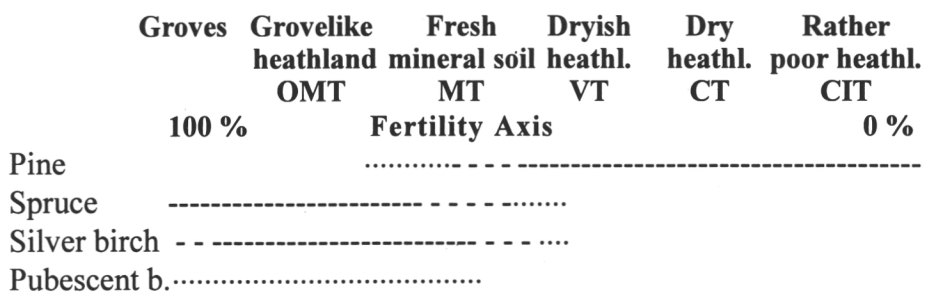


Figure 1. The acceptability of the main economical tree species in forestry sites with different fertility. ----- = suitable for main tree species - - - - = suitable for admixed tree species ..... = suitable for subsidiary tree species if there are not any others.

As the roots of different tree species have a different ability to obtain oxygen from the soil, which their root cells need. With this in mind it is important that we know, for the choice of the tree species to be regenerated, the ventilation of the soil as well as fertility. When draining is in order, the texture of the soil, its compactness and the portion of its fine components are crucial for how well the roots obtain oxygen. A general method for defining the compactness and ventilation of soil is to measure the fine components, that is, the amount of soil which is less than six hundredths of millimetres. According to modern knowledge, it seems that soil is suitable for pine if the amount of the fine components is not more than 30 %. For silver birch the figure is 40 and for spruce 60 %. If there are more fine components, pubescent birch is the only possibility, possibly also contorta pine and in the very south oak. In the most fine-textured soils not even pubescent birch grows well. In natural conditions tree species succeed satisfactorily in still slightly more fine-textured soils, but when regenerating by cultivation the above mentioned figures should be followed for the present, until we obtain further knowledge. In the south the percentages are probably slightly higher than in the north, where the significance of ventilation for root function increases.

Mineral soil is for all tree species the most favourable base on which to regenerate rather than an unprepared surface. In several measurements (excluding the poorest pine heaths) regeneration has been found to be 5—100 times more abundant in bared mineral soil than in the adjacent natural surface. Silver birch and pine benefit from preparation more than spruce and pubescent birch. Mineral soil must be exposed the more, the more difficult the conditions for regeneration are. Regeneration without preparation is in commercial forestry not viable for any tree species.

## 2. The Adaptability of Pine

The pine family is genetically old plant. Its genotype is in many respects narrow, since flexibility has worn off. The seed must not be moved in the north south direction for hundreds of kilometres, as a park tree pine does not endure cutting the branches and shoots, it does not have many branch forms and hardly any other variation in its outlook and it does not regenerate vegetatively e.g. from branches which have bent to the ground. However, it has remained versatile to site conditions, and this is a valuable factor in forestry terms.

The silvicultural definition of productive and non-productive forest soil is based on whether the tree stand can develop to a fairly fully stocked saw-timber stand. If we did not have pine, the poorest soils, or *Cladina* and *Calluna* site types and also the poorest side of the *Vaccinium* site type would be forest lands of low productivity (compare picture 1). Spruce, silver birch and pubescent birch cannot grow to saw-timber there.

Pine is climatically well adapted from the level of the Gulf of Finland to the level of 950 unit temperature sum (d.d. threshold value 5 °C) in the north, or in Finland from the northern side of Tornio to the south-east to the line which runs to the northern part of Kuhmo. Probably the line turns there to the east. There are pine forests even on the northern side of this line all the way up to the tree limit, but in any case, there are more restrictions in the regeneration of pine the more north we proceed. Inflorescence is inconsistent and the ripening of the seeds uncertain. Even a plentiful seed crop may be useless because the germination is low. The poor quality of the soil and the repeated forest fires have favoured pine in the north compared to spruce, which is more climatically durable.

Pine grows best to the south of Finland and Karelia, on the same level with the Baltic countries. This does not, however, diminish the significance of pine in our forestry. Namely, pine produces the best stem form and the best technical quality where there is the area of winter frost. The cold soil slows the mobilization of nitrogen. Already at the level of the Gulf of Finland, in St. Petersburg and southwards from it there is too much nitrogen in the soil for pine. The stem grows thick branches and it becomes easily crooked and forked. When cultivating a pine stand we must be careful since the regeneration and nursing of the young growth, if we want to grow good saw timber in those conditions. Great denseness in the phase of the young growth is a basic factor. Already in part of Aunus the problem of quality must be taken into consideration.

### 3. The Technics of the Natural Regeneration of Pine

It is good if the stand to be naturally regenerated has been treated by thinning and preparatory cutting. So the trees which will be left as seed trees, must have strong crowns and stems which are of good quality, have already grown accustomed to wind, strengthened their root systems and such that their seed production will not become disturbed after release cutting. For the present there are few cultivated forests which meet these requirements.

Regeneration felling in an uncultivated forests means a shock for the trees. It takes them some years before they learn again to flower and produce seeds. After that the seed crop is more abundant than the average, also in otherwise poor seed years. At first they produce only three seed crops on the regenerated area:

- seeds fall off in the spring after the winter felling, from the two years old cones, which are already in the trees
- seeds fall off one year later from those cones which were one year old little cones during felling
- seeds fall off again one year later from those cones which were born from the female flower buds which were ready during the felling and flowered in the spring after felling and developed during two years into cones

It is usually necessary to clear the regeneration area, that is, to remove the trees of poor value which have been left in the felling. Clearing can be done after mechanical soil preparation, when there is less work, since the machine fells some of the weed trees. It is tempting to leave in the regeneration area e.g. some beautiful birches 4—6 metres high but they give a lot of trouble later. Also the taller pines, from half a metre upwards, grow broad branches and become in technical quality useless trees. Only those pine seedling groups which are at least 1—2 acres large or the single, less than half a metre high pine seedlings, are left to develop. Spruces are not spared.

As a result of the clearing of the deciduous trees there rise from the birch stumps, compared to the pine, tall groups of shoots, which must be cleaned before they hinder the growth of the pine seedlings. The right point of time is about 5—8 years after preparation. We cannot help this extra work which the clearing causes. We must accept this duty if we want to get a good final result.

Soil preparation in such a way that at least 20—25 % of the mineral soil is exposed, is the prerequisite for the natural regeneration of pine.

If the seed trees are weak, the climate cold or the conditions otherwise bad, the prerequisites for natural regeneration can be improved by more soil preparation. It is best that the soil is prepared in early May after cutting just before the seeds fall off. The preparation track remains such that it can become stocked with seedlings for 2—3 years, so all seed crops can be made use of. Then the preparation track starts growing moss and the seed crops diminish or stop for some years. Autumn is also a suitable time for soil preparation. However, at this time we lose one year's seed crop if the cutting happened during the previous winter period.

Measurements have shown that mineral soil becomes stocked with seedlings 10—40 times more efficiently than unprepared surface. If the seed trees are weak, the climate is cold or the conditions are otherwise bad, extensive soil preparation can improve the prerequisites for natural regeneration.

When natural regeneration has been secured with rightly timed soil preparation, the next task is to secure that the seedlings become established and that the regeneration area becomes an established forest. There are three prerequisites for the success of this:

- The regeneration area must not be wet. Wetness does not hinder regeneration but it hinders the seedlings survival and development.



*Figure 2. Seedlings regenerate almost exclusively in the soil preparation tracks. In the right hand side edge the preparation track is broken. 12 years have passed from the preparation. Photo Pentti Savilampi.*

- The seed trees must be removed as soon as the regeneration has happened, in any case in five years from the regeneration felling at the latest. Otherwise there appears at the base of every seed tree a 1—3 acre gap in the seedling stand. The best seedling stands have been obtained where after the first spring's seed crop the mother tree stand has been removed in the same summer or the next winter. Letting the seed trees to stand for e.g. ten years destroys well started natural regeneration.
- A tall thicket of sprouts must be destroyed. In moist lands clearing work is needed as early as after five years. A thicket of sprouts does not hinder the pine from regenerating in the early phase, but later it suffocates too great a portion of them because it grows fast. In dry lands we can manage entirely without clearing the deciduous tree stand.

The number of the seed trees vary over a wide range. If there are only 20 pines in the forest which are good enough to be seed trees, they are left. If there are more pines, we leave 50—80 trees. The seed crop is most abundant with the denseness of about 150 trees, but in experiments the regeneration has hardly improved when the number of the seed trees has grown upwards from 40. Therefore it can be considered that 150 trees/hectare is the maximum denseness. Although, a preparation machine cannot work properly in so dense a forest. Already 80 trees hinder the preparation. As the removal of the seed trees is often delayed in practice, there is a good reason to favor spacious stands in seed-tree position, then the seedling stand can develop satisfactorily in spite of the delay.

It is wisest to leave the seed trees in rows or possibly also in groups on thoughts of felling. Then there will not be so many harvesting injuries as when scattered trees are collected.

#### **4. Limitations and Risks in the Regeneration of Pine**

The wind sometimes fells part of the seed trees, this being a risk we must accept. In wet lands tree roots are near the surface and there we get many windfalls. Natural regeneration of pine with the seed tree method is not the method of adopted on wet lands. The root systems of the trees strengthen on dryish and dry lands becoming windfirm in 4—5 years, but then they must be felled, so there is no benefit of the strengthening.

The natural regeneration of dry lichen heaths has proved to be very slow when the seed tree method is used. Probably the sharp night—day

variation of temperatures in the early summer damages the meristem. Although there is generally an abundance of small ten centimetres high seedlings, it can take 30 years before the seedling stand is 70 cm high, after which its growth improves to normal or to the slow growth of a poor heath. In a lichen heath, a preparatory cutting of about 300 trees must be made, under which the seedlings are allowed to develop for 5—10 years. At the same time the upper storey grows. The tree stand is removed in 3—4 phases by diminishing the number of stems by felling e.g. in a series 300—200—100—0 or 300—200—100—50—0. The last felling occurs when the seedling stand is 60—80 cm high. So, in poor sandy soil the rule of moraines and more fertile sandy soils does not hold good, that the mother trees must not be let standing for more than five years above the small seedlings. In sandy soil there do not appear same kind of openings in the seedling stand as in a moraine formation.

Pine is usually not regenerated on fertile land. If, however, we want to e.g. because of the annosus root rot of spruce, to get there pine naturally, the preparation must be more efficient than usual and we must make raised places. Forest harrowing which makes only furrows is not enough. In addition to this, we must be prepared for fighting the ground cover for 3—4 years. Moist fertile soil is a good germination bed for a pine seed and a good substrate for a seedling.

## **5. The Failure of Pine Regeneration**

Sometimes not enough seedlings are born either because operations have been inadequate (clearing not done, ineffective soil preparation, lack of draining) or because of an unexplained reason. If the result is deficient or poor after five years, a new regeneration decision is made:

- new soil preparation is done for natural regeneration, the unwanted wood is removed and the thicket of sprouts is cleared, or
- the seed trees are cut off and the area is prepared and cultivated, or
- the seed tree stand is felled and we content ourselves with the scarce pine material (perhaps 800—1500 pine seedlings/ha) which has been born on the area. With the help of a birch coppice we grow a mixed forest where birch dominates, which is gradually changed with the help of seedling management and thinning so that pine dominates there.

## **6. Natural or Artificial Regeneration (Pine)**

Natural forests have often developed such that the natural regeneration of pine is difficult to carry out. Sometimes spruce has colonized the area totally and the pines have been felled. If pine is the most favourable tree species for the site (e.g. *Vaccinium* site type), it must be acquired by cultivation.

If the site is suitable for pine and there is enough pine in the forest for a seed tree stand (at least 20—30 pieces/ha), the natural method is chosen as the regeneration method. Its benefits are, compared to cultivation, higher reliability, cheaper total expenses and a new forest with technically better quality. As soon as the forests are joined to organized forestry, the area of forests which will be regenerated naturally for pine will increase.

The further north we go, e.g. north from Kostomuksha, the poorer are the conditions for the natural regeneration of pine. The same statement is true also for cultivation. As in the north the interest of the invested money remains small, natural regeneration is therefore more desirable than in the south because it is cheaper.

In cultivation the gain of time is about five years. One need not place a great significance for that because in cultivation, in addition to the expenses, the risk of failing is bigger than in natural regeneration even when both are carried out according to the instructions.

## **7. The Responsibility of the Accomplisher**

Natural regeneration is a disciplined method, where the responsibility stretches from the decision of felling to the seedling stand. The person who is responsible for the work must be able to take care of soil preparation sufficiently well, the removal of the seed tree stand at the right time and the clearing of the seedling stand when need be. Also fighting the heys and grasses during the 2—4 first years is necessary on fertile lands. One must take care of sufficient draining (ditching) of the soil in low lying places.

## **8. Spruce**

Spruce is a tree species of cool and moist climate. It does not have a corresponding adaptation difficulty beyond the 950 d.d. like the pine

has. In Finland's conditions spruce grows better than pine from 300 metres upwards, that is on the hills of Kainuu and Koillismaa, because of the hygricity of the climate, spruce becomes there the absolute dominating tree species, if the soil is not too coarse.

The sites for spruce are good, fertile soils, the better half of the myrtillus site type and the mineral soils which are more fertile than that. Spruce is also able to conquer groves, which it changes during a couple of spruce generations into a grovelike heath when the mull is used up under the spruce stand from the surface of the mineral soil. Spruce spreads also to the heaths of the Vaccinium site type, where it is not economic compared to pine.

The change of the pine and birch stands of moist lands into spruce stands is a normal process of the nature, which is accepted and made use of in organized forestry. Instead, the natural regeneration of spruce into a new spruce stand is a problem. It is in most cases too slow a process. Pine and birch may be given a five year's regeneration timetable, but spruce does not submit to timetables.

*Figure 3. The regeneration area has been prepared with a forest plough six years before the photo was taken. Pine has been planted five years ago. Planting density was 2 000 pines/ha. 1 350 of the pines are alive. In addition, 2 200 pines and 37 500 birches have been born naturally. The majority is pubescent birch. The forest owner has several methods to grow his forest from which to choose. Photo Aarne Lehtosaari.*



The regeneration of an old spruce stand into a new spruce stand has been attempted with the shelterwood method, where about 300 (in the north 200) best trees are left as seed trees and to shelter the seedlings in their sensitive initial phase. Most of the trees should be pines and birches. Mechanical preparation is not possible in so dense a forest. After an adequate restocking with natural regeneration the overstorey is removed in 2—3 phases leaving the pines and birches to last. The problem is, that regeneration is often slow; it can take 20—40 years, during which the fertile land is under-productive. The second problem is felling: most of the seedlings are damaged under the spruce branches. Before felling the seedlings can be found to be adequate and even abundant, but after felling the seedling stand rises understocked and with gaps. We try to fill the gaps by planting birches in the phase when the understocked spruces are 1—1.5 m high, although at this stage elk can still destroy the birches.



*Figure 4. This regeneration area has been forest ploughed seven years ago. Pine seedlings were planted 2 000 pieces/ha. There were alive six years later, when the photo was taken, 1 825 pines. There were 1 400 natural pine seedlings and 18 800 birch seedlings. We can grow a pure pine stand, a mixed forest or a pure birch stand. Photo Aarne Lehtosaari.*

As the amount of the thinned spruce forests increases, we get spruce stands which have become adequately restocked during the regeneration period without a special shelterwood phase. There remains still the problem caused by the seedlings being destroyed under the logging waste.

Another method of regenerating spruce which has been in use for hundreds of years is strip felling system. 30—40 metres wide strips are felled into an old spruce stand, which become restocked by natural regeneration little by little. Soil preparation accelerates restocking. Spruce seed spreads adequately 20—30 metres from a border stand and in spring with high winds when the snow cover has an icy surface, even hundreds of metres. We must, however, not count on this long-distance spreading.

The strip felling system is still serviceable. We must only alter its aim. It is in fact a method for regenerating birch and only secondarily the regeneration of spruce. There rises a birch stand on the strip and under it slowly a spruce stand. The method is in the point of view of forestry, ecologically sound and recommendable. Since we know that birch has a market, it is also economically right especially in the north and otherwise extensive conditions where strip felling system is recommended.

In intensive forestry the natural regeneration of spruce has hardly had any recognition. The growth capacity of a fertile land is not risked for many years. The spruce stand is felled, the soil is mounded and the spruce seedlings are planted in the mounds. Birch comes naturally as an additional tree. The new spruce stand will be raised mixed with birch.

## **9. Silver Birch**

Silver birch does not advance as a competent species as far north as spruce and pine. In Finland it succeeds still 100—150 km north from Rovaniemi. It is probably not worth keeping pure silver birch forests as an aim of forestry north from Rovaniemi. Further north it must be in a mixture among pine and spruce.

Silver birch is nowadays the Finnish forest grower's favourite tree. It suits to fertile mineral soils, where draining is in order. Silver birch grows fast when planted and its rotation is 35—50 years. Only the elk is a threat for it. The cultivation sites must be chosen so that there are no elks, in other words near houses and roads with traffic, Natural regeneration and sowing are most secure if we think about the elk, but otherwise the knowledge of these methods is for the time being inadequate. In Finland we do not have yet enough research on the regeneration of birch.

The natural regeneration of silver birch happens in the same way with the seed tree method as with pine. Seed trees are left only 5—10 stems/ha. The soil is prepared in the early July just before the seeds fall off. The risk, however, is great because the sites of birch are fertile and if there is a poor seed year or the regeneration does not take place because of dryness in the first year, the small seedlings will not survive among the vigorous ground cover from the second year onwards. In the experiments of birch regeneration planting has, on the average, proved to be a better method than natural regeneration. The planted area can already be good young forest while the natural area is still an uneven seedling stand with gaps. Although, there are also well succeeded areas of natural birch regeneration.

Controlled burning of stands in seed-tree position has been tried, also. There must not be a lot of logging waste, so that the trees will not die. Controlled burning must be done as early in the spring as possible before the rising surface vegetation prevents it. When regenerating birch the controlled burning of the stand in seed-tree position is probably serviceable. It is of no use trying it with pine.

It is easy to collect birch seeds. A seed tree is cut in middle July before the seeds fall off. It is easy to sow the area which is planned for afforestation, or a seed-tree area of natural regeneration, prepared and possibly burned, as broadcast sowing. A hectare requires a bucketfull of seed mass which has been stripped from birches. There are a million seeds there. Leaving the seed trees was in this case unnecessary.

## **10. Pubescent Birch**

Pubescent birch is a widespread tree species. Near the tree limit its portion in coniferous forests increases. It advances along the arctic mountain valleys as far as the Arctic Ocean. Already from the south of the level Oulu—Kajaani up to the north its technical quality and form becomes worse. Straight pubescent birch of good form is found only on the best lands. In the birch stands on peatlands in the coastal area far down to the south from Oulu a crooked stem is the normal form. In northern Lapland the stem form becomes so crooked and the whole tree bushlike that the name mountain birch is used for the pubescent birch. Climatically pubescent birch is the most durable of our trees.

Pubescent birch must be classified for now beside pine, spruce and silver birch a subsidiary tree species which is accepted as a forest tree only where there is the lack of a better tree. However, it has an important

and irreplaceable task in fairly well drained marshes where it grows as a pioneer tree species fairly well to the measures of pulp wood and prepares the soil so that it is suitable for spruce. Spruce regenerates under the birch stand before the latter becomes over-aged. A mixture of birch is favourable also for the pines on marsh land.

Also in fine-textured mineral soils, where the ventilation of soil is too poor for the other trees, pubescent birch thrives moderately. Among other things, it is planted on compact silty fields which are going to be afforested. A suitable solution for them, is a mixed forest of spruce and pubescent birch — spruce and pubescent birch in alternative rows — where the task of the birch is to act specially as a pioneer tree. When the birches are in due time thinned, the tunnels of the dead roots are necessary roads for the spruce roots for obtaining oxygen. Without a mixture of pubescent birch the growth of the spruces may stop as early as at the phase of young pulp wood. A stop in growth after the birch has been removed has also been observed in naturally born spruce stands.

Pubescent birch is, compared to other tree species, an aggressive regenerator. It regenerates usually anywhere where there is enough moisture and exactly there where pine, spruce and silver birch do not come. Baring the mineral soil is beneficial also for the natural regeneration of pubescent birch if the regeneration is not certain. A great amount of grass and herbs is not a same kind of obstacle for the seedlings of pubescent birch as for the seedlings of other tree species. To an open space its seedlings come from a border forest hundreds of metres away.

The natural regeneration of pubescent birch does not always come true in the expected way. Among other things, when fields have been afforested, it has been found that although a field is prepared and there are plenty of pubescent birches beside the field, a young birch stand will not necessarily become established.

## **11. Research Results**

Since the beginning of its activity in 1969, The Muhos Research Station has carried out several research projects on natural regeneration. There have been established sample plots where the effect of the amount of seed trees, the methods of soil preparation and the leaving of the seed trees on the regeneration result. In addition, there have been made areal inventories in different parts of the working area. In the following are presented the results of five inventories.

## 11.1 The Prepared Seed Tree Areas in Central Ostrobothnia

In 1984 there were inspected 118 seed tree areas which had been prepared with disc trenching in 1978—82, that is, 2—6 years had passed from preparation. Then there were defined 27 factors which have an effect on regeneration and the resulting regeneration was measured. The temperature sum was 986—1060 d.d. The same areas were examined again eight years later in 1992. Then we found out the results of the final reforestation of the regeneration areas and the factors which influence it. The regeneration of the seedlings and the trees was on an average excellent. The fail in a forestation in some areas was due to man: soil preparation was poor, draining had not been taken care of, the seed trees had been allowed to stand for more than five years and the moist places which had become overgrown with coppice growth (birch) which had not been cleared.

The number of seedlings per hectare was the following

	2—6 years	10—14 years
Pine	5 600	5 900
Spruce	850	590
Silver birch	480	510
Pubescent birch	5 600	6 900
Aspen	..	690
Other deciduous tree	..	2 100
All	12 500	16 800

In the first inventory 58 % of the pines, 55 % of the spruces, 70 % of the silver birches and 70 % of the pubescent birches were on the mineral surface, over all on an average 63 %. The regeneration areas where the inventory had been made were mainly dryish heaths, where there had been pine and spruce seedlings even before felling. This explains the above mentioned small percentages compared to those which are presented later. In the second inventory this could not be measured because the preparation track could not be seen any more. — The portion of the mineral surface was 18 % and the denseness of the seedlings there about 4.5 plants on a square metre. The portion of the untouched surface was 82 % and the number of seedlings 0.56. Thus the capacity of the mineral soil to become stocked with young growth was eight times that of the natural surface.

## 11.2 The Prepared Areas Cultivated for Pine in Northern Ostrobothnia

In 1986 there were surveyed 94 areas which had been seeded or planted for pine 5—7 years earlier. The areas were mainly moist and such that they had become boggy. The temperature sum was 1010—1070 d.d. In addition to the cultivated pine, the naturally born seedlings of pine and other tree species were surveyed. The number of seedlings per hectare was:

Preparation method	0	1	2	3	4
Cultivated pine	1 100	1 200	1 500	1 800	1 800
Natural pine	840	540	890	2 500	2 230
Spruce	170	260	230	490	740
Silver birch	20	10	170	380	720
Pubescent birch	12 000	13 000	3 800	13 000	18 000
Other deciduous trees	5 400	660	3 700	4 800	12 600
All	19 500	13 500	12 200	23 200	35 000

**Preparation methods:** 0 = No preparation. 1 = Scalping with hoe. 2 = Scalping with machine. 3 = Disc trenching. 4 = Ploughing.

When all the preparation methods were combined, the following portions of the seedlings were on the mineral surface: natural pine 72 %, spruce 61 %, silver birch 86 %, pubescent birch 67 % and other deciduous trees (aspen, rowan, willow) 56 %.

## 11.3 The Prepared Seed Tree Areas of Pine in Vuolijoki

In 1989 there were surveyed 79 regeneration areas which had been disc trenched 2—6 years earlier for the natural regeneration of pine. The temperature sum in the surveyed area was 1010—1017 d.d. The number of seedlings per hectare was:

Pine	9 800	In-mineral soil	94 %
Spruce	180		43 %
Silver birch	340		83 %
Pubescent birch	8 900		74 %
All	19 300		84 %

Mineral soil surface became stocked with young growth on average 16 times more efficiently than an untouched natural surface.

#### 11.4 The Prepared Seed Tree Areas of Pine in Kuusamo

In 1990 there were surveyed 62 regeneration areas in Kuusamo, which had been disc trenched 2—9 years earlier. The temperature sum was 750—860 d.d. and the height from the sea level 210—350 m. The whole research area was situated on the northern side of the limit of the adaptability of pine (950 d.d). In high and cold plots natural regeneration was scarce compared to warmer areas. The number of seedlings was:

Pine	6800	In mineral soil	95 %
Spruce	170		66 %
Silver birch	650		91 %
Pubescent birch	5 100		90 %
<hr/>			
All	12 700		92 %

Mineral soil surface became stocked with young growth on average 34 times more abundantly than a natural surface.

#### 11.5. The Natural Regeneration of Spruce in Puolanka

In 1991 there were surveyed 70 strip felling areas in the hilly region of Puolanka, which had been prepared with a harrow or a forest plough 10—15 years earlier. Temperature sum was 830—970 d.d. The ploughed areas had become stocked with young growth more abundantly than the disc trenched ones. On average there were the following number seedlings per hectare:

Spruce	4400	In mineral soil	97 %
Pine	370		99 %
Silver birch	540		98 %
Pubescent birch	7 500		97 %
<hr/>			
All	12 700		97 %

Mineral soil surface became stocked with young growth on average 97 times more abundantly than a natural surface.

We can draw from the five previous researches the following conclusions:

1. With natural regeneration we obtain an abundant and diverse initial material
2. On the cultivated areas many natural seedlings also grow
3. Exposing the mineral soil is the prerequisite for regeneration
4. The importance of soil preparation becomes emphasized in the cold regions (Kuusamo and Puolanka)
5. Also on the hilly regions there comes silver birch to the seedling stand
6. With the help of soil preparation we obtain diverse seedling material, of which it is possible to form a kind of forest which we want, a pure coniferous forest, a mixed forest or a pure deciduous forest.
7. The biodiversity of the forest nature is secured.

## **12. Conclusions**

Natural regeneration offers forestry a positive possibility which must be made use of carefully. A dense seedling stand with mixed tree species, of which it is possible to develop a healthy forest which is technically of good quality and contains different tree species in desired proportions, is a realistic aim, which is easier to reach with natural regeneration than with artificial regeneration.

Natural regeneration has been considered to belong mainly to the area of extensive forestry and artificial method to describe intensive forestry. When the methods have developed and knowledge has increased, we can say that natural regeneration has expanded to the side of cultivation in many places as an equal method. It is no more only the sign of large-scale forestry. Acting in a new way it has also become a method which requires from the manager craftsmanship and a high sense of responsibility to act in the right way starting from the making of the cutting plan to taking care of the seedling stand.

All our four main tree species have their own area of use in forestry and wood production. If we act in right way, it is possible for them to regenerate naturally in almost all forest lands. There remains outside the possibilities of natural regeneration only 1) the dry heaths where spruce has started to grow and where pine has been felled, and 2) the most fertile lands, where the delicate seedling which is born from a seed has no strength to compete with the luxuriant vegetation. In other places the

development of the methods has strengthened the usability of natural regeneration and added thus possibilities for choice in forest regeneration.



*Figure 5. Letting a seed tree stand for too long prevents the birth of a seedling stand on an area of 100—300 m<sup>2</sup>. 12 years have passed from felling. Photo from Muhos, Pentti Savilampi.*

**Eero Kubin**

## **Timing of the Removal of Pine Seed Trees**

**Эеро Кубин**

### **Срок удаления семенных деревьев сосны**

#### **Abstract**

The rate of natural regeneration of pine (*Pinus sylvestris*) was researched on the experiment in Kuhmo between 1986—94. Seed tree cutting was carried out in 1984 and soil preparation by harrowing in 1985. The regeneration in the harrowing furrow was recorded annually (2 times each year) starting in 1986. In addition circular sample plot data was collected when the experiment ended in 1994.

When the seed trees were left standing for a long time this did not increase the number of the seedlings, but an excellent result was obtained already after just one year's seed crop. The fact that the seed trees were let to stand diminished the height growth of the pine and birch seedlings, especially between four and eight years old. The prerequisite, however, is a soil preparation which bares the mineral soil and an adequately good seed crop in the spring right after the soil preparation. Over 95 % of the pine seedlings were in the furrow created by disc-treching.

#### **Реферат**

Темп естественного возобновления сосны изучали на опытном участке в Кухмо в период 1986—1994 гг. Рубку в распоряжение семенников производили в 1984 году, рыхление почвы боронованием в 1985 году и пробную площадь заложили в 1986 году. За развитием всходов в борозде следили ежегодно. Инвентаризацию круговой пробной площади произвели в конце опыта в 1994 году.

Оставление семенных деревьев на длительное время не увеличило количество подроста, а отличные результаты были достигнуты уже по урожаю семян за один год. Оставление семенных деревьев на более длительный срок замедлило прирост сосны и берёзы в высоту, у сосны больше всего в возрасте 4—

8 лет. Больше 95 % подроста сосны развивалось в борозде. Так, естественное возобновление сосны на широте Кухмо удаётся хорошо за один год. Однако, предпосылкой является рыхление грунта для обнажения минеральной почвы и достаточно хороший урожай семян следующей весной после рыхления грунта.

## 1. Introduction

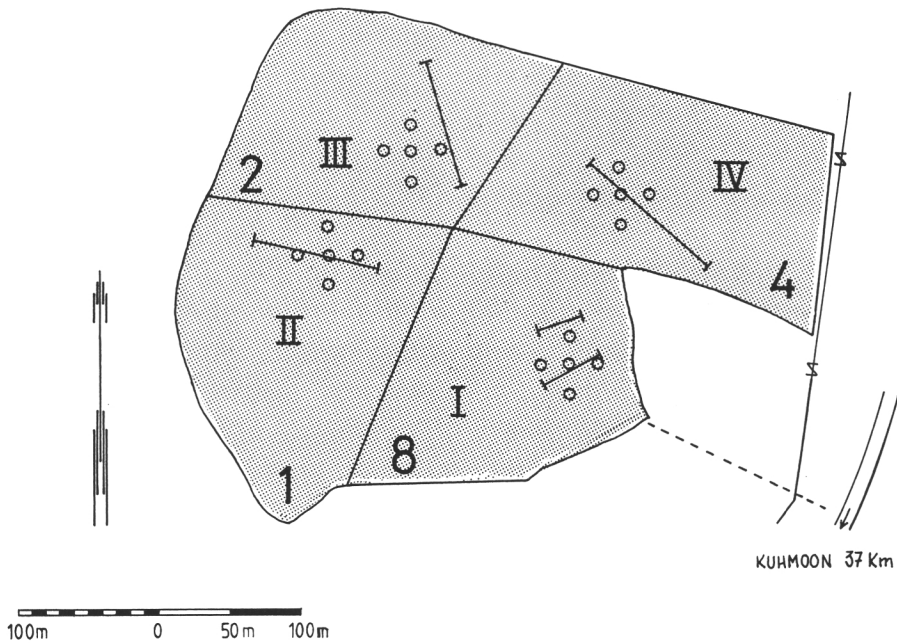
In the natural regeneration of pine there are 40—60 seed trees left per hectare. The recommendation for the point in time when the seed trees should be removed has for a long time been the phase when the new seedling stand is considered to have become established and when the seedlings are still so short that they do not become damaged by the removal. At the beginning of the 1980s we carried out experiments in the forest of the National Board of Forestry at Kuhmo proving that only 1—2 seed crops are needed, and if there is then enough regeneration, the seed trees can be removed immediately. There was, however, no research data available of so sudden removal of seed trees.

In the spring of 1986 there was a record amount of pine seed crop. Already in the late summer we could observe at least in Kainuu everywhere on the natural regeneration plots plenty of small seedlings. This offered a possibility to start researching the effect of a rapid removal of seed trees on the regeneration result. Several experimental areas were founded in order to solve this research problem. They were planned so that their results can be applied straight into practice. This report presents the results of the experimental area of Lehtoniemi in Kuhmo. It was also one place of excursion during the Finnish-Russian seminar 1994, 27th to 30th June.

## 2. Material and Method

The experimental area (Fig. 1) was established in 1986 on the Lehtoniemi forest estate of Kajaani Co. (later United Paper Mills Ltd.) in Kuhmo. The seed trees were let to stand 1, 2, 4, and 8 years after soil preparation by harrowing in autumn 1985. The area of each experimental plot was 2.5—3 ha. Regeneration was monitored on the same sample lines twice a year: in the spring and autumn. At the last measuring (the 7th—10th June 1994) an additional five one acre circular sample plots were established on every area which represented a removal of seed trees. In

these plots the number of seedlings of each species were counted and heights were measured. This report presents these results. The data was analysed by one way analyse of variance.



*Figure 1. The experimental field of Lehtoniemi in Kuhmo. Regeneration felling was carried out in 1984, harrowing in the autumn of 1985 and the founding of the experiment in 1986. In the places shown by the lines the pine seedlings have been counted every autumn and spring from 1986 to 1994, in the circular sample plots all seedlings were counted at the end of the experiment in 1994. Seed trees were left standing 1 (II) , 2 (III) , 4 (IV) and 8 (I) years.*

### 3. Results

#### 3.1 Number of Seedlings

There were almost 15 000 pine seedlings per hectare after the first year and the fact that the seed trees were let to stand for 8 years did not significantly increase the number of the seedlings (Fig. 2, Table 1). Most of the seedlings were in prepare soil (Table 2). The spruce seedlings were mainly in unprepared soil (Table 2) and had been established prior to felling.

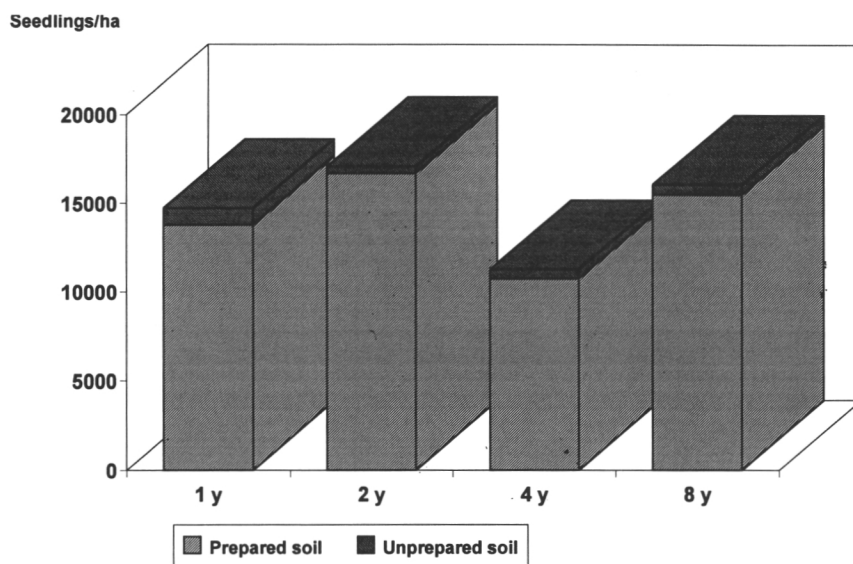


Figure 2. The effect of the time that the seed trees were left standing on the number of pine seedlings.

The birch seedlings were mainly in prepared soil (Fig. 3) and their number diminished because the seed trees were left standing. In addition to pine, spruce and birch there grew rowan and in some places willow in the sample plots. The seed trees which were left standing did not have any effect on their numbers.

Table 1. The effect of the time that the seed trees were left standing on the number of the seedlings.  $p$  = statistical significance.

Tree species	1 y	2 y	4 y	8 y	p
<i>Pinus sylvestris</i>	14 740	17 080	11 280	16 080	0.31
<i>Picea abies</i>	260	320	340	320	0.94
<i>Betula pubescens</i> , seedling	6 240	3 060	4 500	1 480	0.06
<i>Betula pubescens</i> , sprouts	860	460	380	180	0.18
<i>Betula pendula</i> , seedling	1 820	1 420	800	960	0.37
<i>Betula pendula</i> , sprouts	180	0	0	160	-

Table 2. The percentage of the seedlings in prepared soil in harrowing furrows.

Tree species	1 y	2 y	4 y	8 y
<i>Pinus sylvestris</i>	93.5	97.7	95.2	96.4
<i>Picea abies</i>	23.0	0.0	0.0	37.5
<i>Betula pubescens</i> , seedlings	99.0	98.0	92.9	96.0
<i>Betula pubescens</i> , sprout	0.0	0.0	0.0	0.0
<i>Betula pendula</i> , seedlings	93.4	91.6	100.0	100.0
<i>Betula pendula</i> , sprout	0.0	-	-	0.0
Rowan and willow	58.6	0.0	0.0	0.0

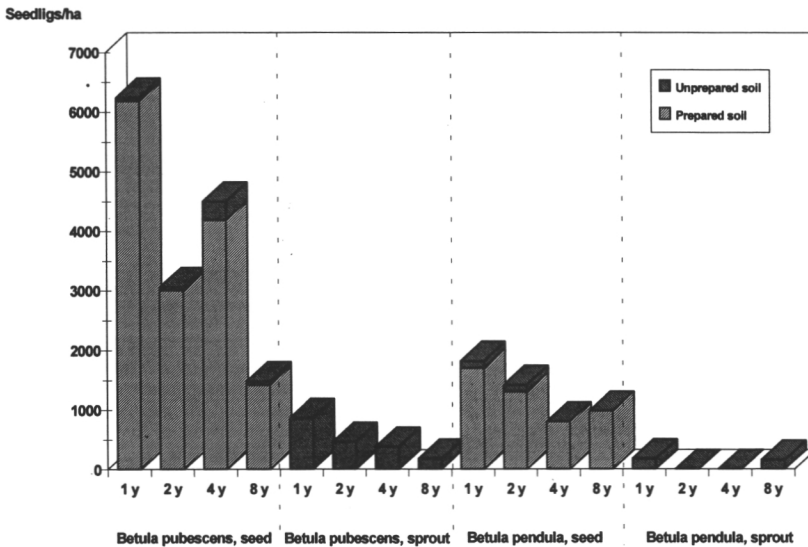


Figure 3. The effect of the time that the seed trees were left standing on the number of birch seedlings.

### 3.2 The Height of Seedlings

When the seed trees were left standing for eight years the mean height of the pine seedlings decreased by less than half. The effect was prominent especially between the fourth and eighth years (Fig. 4). The mean height of *Betula pubescens* and *Betula pendula* seedlings decreased also between the fourth and eighth years (Fig. 5). The differences were also statistically significant (Table 3).

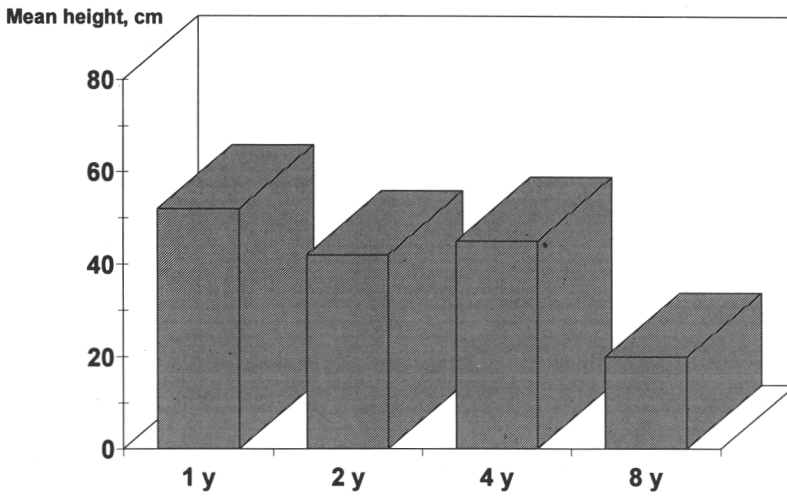


Figure 4. The effect of time that the seed trees were left standing on the mean height of pine seedlings.

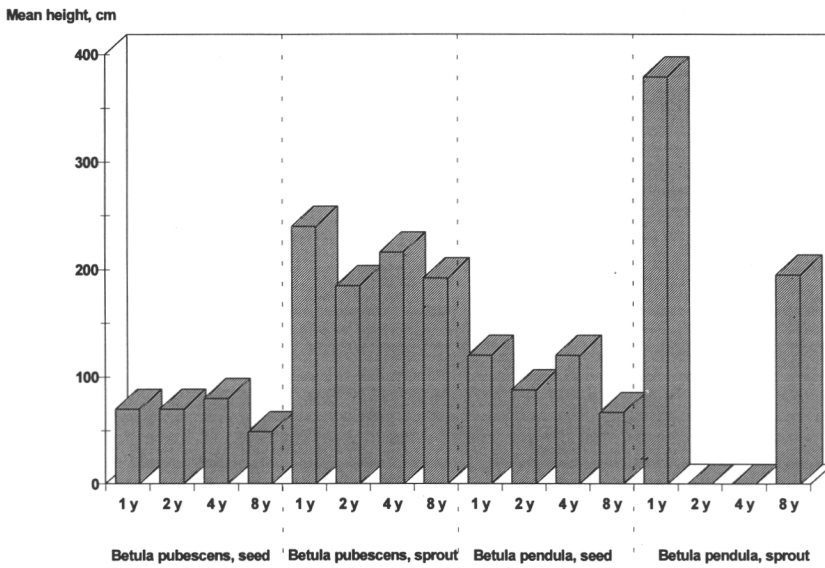


Figure 5. The effect of time the seed trees were left standing on the mean height of birch seedlings.

Table 3. The effect of time the seed trees were left standing on the mean height (cm) of the seedlings. *p* = statistical significance.

Tree species	Standing time				<i>p</i>
	1 y	2 y	4 y	8 y	
<i>Pinus sylvestris</i>	52	42	45	20	0.001
<i>Picea abies</i>	28	48	28	19	0.011
<i>Betula pubescens</i> , seedlings	70	70	80	49	0.001
<i>Betula pubescens</i> , sprouts	240	185	216	192	0.036
<i>Betula pendula</i> , seedlings	120	88	120	67	0.001
<i>Betula pendula</i> , sprouts	379	-	-	195	-
Rowan and willow	90	75	99	112	0.066

#### 4. Conclusions

The prerequisite for the rapid natural regeneration of pine is soil preparation which bares the mineral soil combined with an abundant fall of germinating seeds, preferable immediately after soil preparation or at the longest the following summer. On the latitude of Kuhmo May is still a good time for soil preparation and probably also the beginning of June. On the basis of the results the seed trees can be removed as soon as 1—2 years after soil preparation. One should, however, make sure that there are seedlings before the removal.

No advantage has been achieved with letting the seed trees stand for longer than 4 years with a point of view of regeneration. On the contrary, the following four years diminished the regeneration result and especially the mean height of the pine seedlings. When considering a longer standing time it must be done on the basis of other facts than those which concern regeneration. On the other hand, one should take into consideration possible fungus damage. According to the results of this research and under the conditions which prevailed during the research period, this had, however, no significance.

**Andrey N. Gromtsev**

**Pyrogenic Successions of Forest Communities in Taiga  
Landscapes of Eastern Fennoscandia**

**А. Н. Громцев**

**Пирогенные сукцессии лесных сообществ в таежных  
ландшафтах Восточной Фенноскандии**

**Abstract**

It has been established that during the past few millenia there were formed certain variants of fire regime in Eastern Fennoscandia's natural forests. Their variation was conditioned on landscape peculiarities of the area. In fact, all forest communities represent the various stages of pyrogenic successions. Zoning of the region on a landscape basis, was made taking into account natural fire regime characteristics.

**Реферат**

Установлено, что в последние тысячелетия в спонтанных лесах Восточной Фенноскандии сложились определенные варианты пожарного режима. Их различия были обусловлены ландшафтными особенностями территории. Практически все лесные сообщества представляют собой самые различные стадии пирогенных сукцессионных рядов. На ландшафтной основе проведено районирование региона по особенностям естественного пожарного режима.

**Introduction**

The problem of forest cover dynamics in connection with forest fires has been closely studied by researchers for a long time. Today, fires are considered by forest ecologists as one of the leading ecological factors determining structure and dynamics of taiga forests. В.Н. Скалон and

П.П.Тарасов gave a vivid description of taiga as being an entire burned area at various stages of regeneration because burned areas are so typical of taiga (see: Фурьев & Киреев 1979). But spreading, regularities and periodicity of fires and, consequently, pyrogenic successions of forest communities differ greatly within various taiga regions that is conditioned on structural features of different taiga landscape types.

## **Materials and Methods**

Studies on pyrogenic successions were undertaken as part of the landscape-ecological research project in Karelia. The original classification and the map of taiga landscapes were developed, their comprehensive quantitative and qualitative description was made with the use of field research data (Волков *et al.* 1990, 1995, etc.). Landscapes were differentiated on the basis of relief genetic forms and Quaternary deposits, degree of paludification and dominance of primeval forests. Studies on forest fire regime in different landscapes were carried out with the use of the stratigraphic analyses data on peat deposits where fire layers were recorded and dated. The total number of cores accounted for 700. Apart from this, the presence and thickness of coal layers were recorded for all soil sections, fire scars on trees were dated, inventory of stumps and tree remains having traces of fire were made on the earth surface. While investigating successions of forest communities a set of methods was used: there were established a scale and general trends of changing forest composition and area during different periods in the past; special inventory of natural forest regeneration was done in clearcut areas; descriptions of forest communities at various stages of succession was undertaken. As a result, there were developed, stages of forest community successions in different types of forest habitat. As a whole, the methods of investigation are described in more detail in our other publications (Громцев 1993a, 1993b, etc.). Basic materials characterizing the structure and dynamics of forest cover are obtained from 45 landscape profiles totalling some 220 km in length (descriptions of some 2.2 thousand forest communities are done), on 3 thousand plots (5 m<sup>2</sup>) placed 5—7 meters apart, the total route length through clearcuts being 40 km, etc.

## Results and Discussion

Natural fire regimes in taiga landscapes. Materials obtained as a result of our studies characterize the fire regime in various taiga landscapes during the second half of the Holocene period, i.e. the past few millenia. Let us consider its short generalized characteristic for the landscape groups having similar parametres under consideration (Fig. 1). The territories affected by pyrogenic factor in exceptionally sporadical manner are clearly distinguished (the first group). Here fires broke out with periodicity of 1 fire in a millenium and were total. They seem to have been connected with weather anomalies (droughts). In the second group of landscapes, their core areas were affected by fires 1—2 times in a millenium. But fires were more frequently spread over the part of the landscape territories along sandy hills and ridges of fluvial-glacial genesis affecting sites adjacent to these relief forms also. The third group of landscapes is noted for high periodicity of fires spread along the most part of their territory once in 300 years on the average. Ground fires on mineral soils were much more frequent.

The fourth group of landscapes can be regarded as a standard of pyrogenic vulnerability. The most part of the territory was affected by the pyrogenic factor once in 200 years. At that, maximum frequency of fires was recorded in some places here (18 fires in the past 300—1500 years). On mineral soils ground fires occurred one to two times in 100 years.

Pyrogenic succession under conditions of natural fire regimes. Spruce stands are known to be destroyed even by weak ground fires. On the other hand, fire outbreaks in spruce stands could occur only in dry years. In this case, spruce stands on mineral soils were practically destroyed by fire, and fragments of spruce trees survived only in most paluded habitats (mainly, along different elements of hydrographic network). In the open burned areas there started regeneration of birch. After deciduous phytocenoses were formed, there appeared spruce under canopies that penetrated here from preserved spruce fragments. Further on, succession developed according to the established scheme. Under the birch canopy undergrowth was formed and then the second spruce storey. 120—130 years after fire spruce dominated in the first storey and birch degraded. In the following successions lasting for hundreds of years there takes place the process of gradual formation of unevenaged spruce stands (close to climax) broken off by the next fire. This pyrogenic succession stages were most common in taiga spruce-dominated landscapes with the most varied geneses and paludification degree.

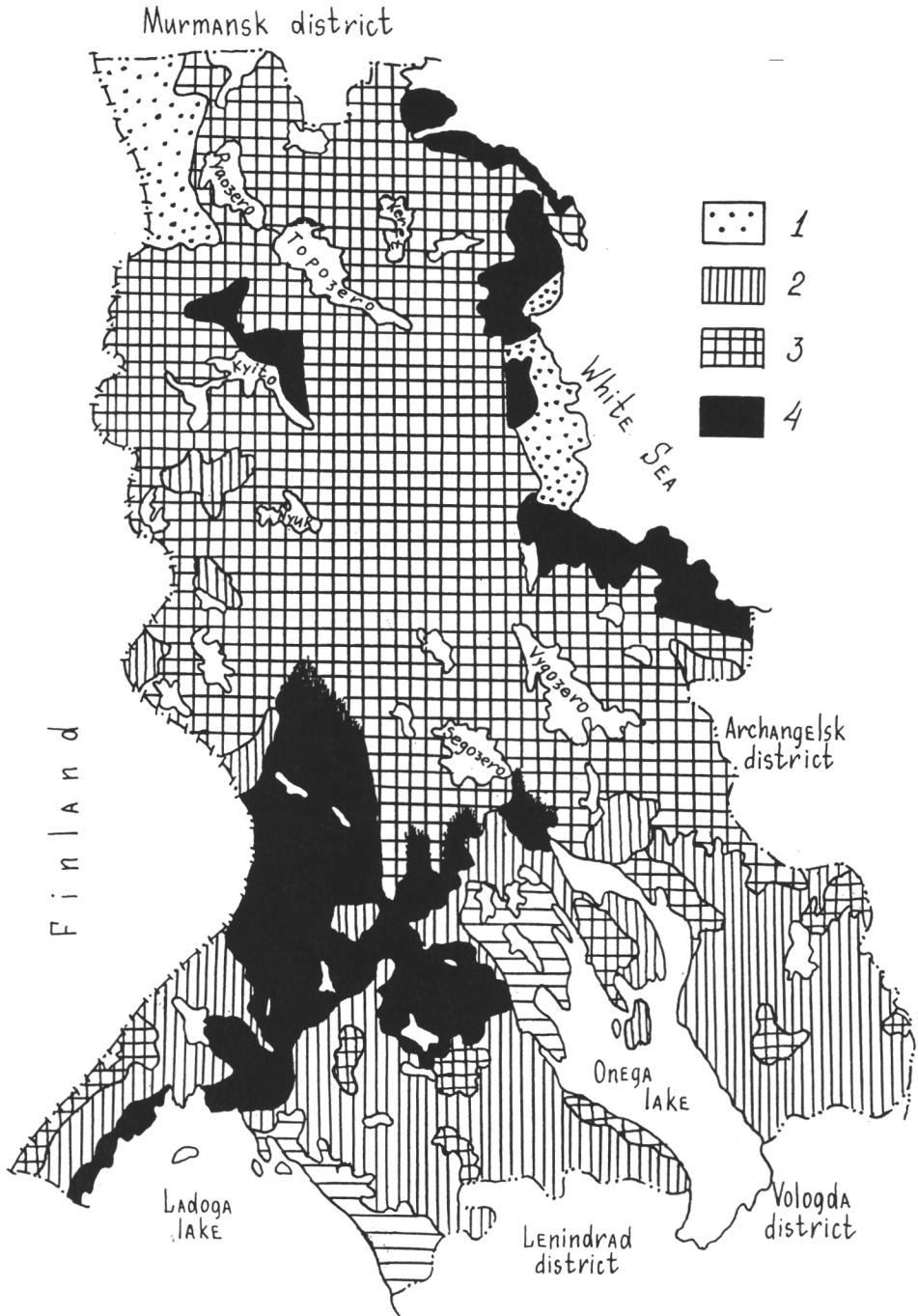


Figure 1. Zoning the region of Eastern Fennoscandia as regards regularities of natural fire regime. Symbols: 1) lowest, 2) medium, 3) high and 4) highest fire periodicity. Explanatory notes can be found in the text.

In pine-dominated landscapes with various geneses and paludification degree typical pyrogenic successions were composed of phytogenetic groups differing in number of pine trees.

Depending on fire intensity primeval pine stands could be either destroyed to varying degrees or completely unaffected. As to the degree of pyrogenic disturbance it is possible to create a series starting from fully destroyed pine stands to well-preserved ones. Next, in the open burned areas pine mass-regenerated and even-aged stands were formed which later on transformed into different variants of uneven-aged stands under the influence of ground fires (as part of the first-storey trees died back and understorey grew up in the openings—"windows"). In stands semi-destroyed by fire of the openings there also occurred pine regeneration and uneven-aged communities were formed, and the degree of clearly defined even-ageness depended on periodicity and intensity of ground fires eliminating a certain part of the stand and ensuring the birth of a new "wave" of regeneration.

Between these extreme successions ("pine" and "spruce") there existed a wide range of intermediate variants.

Pyrogenic successions under conditions of anthropogenic transformation of natural fire regimes. The process of anthropogenic transformation of natural fire regimes in the region is not simple. On the one hand, it was noted that in the course of past centuries fire periodicity was higher in connection with developing of virgin lands. On the other hand, fire fighting technique is being improved. These opposing factors plus the system of clearcutting make it difficult to determine the regularities of forest cover dynamics in connection with changing periodicity of fires as well as peculiarities of its spreading. To say more, spontaneous successions are broken off by cutting at the age of 100—120 years (cutting age). This problem is most pressing in protected areas where it is possible for forest communities to exist naturally only if their naturally fire regime is maintained.

Successful pine regenerating in clearcut areas is in direct connection with the speciality of current fire regime. Pyrologic zoning is compatible with dividing the territory according to peculiarities of pine forest regeneration. As a rule, in landscapes having "high" and "highest" fire periodicity indices, natural pine regenerates successfully on more than 75 per cent of clearcuts, i.e. this species dominates at all succession stages. In landscapes with low fire periodicity pine changing for spruce and deciduous species is quite common. In spruce clearcuts mass regeneration of deciduous species takes place regardless of speciality of fire regime.

## Conclusion

Practically all natural forest communities within Eastern Fennoscandia represent different stages of post-fire successions. There exist a lot of various opinions about the role of pyrogenic factor in spontaneous and anthropogenic dynamics of forest, but they differ only in evaluating the degree of fire influence. The degree of fire influence is determined by a fire regime variant-frequency, intensity and regularity of fire spreading. These variants are clearly conditioned on landscape features of taiga territories.

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Vitali I. Krutov

**Fungal Diseases of Young Coniferous Forests  
in Russian Karelia**

**В. И. Крутов**

**Грибные болезни хвойных молодняков в Карелии**

Abstract

The following diseases of young pine forest could be estimated as the most widely spread and dangerous in Karelia: Snow blight, Scleroderris canker and pine twisting rust (*Melampsora pinitorqua*). The distribution of these diseases usually has a character of epiphytobia. Several other types of disease occur sporadically. Among them Lophodermium needle cast (*Lophodermium seditiosum*) and Lophodermella needle cast (*Lophodermella sulcigena*) are noted more often than Blister rust (pathogenic agent *Cronartium flaccidum*), biatorella canker and some other diseases.

For larch (*Larix sibirica*) that was widely used for artificial reforestation of clearfell-areas in Karelia in the 50's, the most dangerous diseases are Larch canker and Armillaria root rot.

Spruce (*Picea abies* and *P. obovata*) and siberian cembra (*Pinus sibirica*) are attacked by fungus diseases rather seldom and to a little extent. Spruce needle cast (pathogenic agent *Lophodermium macrosporum* = *Lirula macrospora*) and northern or golden needle trust (*Chrysomyxa ledi* and *Ch. abietis*) can be estimated as the most widely spread spruce fungal diseases.

**Реферат**

Наиболее распространенными и опасными болезнями сосновых молодняков в Карелии являются: снежное шютте, побеговый рак (склеродерриоз), ржавчина побегов, или сосновый вертун. Распространение этих болезней нередко носит характер эпифитотии. Спорадически отмечались вспышки шютте обыкновенного, шютте серого, изредка отмечаются случаи поражения

пузырчатой ржавчиной (возбудитель — *Cronartium flaccidum*), биаторелловым раком и некоторыми другими болезнями. Для лиственницы сибирской (*Larix sibirica*), которая в 50-х годах широко использовалась для закультивирования вырубок в Карелии, серьезную опасность представляют ступенчатый, или дазисцифовый рак и корневая гниль от опенка — *Armillariella mellea*. Ель (*Picea abies* и *P. obovata*) и кедр сибирский (*Pinus sibirica*) поражаются грибными болезнями редко и в слабой степени. Из болезней ели можно назвать шютте ели (возбудитель — *Lophodermium macrosporum* = *Lirula macrospora*) и северную, или золотистую ржавчину хвои (возбудители — *Chrysomyxa ledi* и *Ch. abietis*).

## Introduction

One of the main goals of forestry in the Republic of Karelia is the rapid and successful regeneration of forests which have declined due to clear cuttings. This is provided by the right combination of natural and artificial reforestation with conifers. Academician И.С. Мелехов (1993), speaking about current problems facing forests, puts the emphasis on the task of "... recovering pine forests in taiga regions" together with working out the measures for "... the protection of pine against pathological effect".

Fungal diseases cause a marked damage on the initial stages of establishing young pine forests. According to prof. И.И. Журавлев (1958) the total mortality due to fungal diseases (damping-off and needle cast) is about 50 % of young seedlings appearing naturally in the first years after felling. Among 7 year-old pines the mortality may reach even 80 %. Investigations conducted on cutting areas in Karelia show 20—21 % (without including damping-off) mortality (Крутов & Волкова 1975). Artificial plantations, especially pine ones (*Pinus sylvestris*), suffer the most. About the age of 10 years, on average, 50 % of all seedlings (about one third of seeding places) are dead in plantations established by sowing and about 10 % — in those restocked by planting (Крутов 1989).

## Results

**Snow blight.** (pathogenic agent *Phacidium infestans*). The most common pine disease. This seems very dangerous for young pine forests until the trees reach 0.5—0.6 m in height which exceeds the average level of snow cover. In southern part of Karelia pine seedlings reach such height at the age of 5—6, in the northern area at 11—15 years. The pathogenicity of this disease increases from north to the south due to worsening of the soil and climatic conditions. The dynamics of the occurrence of the disease in terms of timing and latitude is determined by air temperature in March and April and by the longevity of snow cover depending of these temperatures. The optimum conditions for the development and distribution of snow blight exist in the northern taiga subzone, where cutting areas in pine forests are predominantly on pure sandy soils. In these conditions pine grows slowly, with the ground vegetation consisting of dwarf-shrubs (*Vaccinium vitis-idaea*, *Calluna vulgaris*), mosses and lichens that do not preclude dissemination of infected needles. Besides, the period of snow cover here is very long (155—185 days).

In the middle taiga subzone (middle and southern Karelia) Snow blight has a patchy distribution due to differences in the character of the ground vegetation in cutting areas. The majority of cutting areas are covered by grasses, birch and aspen, which makes the transportation of infection more difficult. Moreover, in more fertile soils pine reaches a height above the snow faster. In recent years more than 50 % of pine plantations in southern Karelia were established by planting which is known to suffer this disease to a less extent.

**Scleroderris canker** (*Gremmeniella abietina* with the conidial stage *Brunchorstia pinea*) is a dangerous and comparatively new disease of pine plantations in the northern Karelia and Murmansk region. It was found for the first time in the end of the 60's in pine plantations established with seed brought from Central Russia, Ukraine and Byelorussia because of the constant deficiency of local seeds. Such plantations were characterized by good growth during the first years, but about the age of 10—11 years they completely died due to the mentioned disease. The same can be said about Lophodermium needle cast. On the native pine both diseases are exceptionally rare. A considerable damage by Scleroderris was noted in the test with nine-year mineral fertilization conducted in southern Karelia (Крытов 1989). Scleroderris canker prefers the same vegetation conditions like Snow blight, often jointly occurring.

**Pine twisting rust** (*Melampsora pinitorqua*), the distribution and harmfulness of this disease grow from north to south depending strictly on

soil and climatic conditions. The distribution to the north is limited by a range of factors: prevalence of cuttings in areas with poor sandy soils (unfavorable for aspen, an intermediate host of the disease), cool climate and short growing season. On more rich cutting areas, under favourable weather conditions, the damage caused by Pine twisting rust reached (in 1971, 1973, 1976, 1983, 1985) 90 % especially in cultivated areas. Young stands (under 10—12 years) are damaged most, and older stands (up to 20 and more years) can be also strongly damaged. The seasonal dynamics of the disease are affected by the weather conditions of the previous growing season: the sum of temperatures equal and higher than 10 °C during June, July and September, the total amount of precipitation in August under the temperature equal or higher than 5 °C. On this basis we developed a mathematical model of long-term disease forecast, which was tested during several years and proved to be very precise.

Biatorrella canker (*Biatorrella difformis* with the conidial stage *Biatorridina pinastri*) is a disease of young pine stands, growing in unfavourable conditions: in the places with surplus moisture under the forest canopy. On damaged pines canker wounds with sharp margins and dark-brown surface form, from 3 to 10, sometimes up to 20 on a single trunk, often on its central part. According to В.И. Щедрова (1979), the damage caused by this disease reached 80—100 % on the stands with high moisture and 30—40 % under forest canopy in dry pine stands of low density.

Other pine diseases do not affect considerably the coniferous forest regeneration on cutting areas.

Larch canker (*Dasyscypha (Lachnellula) willkommii*) is ubiquitous, but seems to be the most harmful for Larch in unfavourable conditions of dry and moist areas. In some of such places up to 50—70 % of young trees (10—12 years old) died. The frosts, possible during the whole growing season, promote Larch damage.

Armillaria root rot is one of the main reasons for the poor survival rate of Larch plantations, established on cutting areas in coniferous forests in southern Karelia. Other tree strains are damaged by this disease exceptionally rarely.

For reducing the damage, caused by fungal diseases, a system of protective measures is proposed. This system includes forestry operations and phytosanitary prophylactics.

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**Pentti Niemistö**

**Influence of the Density of a Pubescent Birch Stand on  
Understorey Spruce Development on Peatland**

**Пентти Ниёмистё**

**Влияние густоты древостоя берёзы пушистой, на  
развитие ельника, формирующего нижний ярус  
насаждения на торфяных грунтах**

**Abstract**

The aim of the research was to study how spruce seedlings grow and how their condition depends on the density of an above growing mature pubescent birch stand. Also, the damages to the spruces caused by the felling and haulage of birches studied. As a study material a wide-scale thinning experiment in a pubescent birch stand was used. Spruces had been planted under the birches in 1967. Partly in the experimental area there are a lot of natural spruce seedlings. The birches were measured in 1974 and 1979 and both species in 1984, 1988 and 1993. The density of the birch stand varied between 350—2000 stems/ha, and the dominant height in 1993 was 17.7 m.

The spruce seedlings developed at first slowly, so at the age of 18 years they were only about 1.6 m high and in an unthinned birch stand even smaller. As spruce is a shade tree species, it managed moderately in a fully stocked birch stand. The pubescent birch stand was thinned first in 1974 and then for a second time in 1984. After the second thinning clear differences became apparent between the growth of the spruces. At the age of 27 years the mean height of planted spruces was 4.5 m in the density of 400—500 birches/ha and correspondingly 2.5 m in the density of 2000 birches/ha.

In unthinned birch stands the mean diameter of the spruce seedlings was 1.5—2.0 cm smaller than in the thinned ones. In three sample plots all birches were removed in 1989. The released spruces grew as much in height but clearly more in diameter than the spruces in a thinly stocked birch stand. It is probable that the height growth of the released spruces accelerates when they adapt themselves to the increased light after fel-

ling. The spruces remained healthy with no difference in mortality between the thinned and the unthinned birch stand.

In June in 1994 the birches were felled in ten sample plots using the Scandinavian assortment system and hauled by forwader. When being felled the tops of the birches were directed towards the logging roads or over the ditches, so there was only a small amount of damages to spruces. The majority of the damages was caused by them being smashed under the tractor wheels, falling between the tracks or haulage damages near the logging roads. As a whole, the spruce stand recovered from the felling better than what was expected. Number of remained spruces in good condition was 1500 seedlings/ha and only 200—300/ha (10—20 %) were damaged. The modern felling machines would probably reach an as good a result as in manual felling, but in that case the spruce stand should not be too high.

It is known that spruce often regenerates naturally under deciduous tree stands. The natural regeneration of spruce is common in pubescent birch stands in fertile peatlands. A too widely spaced birch stand, however, does not work as frost shelter. Thinning a birch stand just because of spruces or a final cutting in several stages does not seem to be necessary. Increasing the understorey is one method to increase the biodiversity of forests, in order to avoid tree stands with one species and to reduce both the economic and landscape problems.

## Реферат

Целью настоящего исследования было изучение зависимости прироста и состояния саженцев ели от густоты взрослого древостоя березы пушистой, образующего верхний ярус насаждения. Изучали также повреждение саженцев ели во время рубки и вывозки древесины. В качестве материалов исследований использовали результаты за 20 лет по опытному разреживанию березняка, в котором в 1967 году под пологом лиственной породы высадили саженцы ели. Местами в березняке было достаточно много подроста, формирующегося путем естественного возобновления леса. Измерения ели проводили в 1984, 1988 и 1993 гг. Густота березняка колебалась в пределах 350—2000 берез на гектар и высота доминирующих деревьев составила в 1993 году 17.7 м.

В начале саженцы ели развивались медленно, и в возрасте 18 лет их высота составила только ок. 1.6 м, а на участках, не подвергнутых рубкам разреживания даже меньше. Однако, как по-

рода с высокой теневыносливостью, ель переносила относительно хорошо условия даже в березняке с первоначальным запасом древостоя. Березняк из березы пушистой подвергалась рубке разреживания первый раз в 1974 году и второй раз в 1984 году. После второй рубки в приросте саженцев ели начали наблюдаться явные различия. В возрасте 27 лет высота саженцев составила в среднем 4.5 м при густоте березняка 400—500 берез на гектар и соответственно 2.5 м при густоте березняка 2000 берез на гектар.

На толщину ели густота березняка имела более сильное влияние, чем на высоту. В березняке, не подвергнутом рубке разреживания, средний диаметр саженцев ели был на 1.5—2.0 см меньше толщины ели в прореженном лесу. С трех участков удалили все березы 1989 году. У освобожденных саженцев ели прирост в высоту был одинаковым, но прирост в толщину явно больше по сравнению с елями в разреженном березняке. Можно предполагать, что у освобожденных елей прирост в высоту ускоряется после приспособления к большей освещенности. Что касается состояния здоровья и жизнеспособности ели, эти характеристики были одинаковыми как в очень густом, так и в прореженном березняке.

В июне 1994 года произвели вырубку берез на десяти опытных участках с использованием системы сортимента, для трелевки использовали обыкновенный лесной трактор. При вырубке кроны берез ориентировали на трелевочные волокна и канавы и следовательно, повреждений ели было мало. Прежде всего ели страдали в следствие попадания под колеса трактора, сваливания между колеями или получения ударов вблизи трелевочных волокон. В целом молодняк переносил рубку лучше, чем ожидали. Количество елей, которые сохранились в хорошем состоянии, составило в среднем 1500 шт. и количество погибших саженцев 200—300 шт. (10—20 %) на гектар. Предположительно с использованием современных валочных машин можно было бы добиваться таких же результатов как при производстве работы лесорубами, но в том случае ельник не должен быть слишком высоким по росту.

Известно, что ель возобновляется часто естественным путем под пологом древостоев из лиственных пород. Особенно благоприятными в этом отношении являются древостои пушистой березы на плодородных торфяных почвах. Однако, слишком прореженный березняк не дает защиты от заморозков. Кажется, что

разреживание древостоя березы пушистой с точки зрения ели не требуется, так же как и проведение очистной рубки в несколько этапов. Увеличение нижнего яруса леса является одним из способов диверсификации леса, предотвращает формирование древостоев из одной породы, сокращает расходы и уменьшает проблемы с формированием ландшафта.

## Introduction

Spruce seedling stands which have been established in clearcut areas often suffer in Finland from early summer frost (Multamäki 1942, Leikola & Pylkkö 1969, Leikola 1975, Leikola & Rikala 1983, Heikurainen 1985). Especially the low-lying areas and peatlands are sensitive to night frosts and spruce needs a nurse crop for shelter. In fertile peatlands there grows an abundance of pubescent birch, most often in a mixture with spruce and pine, but pure pubescent birch stands are also common especially in Ostrobothnia and southern Lapland (Kuusela *et al.* 1986).

The natural regeneration of spruce is common in drained birch stands (Seppälä & Keltikangas 1978), and they can be supplemented by planting if necessary. Growing this kind of two storied birch—spruce stand has several advantages. A fully stocked mature birch stand in fertile peatland produces a moderately good economical result simultaneously with the young seedling stand of the spruce (Keltikangas & Seppälä 1977, Niemistö 1991, Mielikäinen & Valkonen 1994). In addition, the quality of site benefits from the birches' leaf litter, deep root system and the abundant evaporation (Laitakari 1934, Huikari 1954, Mikola 1954, Sirén 1955, Paavilainen 1966, Mälkönen 1977, Kaunisto & Päivänen 1985). On the other hand the competition caused by the birch may slow down the early development of the spruce seedlings, cause technical injuries or weaken the health of the spruces (Cajander 1934, Leikola 1976, Folkesson & Bjärring 1982, Leikola & Rikala 1983, Heikurainen 1985, Braathe 1988).

The rotation of the pubescent birch is short in Finland — about 60 years — and the species seldom produces valuable veneer logs (Verkasalo 1988). Because of early biological aging the growth capacity of pubescent birch diminishes and the susceptibility to decay increases, consequently growing a mature pubescent birch storey is hardly economically profitable for a long rotation (Koivisto 1959, Keltikangas & Seppälä 1977, Sarämäki 1977). Alternatively, letting good quality silver birches grow to full maturity over a long time above a spruce stand in fertile mineral soil may

be an economically profitable alternative (Mielikäinen & Valkonen 1994, Tham 1988). The release of a spruce stand is both technically and biologically problematic (Thesslund 1975, Maukonen 1987, Peltoniemi 1991). If the birches are taken away too early that increases injuries caused by the frost and the sudden increase of light may cause the needles, which have adapted themselves to shade, to desiccate (Cajander 1934, Bergan 1971, Leikola 1975, Skoklefeld 1976, Andersson 1988, Saarinen 1995).

This research studies the development of planted and natural spruce seedlings in a peatland pubescent birch stand with varying density. The aim is to find out the effect of overgrowing birch on the spacing, height, diameter increment and the condition of the undergrowing spruces.

## **Material**

The location of the experimental stand is in the district of the National Board of Forestry in Haapavesi (combined coordinates 7111/412). The pubescent birch stand was established naturally in connection with new drainage in 1936—37. The site is a herb rich heathy peatland with the peat about half a metre thick. On the majority of the area the spruce seedlings were planted in the spring of 1967. The area was supplementary drained in 1974—75 and near the ditches there has developed at places a dense natural spruce undergrowth. A thinning and fertilizing experiment of pubescent birch was established in the autumn of 1974. After the first thinning the density varied between 700—2100 trees/ha. Since the birches have been measured at 5 year intervals (Oikarinen & Pyykkönen 1981, Niemistö 1991). A second thinning was done in the spring of 1985 (table 1), after which the density of the growing birch stand varied between 400—2000 stems/ha in 5—7 replications.

The number of spruces and the mean height were estimated when the birch stand was thinned a second time in the spring of 1985. The actual measurement of the spruces was done in the autumns of 1988 and 1993. In 1988 close to the thinning experiment there were established three supplementary sample plots in which all the birches were then removed. Breast height diameter was measured from all spruces over 1.3 m in height and the height of all spruces under 1.3 m in height. In addition, the height of every fifth spruce which was over 1.3 m high, was measured. From a height curve drawn with the help of these sample trees the heights for all the spruces present were estimated.



*Figure 1. An understorey spruce stand in a thinned pubescent birch stand, where the stem number is 700 stems/ha and the total volume of stems 140 m<sup>3</sup>/ha.*

*Table 1. The mean diameter and stem volume in the experimental pubescent birch stand after second thinning, mean volume increment during the following nine year period and the density of the understorey spruce stand in different thinning grades of the birch stand.*

Density	Pubescent birch stand after thinning			Planted spruces		Natural spruces	
	Mean diameter cm	Volume m <sup>3</sup> /ha	Growth m <sup>3</sup> /ha/y	Number of sample plots	Spruces /ha	Number of sample plots	Spruces /ha
0	(birches removed 1988)			3	1400	0	-
400-500	18.1	81	3.2	4	950	2	1300
500-800	16.7	100	3.3	5	1400	1	3400
800-1100	16.7	126	3.8	5	1050	3	850
1100-1500	15.3	134	4.1	4	1300	2	2400
1500-2000	14.7	155	4.1	7	1050	1	1300

Distinguishing between the natural and planted seedlings on the basis of their location and size was still possible although not exact. For this reason small ingrowths between the natural and planted spruces were possible from first measurement to another. Of all the spruces there was made the following classification of quality: 1 = no injuries, 2 = stem crooked or forked, 3 = change of top during the last five years, 4 = top injured, dry or diseased, 5 = dead.

The planted spruces were measured 22 and 27 years after planting in 28 sample plots, total of 2.8 hectares. A significant amount of natural seedlings (> 300 trees/ha) were found in nine sample plots. The results from the sample plots were combined on the basis of the density of the birch stand into six grades as follows: no hold-over birches, 401—500, 501—800, 801—1100, 1101—1500 and 1501—2000 stems/ha.

In June 1994 all birches were felled in 10 experimental plots, which were chosen so that the seedling stand was released in several adjoining sample plots. The density of the removed birch stand varied between 450—2200 stems/ha. The trees were felled using chain saw with the shortwood logging system. Tops were mainly directed to the logging road which ran in the middle of the 30 m wide sample plots or alternatively towards the ditch line on the border of the experimental plot. The timber was loaded and hauled away with a medium heavy forwader, which had to make some spur roads in order to reach all timber with its 10 m long boom loading device. After felling all the injured and damaged spruces were measured and classed on the basis of the type and cause of injury.

## **Results**

### **The Density of the Undergrowth Spruce Stand**

The amount of the living planted seedlings did not depend on the density of the above growing birch stand (Table 1), neither did it diminish during the measuring period. There were an average of 1200 planted spruces/ha and the range between the density classes of the birch stand was 950—1400 spruces/ha.

There were natural spruce seedlings on nine sample plots in the first measurement an average of 1800 spruces/ha and five years later 1450/ha. The amount of natural spruces diminished most, about 30 %, under the densest birch stand. The natural seedling stand was more varied than the planted one. On those sample plots where occurred natural spruces, there were 300—3600 spruces/ha. Also, inside the sample plots the natural

seedling stand varied so that there were more spruces along the ditches than in the middle of the field. In general the natural seedlings occurred in the same sample plots as the planted ones, but in the unplanted area there were two sample plots where there grew about 3500 natural spruces/ha. Except for these two sample plots a fully stocked spruce stand would not have been established without planting.

### **Height and Diameter Increment of Spruces**

The mean height of the planted spruces was in the spring 1985 at the age of 20 years about 1.6 m in the birch stands, where the density was less than 1100 birches/ha. In denser sample plots the mean height of the spruces was half a metre smaller. During next four years in unthinned sample plots the mean height of the spruces increased to 1.5 m and in heavily thinned sample plots to 2.5 m (Fig. 2a). During the following 5 year period the height increment of the spruces was highest (about 40 cm/year) under the sparsest birch stand. In an unthinned birch stand the height growth of spruce was the lowest. The other thinning grades did not differ from each other and in the released spruce stand the height increment was equal to them.

The natural spruces were in 1988 higher than the planted ones (Fig. 2b). Their mean height, too, depended on the density of the birch stand in the same way as that of the planted spruces. The mean height of the natural spruces varied from 2.2 m to 4.6 m, when the density of the birch stand changed from 1600 to 450 trees per hectare. Five years later the mean height of the spruces varied correspondingly from 4.0 to 9.2 m. An exception were the sample plots, where the density of the pubescent birch stand was 500—800 trees/ha because of large number of small natural spruces. On other plots the height increment of the natural spruces was, during the whole measuring period, the lower, the denser was the birch stand above.

60 % of the total height of planted spruces has grown during the last nine years. The seedlings have thus passed their slow initial growth stage. During the 20 first years the mean height increment of planted spruces was only 1.5 m. The mean height of the natural seedlings doubled during the last 5 year period, but the mean height increment was an over-estimation because of the death of the smallest spruces.

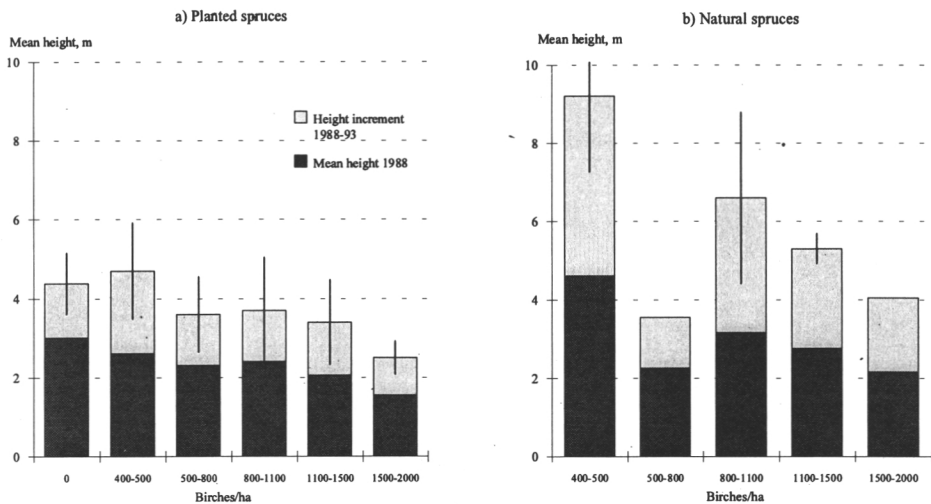


Figure 2. The development of the mean height of spruces and standard deviation between the sample plots under a pubescent birch stand which has been thinned with different densities on peatland.

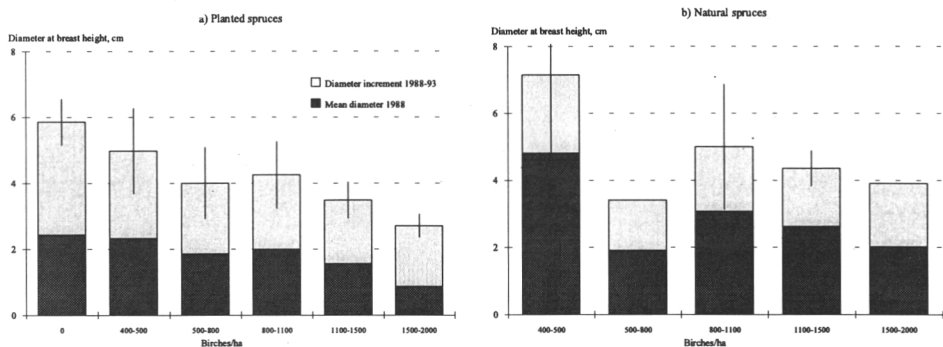


Figure 3. The development of the mean diameter of spruces and standard deviation between different sample plots under a pubescent birch stand which has been thinned with different densities on peatland.

For the natural spruces the clear differences between the densities of the upper storeys existed already in the year 1988 (Fig. 3b). The density of the birch stand had thus a very clear effect on the diameter increment of the undergrowth spruces. One must also take notice that the height increment of the released spruces did not differ during first five years from the mean value of those growing under a birch stand but there was a clear difference in the diameter growth for the benefit of the released ones.

## The Quality of the Spruce Seedlings

Of the planted spruces the proportion of the seedlings free of defects varied in the first measurement from 75 % to about 60 %, when the density of the above growing birch stand increased (Fig. 4a). The most common injury was the change of the apical shoot during the last five years, which became clearly more common when the density of the birch stand increased. The amount of other kinds of damaged or diseased tops varied equally. For some reason crooked and forked spruces became common in the opposite order. The reason could be the harvesting injuries which had taken place during the first thinning of the birch stand.

During the last five years the quality of the seedlings improved. The portion of the seedlings of good condition increased to the level of 80—90 % and no dependence on the density of the birch stand could be observed any more (Fig. 4b). Especially the amount of the changes of apical shoot had diminished. Alternatively, in the seedling stand which had been released there occurred faulty tops in every fifth spruce.

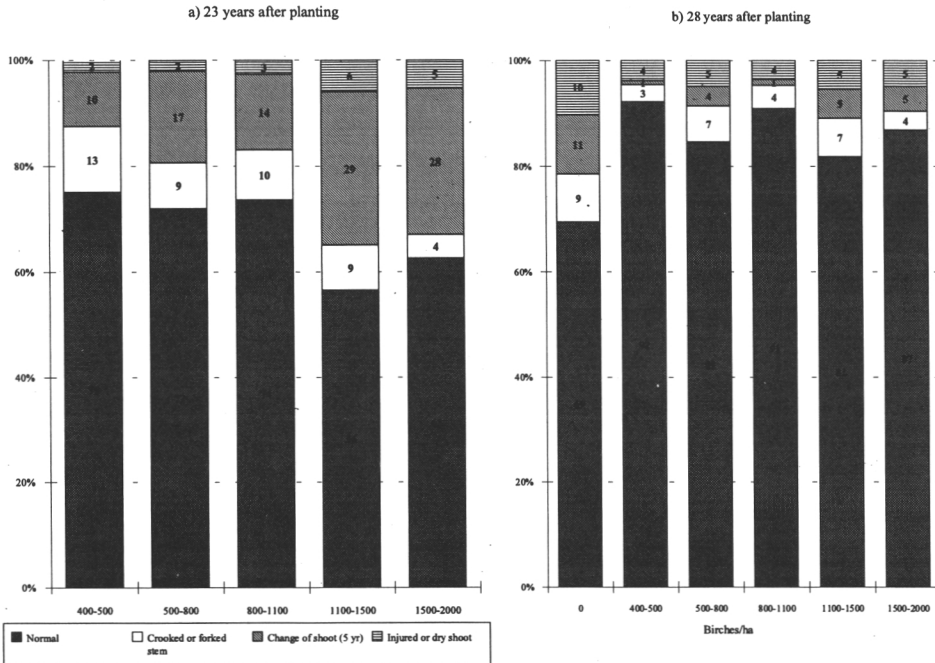


Figure 4. The influence of the density of a pubescent birch stand on the quality of the planted undergrowth spruces.

## The Release of the Seedling Stand

The number of stems which had been removed from above the spruce stand varied between 450—2200 birches/ha and the stem volume between 89—190 m<sup>3</sup>/ha. When the outturn increased, the number of the damaged and injured spruces per hectare increased from 190 to 300 (Fig. 5). An exception was caused by three sample plots, where less seedlings were damaged because there were clearly less spruces on the logging road placed on the middle of the field than nearer the ditches. Above mentioned 3 exceptional observations were discarded.

In the rest of the sample plots there were an average of 260 broken, fallen or loosened spruces/ha. The portion of dead or dying seedlings varied between 7—20 % according to the sample plot with 15 % as an average. The number of fallen and broken spruces made up 70 % of the harvesting injuries (Table 2). Usually the reason was the wheels or the frame of the forest tractor, which caused 83 % of the observed injuries. Part of the injuries caused by the machine frame were the bark injuries and tilting of the surviving trees. Practically, all spruces growing on the tracks of the machine or between the tracks, were destroyed.

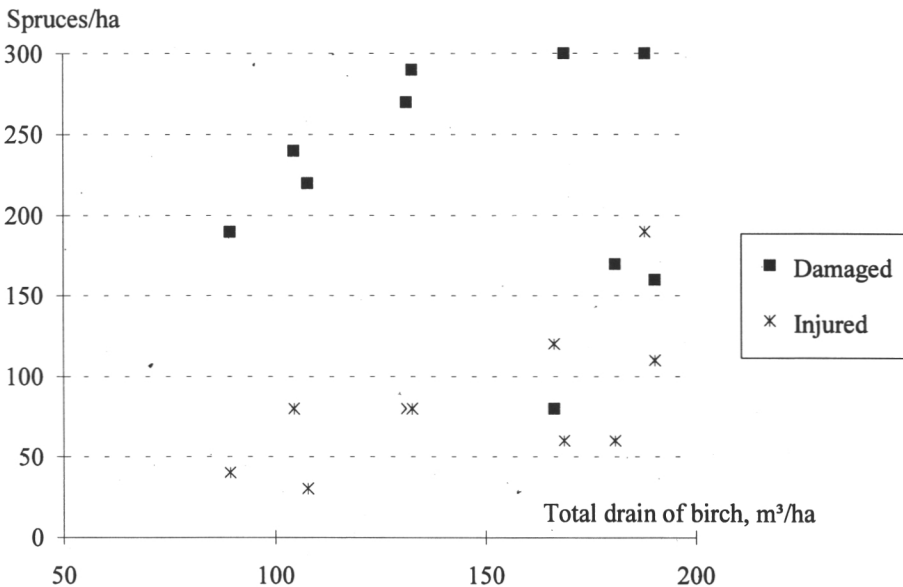


Figure 5. The influence of the drain of an overgrowth birch stand on the number of damaged and injured spruce seedlings.



*Figure 6. A spruce sapling stand five years after the release.*

Of all the spruces about 5 % were injured lightly and they were considered as surviving. The number of tilting seedlings constituted rather less than half of these and in the rest the top injuries were slightly more common than the bark injuries (Table 2). The reason for the lighter injuries was more often felling than loading. The reason for tilting and bark injuries was mainly the frame or wheels of the forwader. There were also more injured spruces if a birch stand have been a denser one (Fig. 5). The correlation coefficient ( $r$ ) between the drain and the injured seedlings was 0.63. The portion of the injured seedlings for a sample plot was 1—10 %. The correlation was most intense between the top damages of the seedlings and the volume of the drain ( $r = 0.68$ ), but tilting seedlings were also found more after increased drainage. The reason for the effect of the drain seemed to be in the moving and loading of the timber, but not so much in felling.

The amount of undamaged seedlings was at most 93 % and at least 76 % of total number of spruces. Usually the damaged or injured seedlings were slightly smaller than the other spruces in the sample plot. The difference was, however, clear only in such sample plots, where there grew along the ditch margins natural spruces which were bigger than the other seedlings.

*Table 2. The distribution of the injured and damaged spruce seedlings in the final felling of the pubescent birch stand according to the type and cause of the injury.*

Type of injury	Top injury	Bark injury	Tilted	Fallen or broken	In all
spruces/ha	28	23	44	212	307
% of seedlings	1.4	1.2	2.2	10.8	15.6
% of injuries	9.1	7.5	14.3	69.1	100
Cause	Felling	Loading	Machine frame	Machine wheels	In all
spruces/ha	34	20	98	155	307
% of seedlings	1.7	1.0	7.9	5.0	15.6
% of injuries	11.1	6.5	31.9	50.5	100

## Discussion

The research followed the development of the spruce seedlings which had been planted or naturally regenerated in fertile peatland under a 30 years old pubescent birch stand in 1960's. A fully stocked birch stand (about 2 000 stems/ha) was treated by different grades of thinnings 8 and 18 years after the spruces had been planted. In 3 sample plots the spruce stand was released 22 years after planting and in ten sample plots after 27 years. The overstorey was measured after the first thinning at five year intervals and the understorey spruce stand 22 and 27 years after planting.

The development of the planted understorey spruces were slow during the first 20 years. When the growth stagnation period ended the spruces were about 1.5 m high and about 20 years old. After that time the development of the height and diameter of spruces depended clearly on the density of the above growing birch stand. In a heavily thinned birch stand the height of the spruces 27 years after planting was almost double compared to an unthinned stand. During the last 5 year period the height increment was highest in a heavy thinning stand (400—500 birches/ha; 40 cm/year), in comparison a released spruce stand was 25 % lower. The temporary stagnation of the height increment in a released spruce stand has been observed earlier among others by Cajander (1934), Skoklefeld (1967), Bergan (1971), Heikurainen (1985) and Koistinen & Valkonen

(1993). Eriksson (1976), Bergan (1987) and Tham (1988) have observed that a released spruce stand grows after a 2—5 years' stagnation even faster than a spruce stand which has grown free from the beginning.

The diameter increment of spruce reacts to the thinning of the birch stand in the same way as height increment, but the diameter increment of the released spruces was clearly higher than that of the understorey. No injuries were observed in the released spruces caused by the sudden increase of light. Perhaps the spruces have grown accustomed to more light during the leafless time of the birch, so the removal of the overgrowing trees did not cause too great a change in lighting (Saarinen 1995). During the measuring period there were not observed any frost damages, either, which could have taken place in connection with wider-scale fellings.

The development of the natural spruces was faster than that of the planted ones. The reason was probably their location in better site conditions close to ditches and, on the other hand, their more advanced stage of development. When the measurements were started the natural spruces were on an average higher than the planted ones. The density of the pubescent birch stand influenced the development of both the planted and the natural seedlings in the same way.

In the densest natural seedling stands spruces were damaged during the measuring period, but the mortality did not depend on the density of the birch stand. The spruce seedlings were mostly healthy and had a good stem. During the first years after the second thinning of the birch stand the spruce tops were of poorer condition in the dense birch stands than in the thinned ones. At the same time occurred the exceptionally cold winter of 1986—87 with deep soil frost, which have been found to have weakened the growth and health of tree stands especially on peatlands. The influence of the density of the birch stand on the quality of the spruces seemed temporary, because the differences in the condition of the crowns diminished during the second measuring period.

The yield of a heavily thinned pubescent birch stand was during the measuring period 3.2 m<sup>3</sup>/ha/year and 4.1 m<sup>3</sup>/ha/year in a slightly thinned or unthinned stand. The earlier incomes in thinned and the mortality in unthinned birch stands cause the fact that there are no great differences in the profitability between the treatments of the pubescent birch stands in spite of the differences in growth. For this reason the effects on the development of the undergrowth spruces can be taken flexibly into account when treating the above growing pubescent birch stand. A dense overgrowth birch stand slows clearly the height and diameter development of the spruce seedlings. On the other hand, not even an unthinned birch stand is an obstacle for the establishment of a spruce seedling stand

— the spruces just develop slower and because of the higher volume of the drain it may be technically more difficult to release the seedling stand, compared to a sparse birch stand.

The amount of the spruce seedlings which were damaged on the experimental sample plots depended on the amount of wood removed from the birch stand. The damages and light injuries to spruces in the felling, moving and loading of wood increased with higher volume of the drain. The total amount of the damaged and injured spruces was 230—500 seedlings/ha. The felling which was done at summer time with chain saws succeeded very well, when the birches were directionally felled so that their tops hit as often as possible on the logging road or over a ditch. The fallen and broken spruces occurred almost without an exception on the tracks of the forest tractor or between them. The proportion of the damaged seedlings (15 %) corresponds to the about 4.5 m wide area of the logging road on the sample plots, the width of which was on average 32 m. There were less damages on those sample plots where the ditch margins had become stocked with seedlings better than the average and more on those where there were supplementary spur roads or turning places for the logging machine.

In the research of Peltoniemi (1991), the mature shelterwood was removed, half of which were spruces. When felling machines were used, 19—26 % of the seedlings were injured, in the combination of machine and men 26 %, and with manual logging 11—23 % of the seedlings. In Maukonen's (1987) research 33 % of the understorey spruces were injured in manual logging, when the average outturn of the overstorey was 133 m<sup>3</sup>/ha, birches constituted about half and pines and spruces a quarter each. The reason for the better result in a pubescent birch stand may be that the branches of initially very dense pubescent birch stand, are slender and stems smaller compared to e.g. researches, where a falling tree and the logging waste were the most common causes of injury. Also, the use of ditch lines in directional felling can diminish injuries on peatland.

According to Mielikäinen and Valkonen (1994) the release of a spruce stand must not be hastened. It is worthwhile to thin a youngish dense birch stand which is growing above a spruce seedling stand in order to increase the yield of birch, but to avoid heavy thinnings in a mature birch stand. In the pubescent birch stands on peatland the amount of veneer stems remains small and it didn't increase after thinning (Niemistö 1991). Even if the overstorey birch stand would produce only pulpwood, it is probably not worth removing from above the spruce stand before its own economical rotation is closed at the age of 60—70 years. The situation is different if the age gap between the birch and spruce stands is so small

that the spruce tops have time to rise between the living crowns of the birches and then the birches can whip the spruces (Leikola & Rikala 1983, Heikurainen 1985). Then it is worthwhile to thin the birch stand heavily and if necessary, to remove the trees earlier than in a corresponding pure birch stand.

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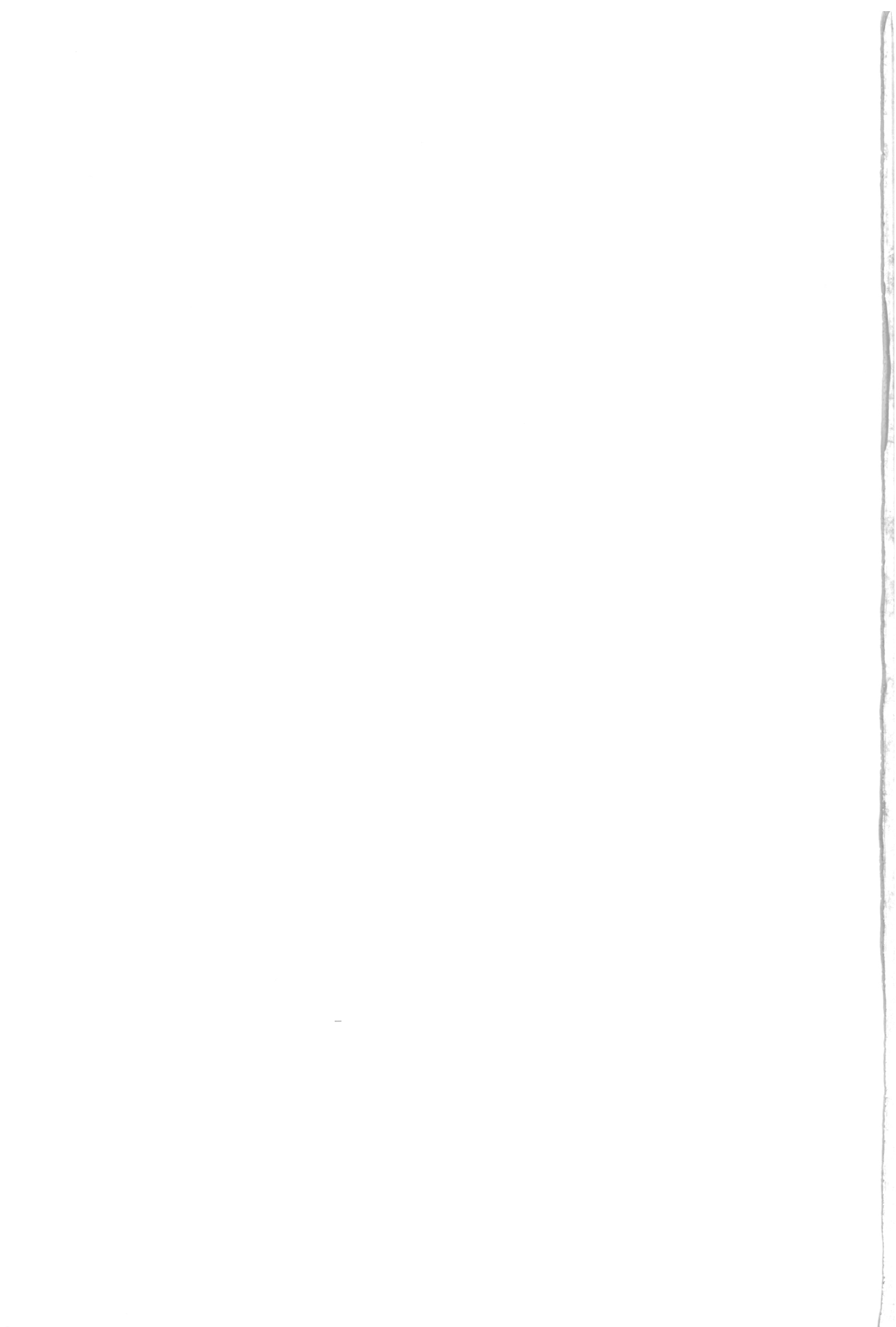




*A silver birch forest near Rovaniemi ten kilometers to the south of the arctic circle. The clear cutting area of 104 hectares was burnt 40 years ago. The birch was regenerated in a natural way. The soil is in a healthy condition because of the burning and the new leaf fall every autumn. Photo Jukka Valtanen.*







### **Muhoksen tutkimusaseman tiedonantoja -sarjassa julkaistu seuraavat tiedonannot:**

- Nro 1. Jukka Valtanen. Avoalan suuruuden vaikutus männynviljelyn tulokseen Pohjois-Suomessa. 1971.
- Nro 2. Tutkimuspäivän alustukset 1972.
- Nro 3. Jukka Valtanen. Avoalan suuruuden vaikutus männynviljelyn tulokseen Pohjois-Suomessa. 1972.
- Nro 4. Kalevi Karsisto. Esituloksia suometsien fosforilannoitelajikokeista. 1973.
- Nro 5. Kalevi Karsisto. Lannoitteiden levitystasaisuudesta moottorikelkkaa käytettäessä. 1973.
- Nro 6. Kalevi Karsisto. Kokeita typpilannoitteiden häviämisestä säkeistä. 1973.
- Nro 7. Kalevi Karsisto. Isorakeisen typpilannoitteen uppoamisesta lumeen. 1975.
- Nro 8. Markku Turtiainen ja Jukka Valtanen. Metsänviljelytutkimuksen välituloksia Pohjanmaan ja Kainuun metsäaurealueilta. 1974.
- Nro 9. Jukka Valtanen. Avoalan suuruuden vaikutus männynviljelyn tulokseen Pohjois-Suomessa. 1974.
- Nro 10. Esteri Ohenoja ja Niilo Takkunen. Alustavia tietoja lannoituksen vaikutuksesta kangasmetsien sienisatoon. 1974.
- Nro 11. Kalevi Karsisto ja Jorma Issakainen. Riistan tuottaminen metsänparannusalueilla. 1974.
- Nro 12. Kalevi Karsisto. Peatland forestry experiments in Pyhäkoski experimental area. 1974.
- Nro 13. Kalevi Karsisto. Ojituksen ja metsänlannoituksen vaikutus vesien saastumiseen. 1974.
- Nro 14. Tutkimuspäivän esitykset 1975.
- Nro 15. Metsäntutkimuspäivä Haapavedellä 1976.
- Nro 16. Metsäntutkimuspäivä Sotkamossa ja Ämmänsaarella 1977.
- Nro 17. Metsäntutkimuspäivä Haukiputaalla ja Muhoksella 1978.
- Nro 18. Metsäntutkimuspäivä Kannuksessa 1980.
- Nro 19. Mikko Moilanen ja Matti Oikarinen. Perkausajankohdan vaikutuksesta hieskoivun ja haavan vesomiseen kangasmaalla. 1980.
- Nro 20. Tuha metsänlannoitteena. Toimittaneet Pekka Pietiläinen ja Markku Tervonen. 1980.
- Nro 21. Metsäntutkimuspäivä Muhoksella 1980.

### **Metsäntutkimuslaitoksen tiedonantoja -sarjassa julkaistu seuraavat tiedonannot (Muhoksen tutkimusasema):**

- Nro 3. Jussi Saramäki. Hieskoivun kasvu ja kasvatusta Pohjanmaalla ja Kainuussa. 1981.
- Nro 17. Jorma Issakainen ja Mikko Moilanen. Lentolannoituksen levitystasaisuudesta ja työjäljen valvontamenetelmän kehittämisestä. 1981.
- Nro 24. Metsäntutkimuspäivä Taivalkoskella 1981.
- Nro 29. Mikko Moilanen ja Kalevi Karsisto. Lannoitteen levitystasaisuuden vaikutuksesta nuoren suomännikön pituuskasvuun. 1981.
- Nro 70. Metsäntutkimuspäivä Oulaisissa 1982.
- Nro 101. Jarmo Poikolainen ja Eero Kubin. Tuloksia kapealatvaisen kuusen juurruttamisesta. 1983.
- Nro 119. Metsäntutkimuspäivä Suomussalmella ja Sotkamossa 1983.
- Nro 133. Mikko Moilanen ja Jorma Issakainen. Ojituksen, lannoituksen ja muokkauksen vaikutuksesta luontaiseen uudistumiseen piensararämeellä. 1984.
- Nro 158. Metsäntutkimuspäivä Oulussa 1984.
- Nro 198. Eero Kubin ja Hannu Raitio. Puustovauriot keväällä 1985 Suomessa. Metsämattimiehille osoitetun kyselyn tulokset.
- Nro 199. Mikko Moilanen. Runkokäyrämallien tarkkuus lannoitetussa rämemännikössä. 1985.

- Nro 204. Mikko Moilanen ja Jorma Issakainen. Lannoitusvaikutuksen riippuvuus levitysjankohdasta nuorissa rämemänniköissä. 1985.
- Nro 206. Metsäntutkimuspäivä Kannuksessa 1985. Kannuksen ja Muhoksen tutkimusasemien yhteinen julkaisu.
- Nro 222. Matti Oikarinen ja Yrjö Norokorpi. Vuosina 1956-65 viljeltyjen männyntaimikoiden tila valtion mailla Pohjois-Suomessa. 1986.
- Nro 255. Metsäntutkimuspäivä Taivalkoskella 1986.
- Nro 281. Mikko Moilanen, Ari Ferm ja Jorma Issakainen. Kasvihuonekokeita erilaisten jäteaineiden vaikutuksesta hieskoivun alkukehitykseen turvealustalla. 1987.
- Nro 290. Pentti Niemistö. KTP-84 tiedonkeruupätee metsässä kerättävän tiedon tallennusvälineenä. 1988.
- Nro 295. Metsäntutkimuspäivä Kärsämäellä 1987. 1988.
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- Nro 387. Metsäntutkimuspäivät Haapajärvellä 1990. 1991.
- Nro 388. Jukka Valtanen ja Aarne Lehtosaari. Männyn uudistumiseen vaikuttavat tekijät Siikalatvan alueella. 1991.
- Nro 389. Matti Oikarinen. Suomussalmen männynviljelyinventointi. 1991.
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- Nro 432. Pentti Niemistö. Runkolukuun perustuvat harvennusmallit. 1992.
- Nro 461. Eero Kubin. Metsäekologisen havaintoverkoston kehittäminen. 1993.
- Nro 464. Metsäntutkimuspäivä Kajaanissa 1992. 1993.
- Nro 499. Jorma Issakainen, Mikko Moilanen & Klaus Silfverberg. Turvetuhkan vaikutus männyn kasvuun ja ravinnetilaan ojitetuilla rämeillä. 1994.
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