THE

THEORY OF FOREST TYPES

BY

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Contents

Preface.

The publication now issued is a translation, with some additions and improvements, of the work, »Metsätyyppiteoria», published in Finnish by the author in the beginning of 1925. The translation of this work into some world-wide language appeared to be desirable, having regard to the interest which the forest types have aroused in recent years in different countries.

The translation has been kindly revised by Dr. M. L. Anderson, Research Officer of the Forestry Commission in Scotland.

The Classification of Forests According to Quality.

Forests, both in the form in which they occur under natural conditions and that in which they occur under systematic forestry, differ widely from one another. For this reason, it very soon became obvious that, for forestry purposes, a classification of forests, according to their yield, into a few main classes, was necessary, and with progress in systematic forestry, this need has become more and more urgent. — It is customary to call the productivity classes of forests quality classes (Bonitäten).

There are, in principle, two kinds of forest classification — classification of the stands themselves according to quality, and classification of the localities (forest soils) upon which the forests grow. In the first case, the classes are stand quality classes (Bestandesbonitäten) and in the second case, locality (site) quality classes (Standortsbonitäten).

The object of classifying localities into quality classes is to combine into one and the same class all those localities the capacity of which for growing forest is the same or approximately the same, and to separate into different classes those in which the yield capacity differs more markedly.

In the classification of stands into quality classes attention is fixed on the present actual yield of the stand actually growing on the locality, and this may vary greatly for the same locality, depending on the density, gaps in the stand, treatment, etc.

Comparison of one locality with another according to their yield capacity, presupposes that the stands growing on the localities to be compared are of the same kind; that they are composed of the same species of trees; that they are of the same age and density; that they

are tended by the same method, and so on. The most objective method of procedure is to compare localities on the basis of the yield of those stands growing thereon, which, besides being composed of the same species of tree and of the same age class, are normally stocked and are also normally developed in other respects. It is a feature of normally stocked and normally developed stands, that they represent stands of normal quality class. Quality of locality, accordingly, is generally gauged by the yield of stands of normal quality class. The existing quality of the stand actually growing on a locality may happen to coincide with the normal quality class, but in most cases, it diverges from the latter to a greater or less degree, generally in the *minus* direction, for which reason in the majority of cases the actual quality of a stand may be expressed as a fraction of its normal quality.

The determination of the locality quality class is indispensable under systematic forestry, because it is an essential preliminary for all calculations of yield and only when it is known is it possible to determine, amongst other things, which species of tree is economically most profitable; what length of rotation and which method of treatment etc. are most advantageous — points which are of decisive importance in forest management. In default of this knowledge, moreover, it is impossible to compute the expectation value of forests and forest soil, which is necessary, for instance, in valuations in connection with indemnification, expropriation, etc.

Special mention must be made of the fact that an exact determination of the quality of the locality is indispensable in scientific research in forestry, whether the investigation be based on experiments expressly arranged for the purpose of research or on comparative observations of existing forests. For if the separate action of one factor or the combined action of several distinct factors on stands or trees is to be investigated, it is necessary, in order that the result of the comparison may be valid, to make certain that all the other factors bear the same relationship to all the objects under observation (stands or trees). Above all, it is essential that all the stands (trees) to be compared with one another should grow on localities equivalent from the biological point of view, — a condition which has often been violated in research relating to forestry as well as in phytogeographical investigations.[1]

The actual quality of stands is also naturally of the utmost practical importance. For the forest owner, indeed, it is in most cases far more important to know the actual quality of his forest and how much it actually produces than to know what it would be like in its normal condition and what its yield would be under such circumstances. The actual quality of stands, however, is to so great an extent the result of combinations of so many factors which have as yet been only incompletely elucidated and whose effect cannot be estimated in advance, and of arbitrary operations by the forest owner or forester, that its determination is, as a rule, beyond scientific treatment, especially in individual cases; whereas the quality of the locality is a conception the scientific elucidation of which is both possible and indispensable.

1 One of the commonest errors committed is to compare coniferous forest on poorer land with broadleaved or mixed forest on better land, an error which is due to the fact that the bulk of coniferous forests occur on poorer soil than the bulk of broadleaved or mixed forests. Such a comparison, however, amounts to the deduction of two unknown quantities from a single equation, which is a logical impossibility.

Methods formerly used for Assessing the Quality of the Locality.

The classification of localities (= sites) according to quality was at first quite subjective. The classification was based on the fact that localities differ widely from one another in respect of their forest yield capacity and that this is a more or less permanent property of localities, on the degree of which man with his operations can, in practical forestry, exert generally only a very limited influence. A quite arbitrary number of locality classes was set up, ranging from the most productive down to the least productive, or *vice versa*, and by relying on the proficiency of ocular estimation and on acquired experience, every locality area or map unit used in forestry was referred to the quality class to which it was considered, from an assessment of this kind, that it belonged.

Thus Heinrich Cotta, in his classical manual »Systematische Anleitung zur Taxation der Waldungen» (1804), recommends a set of 100 quality classes, in which zero was to stand for absolutely barren land, incapable of producing any wood, and 100 was to represent the best possible land imaginable. A contemporary of Cotta, Georg Ludwig Hartig gives in his equally classical work »Anweisung zur Taxation und Beschreibung der Forste» (1795) the advice that in classifying forest soils, one should be content with the classes, — good, medium and poor. He adds, at the same time, the remark that, although it is of importance that this differentiation should not be carried out carelessly, it is equally important not to be too exacting in its use, and he specially emphasizes that it is useless to waste time in chemical analysis of the soils, as it only confuses the main issue.

In Central Europe, that method of classifying forest soils which contains five quality classes seems to have been most common. As a matter of fact, in the 8th edition of the well-known manual by JUDEICH, »Die Forsteinrichtung», edited by NEUMEISTER (1923) the following five quality classes are distinguished, each, however, having two grades: —

excellent	1	and 0.9
very good	0.8	0.7
good	0.6	0.5
mediocre	0.4	0.3
poor	0.2	0.1

This method of classification, however, is very subjective, and so, before long, the need was felt for a somewhat more exact definition of quality classes. It is true that by prolonged training in the repeated measurement of sample plots and from a knowledge of book-keeping data of the actual yields of different felled stands, obtained under systematic forest management, a forest surveyor may learn to carry out the classification with considerable consistency. Between the standards of estimation of the different forest surveyors, however, quite considerable divergences may occur, and for the less experienced estimators the method as such does not give any reliable guidance. For this reason efforts have been made to discover some easily recognisable indices for the classes, by which they could be identified and by means of which the standards of estimation of the different surveyors could be regulated. Especially in northern countries have efforts been made with this object in view.

As one instance of this it may be mentioned that A. G. BLOMQVIST, for many years director of the Forest School of Evo, in Finland, in his study — »Tabeller framställande utvecklingen af jemnåriga och slutna skogsbestånd af tall, gran och björk» (Tables illustrating the development of even-aged, fully stocked stands of Scots pine, Spruce and Birch) (1872), divided Finland, from south to north, into three growth zones, and in each of these he distinguished three quality classes. The division into quality classes was effected by referring to the lowest class all the

dry sand and gravel heaths, pine and ling barrens, on which Scots pine occurs in pure stands, and on which, thanks to its moderate demands, the Scots pine continues to have precedence over all other tree species; to the medium class all the moister forest soils, on which, along with the pine, the Norway spruce and birch can also thrive and which as a rule were indicated on the Survey Maps of Finland as ground suitable for burning for cropping purposes; to the best class only the most productive forest soils and those lands suitable for agriculture, where the soil was in most cases loam or clay. In Northern Finland, where exposure greatly influences the growth of trees, the situation of localities had also to be taken into account in the classification of forest land. — This system of classification was used by Blomqvist as a basis for the preparation of yield tables.

As another instance may be mentioned a circular issued by the Board of Crown Lands of Sweden in 1916, entitled, »Föreskrifter angående de allmänna skogarnas indelning till ordnad hushållning» (Instructions regarding the organisation of public forests under systematic management). According to these directions 9 quality classes were to be distinguished. Of these classes, Class I denotes the best land, growing Norway spruce and hardwoods and Class II, the best Scots pine forest land, both of which classes are rare and are confined for the most part to Southern Sweden. With regard to the rest of the classes, it is remarked in the directions that the quality of the land on the whole falls gradually from the south to the north, Class VIII standing for the poorest forest land of the forest regions proper, whilst Class IX comprises all the places where conifers, owing to alpine winds, are unable to form fully stocked stands, although they cannot be classed as waste land. As waste land all the land is classed where the mean annual increment, even when the growth of the stand is at its best, does not amount to 15 cubic feet per acre (1 cubic metre per hectare).

In Finland the following scale has been in quite general use in the classification of the so-called economically productive forest land: —

dry heaths,
moist heaths,

low-lying heaths,
land of the nature of spruce- and broad-leaf tree-moor, and
land of the nature of pine-moor.

Undoubtedly systems of classification like these, especially the last-mentioned, may under certain circumstances, lead to fairly satisfactory results, and they are an expression of tendencies striving away from artificial systems of classification towards as natural ones as possible. So far as the southern half of Finland is particularly concerned, the last-mentioned system is fairly natural and it has been largely used. Accurate, however, it is not; for moist heath, for example, may include localities differing considerably in yield capacity, and low-lying heath is a very ambiguous expression, unless it is set on a par with Blomqvist's best class, which, as a matter of fact, also covers a very wide range of variations. It was realised that this system of classification, which in many ways is very natural under the conditions prevailing in South Finland, did not come up to the standard of an accurate system of classification according to yield capacity, and so, in order to indicate the quality of forest land, a method was often used in Finland in which the legend on survey maps was furnished with two columns, in one of which was given the yield or quality Classes (I—V), determined by eye and by experience, and in the other the character of the land (dry, low-lying, etc). The defects of the system of classification under consideration stand out still more clearly, when an attempt is made to apply it to wider areas, e. g. when this system is applied to Lapland or Central Europe. Systems like this are mainly of local importance, and even as such, they have a comparatively narrow scope for application. It seems impossible to work out on such a vague basis as this a system of classification of localities according to productive capacity, which would be of universal application, although the system in question contains the rudiments of a natural classification of localities.

After JUSTUS V. LIEBIG had demonstrated the great importance for the nutrition of plants and their well-being in general of the chemical composition of the soil, it was quite generally hoped that the question of the quality of the soil — of arable land in the first place — could be

accurately solved by a chemical soil analysis. These hopes, however, were disappointed. This was partly due to the imperfections and shortcomings of the method of chemical analysis of soils; it is difficult to extract from a soil the plant nutrients exactly in the same proportions and under the same conditions as those in which they are available to the living plant in nature; and partly to the fact that the plant nutrients in the soil are not the only growth factors which concern the life of plants, for the physical properties of the soil, for instance its moisture-content, its porosity, etc., are of equal importance. Finally also, the climatic factors may act as influential growth factors.

Although soil-analysis in agriculture has not come up to the hopes at first entertained, it has, however, been proved to be, within definite limits, of some consequence, especially for forestry. Thus SCHÜTZE (1871) has, by examining six areas of forest land in Northern Germany, which from a forestry point of view had been assessed as representing different quality classes, demonstrated that their yield capacity was largely reflected in their chemical composition, as may be seen from the following figures representing the percentages of mineral matter soluble in hydrochloric acid, contained in a surface layer, 5 3/4 feet deep —

Quality Class	P_2O_5	CaO	MgO	K_2O	Na_2O
I	0.0501	1.8876	0.0484	0.0457	0.0129
II	0.0569	0.1622	0.0716	0.0632	0.0065
II—III	0.0464	0.1224	0.0981	0.1235	0.0097
III	0.0388	0.0963	0.0800	0.0392	0.0029
IV	0.0299	0.0270	0.0505	0.0241	0.0016
V	0.0236	0.0453	0.0438	0.0215	0.0031

These figures show that all the substances examined were present under these conditions in quality class I in greater proportion than in class V, further, that the proportions of phosphoric acid and lime show a fairly distinct falling off from the first class to the last.

Subsequently, however, v. FALCKENSTEIN showed that in the sandy lands of Northern Germany the humus and its nitrogen content are even more important than the substances mentioned. From his analyses he gives the following series of figures which indicate the amount of humus and of nitrogen, in pounds per acre, contained in a surface layer, 23.6 inches (60 cm) deep: —

Quality Class	Humus	Nitrogen content
I	30,470	1,044
I	25,140	819
III	32,480	587
III (IV)	20,000	479
IV	10,460	393
IV	7,340	292
IV	8,810	258
IV	10,100	225

Based on soil-analyses carried out by Valmari, which will be reviewed in the sequel, Yrjö Ilvessalo has calculated the coefficient of correlation between the growth of normally developed Scots pine stands and the chemical composition of the soil for the forest land in the southern half of Finland and has obtained the following figures for the coefficient of correlation: —

For nitrogen .... 0.736 ± 0.056
lime .... 0.612 ± 0.069
potash .... 0.214 ± 0.091
For phosphoric acid there was no correlation.

Of these chemical constituents of the soil, nitrogen and lime exerted the greatest influence on the yield capacity of the forest land in the southern half of Finland, and in this connection the agreement between these figures and the results obtained by Schütze and v. Falckenstein is readily apparent, whereas the potash content proved to be of minor importance and the phosphoric acid content, within those limits between which it occurred in the cases dealt with, of no influence whatsoever.

Investigations like these show that the constituents of the soil have a definite influence on its productive capacity. Liebig had already advanced the so-called law of the minimum, according to which the productive capacity of the soil depends on that food constituent the proportion of which in the soil is relatively least. Accordingly, the productive capacity of the soil could be continuously raised by increasing the proportion of that nutrient which is present in relatively the smallest quantity until the proportion of some other constituent begins to be the smallest. Wollny amplified this law so as to include also the physical properties of the soil. Taking into account the possibility of a growth factor being present in too great a strength, Vater put forward this law in such a form that the productive capacity of the soil became dependent on its most unfavourable constituent.

Although it is possible to establish a distinct correlation between the productive capacity of a locality and its constituents, the gap from this, however, to a natural classification of localities is still wide. It is true that correlations between the yield and growth factors can be demonstrated, but on the other hand, investigations especially of more recent date — those of the school of Mitscherlich in particular — have shown that the growth factors operate in partnership even so that a deficiency of one factor may be made up for by a surplus of another; accordingly, it is not a definite »minimum factor» we are dealing with, but rather, attention has always to be riveted on the combined action of the different growth factors, even if one factor may be more significant than the rest. It must be noted particularly that in nature the intensity of the different growth factors varies, to a great extent independently of one another, with the result that an unlimited number of different combinations of the factors is brought about. In changing from one climatic region to another, the significance of all these combinations for the well-being of trees (plants) will be more or less altered. Above all, the growth factors constantly vary between some definite limits, so that their measured values do not show any sudden fluctuations. By considering the growth factors alone, either each one by itself or in various combinations with the others, the chances of fixing natural units for the classification of localities seem to be extremely hazardous.

On the other hand, if it were possible first to delimit the quality classes naturally by some other means, even if it were only in outline, it might not be impossible by prolonged investigation to get each of those quality classes defined in regard to its growth factors. Moreover this is not all, for it is conceivable that ultimately — though in this case the method is certainly indirect — a natural classification of localities might be effected exclusively on the basis of growth factors. An analogous instance from the domain of climatology may be mentioned. W. Köppen, in his well-known publication: — »Versuch einer Klassifikation der Klimate vorzugsweise nach ihren Beziehungen zur Pflanzenwelt» (1900), has delimited according to the general features of the vegetation of the globe, a great number of climatic regions, the characters of which have been defined by purely climatological factors and of those regions, the ones which correspond to one another in the different parts of the globe have been combined into the same main types. It is conceivable that along such lines a suitable method for the classification of localities may be evolved.

As regards the classification of localities it is natural that recourse should be had in the first place to classifying them directly, i. e., to a classification which is based on the characteristics of the localities. As forestry, however, is not concerned with the classification of localities as such, but with their classification in respect of their yield capacity from the point of view of forestry, it is equally natural to endeavour to use the yield of stands as a suitable basis for the classification of localities. This method has actually been adopted.

One of the methods based solely on the yield of stands is the so-called strip method, the idea of which probably first originated with a Frenchman, De Perthuis (1788), but which was introduced into general use by a German, Fr. Baur (1877). Baur employed it in the preparation of yield tables. Baur proceeded in the following manner: —

In the forest region for which yield tables had to be prepared, as large a number of sample plots as possible was taken in even-aged, uniform, pure, regularly developed stands of all ages, and care was taken that

the sample plot data were distributed over the whole of the area to be investigated as evenly as possible and represented, as far as possible, all kinds of localities. On the assumption that the number of quality classes was to be five, at least 150 sample plots had to be taken for each species of tree, while care had to be taken that among the sample plots the best and the poorest quality classes were as satisfactorily represented as regards numbers as possible. On these sample plots all the measurements necessary for yield table purposes were carried out. The data thus collected were further treated by plotting the timber volumes per hectare of the sample plots graphically — the sample plots of each species of tree in a separate system of co-ordinates — the abscissae of the co-ordinate system representing the ages of the sample plot stands and the ordinates their volumes. In the graphical representation, the points representing young stands are naturally located in the vicinity of the origin, and with increasing age the points form an ever-broadening strip, lying above and to the right of the origin, like the tail of a comet. This being done, free-hand curves were drawn passing approximately through the highest and the lowest points of this tail. These curves, accordingly, bounded the points along the top and along the bottom. Assuming that 5 quality classes were to be distinguished, the strip bounded by the curves was then divided by four curves, conforming to the trend of the first curves, into 5 sectional strips of equal breadth, by which the points, i. e., the sample plots, were divided up into 5 quality classes. Through the centre of each sectional strip a curve was drawn, conforming to the trends of the previous curves. Each such curve was taken to represent the volume increment in cubic metres per hectare of normal stands of the particular quality class in question, for the species of tree under consideration, and for every age gradation in the life of the stands from the seedling stage up to the mature forest.

The device employed by Baur was very simple indeed. It does not, however, satisfy scientific requirements. The following objections can be raised against it: —

1. It is a device which is quite artificial and the quality classes obtained by its use are mere graphical abstractions, which have been fixed

quite arbitrarily, inasmuch as it is possible to distinguish 5, 6 or more quality classes as may be desired. The result is that there is nothing, which can be distinguished in nature corresponding to these classes as such.

2. No guarantee can be given that the growth of any stand of normal development is in reality such as is represented by the normal curves drawn in the manner described.

3. It is based entirely on the most productive and least productive stands, even to such an extent that it is quite superfluous to use any sample plots from the mean quality classes. It is just in those extreme quality classes, however, that normal stands are most difficult to find in sufficient numbers. Baur himself failed to find for his beech yield tables more than 8 sample plots of the lowest (V) quality class, and closer inspection reveals the fact that the extreme sample plots out of these 8 have been of very little consequence in drawing the lower boundary curve [1].

4. It is true that the defect just mentioned could be amended by basing the normal curves not on the limiting curves, the locating of which is so uncertain, but on such a mean curve as would be obtained by taking into account all the sample plot points and which could thus be drawn with considerable certainty. Even this device, however, is impracticable because one of the basal assumptions of the procedure under consideration is that the normal curves of the different quality classes have an identical course, — an assumption which is not only without any foundation, but, as the present writer showed before (1909), in many cases even demonstrably erroneous.

Granted, however, that the procedure were unchallengeable in all the points discussed, and that by it the sample plots really would be divided into natural quality classes, nevertheless some index is needed whereby these quality classes worked out on paper can be recognised also in the forest. Volume per acre cannot serve as such a criterion, for although it were possible to acquire skill in estimating the volume of a stand by eye so confidently that it would be possible to refer a stand by Baur's method to its proper quality class, the method would be applicable only to normally developed stands, which in actual forests generally make up only a very small percentage of the whole. In regard to volume, as well as to other characters, an overwhelming majority of stands are more or less abnormal, so that the volume of a stand estimated by eye would be of very little guidance in referring the stand to some definite strip, since such a reference would necessitate the correction of the actual volume to normal. That would leave, however, too much room for subjective judgment, more especially in the case of uneven-aged stands. For this reason Baur proposed as an index for the quality class, the mean height of stands at each age gradation and he determined this mean height graphically by a procedure exactly parallel to that described above.

[1] In EICHHORN's silver fir sample plot data, only 5 plots belonged to quality lacss I and a total of 5 for quality classes IV and V combined.

Exception can, however, be taken to a method like this, in that a mean height curve arrived at in this way is subject to the same defects as the volume curves discussed above. If the height curve is traced in the manner described, i. e. independently of the volume curve, there is in addition no guarantee that the volume curve and the height curve will correspond with one another. This source of error can, certainly, be avoided by taking the sample plots of each class separately, classification being carried out by means of the volume strip method, and by drawing the mean height curve of each quality class, based on the mean heights of the sample plots of this class only. Apart from the fact, however, that an accurate ocular estimation of the mean height of a stand is not very easy, the mean height of a stand is to a very great extent dependent not only on the locality, but also on the nature of the thinnings applied to the stand, and more generally, on the method of treatment to which it is subjected. The more abnormal a stand is, the less reliable is it as a criterion of the quality of the locality, whilst in uneven-aged stands, mean height as an index of quality class completely falls through. In order to correct this defect the so-called dominant height, i. e. the height of the dominant trees has been employed as a criterion. To the dominant trees of a stand there may be referred 20, 40 or 80, etc. trees of the largest diameter per acre. An ocular estimation of their mean height, however, is a difficult task, because they are scattered among the other trees.

Furthermore it has been established that even the dominant height even of normally developed stands is no certain index of the quality of the locality, for the investigations carried out by Y. Ilvessalo have shown that in the southern half of Finland, a Scots pine stand attains to the maximum dominant height even though the land is only medium (MT)[1], whilst on land superior to the average (OMT) the stems of the dominant trees of Scots pine stands certainly reach a greater diameter, but no greater height. It is further to be noted that the dominant height may, even on the same locality, vary with the density of stocking of the stands; open Scots pine stands, for instance, do not reach the same height as normally stocked Scots pine stands. If fellings have been made in a stand which affect, to some extent at least, the dominant crown canopy (selection fellings, crown thinning, etc.), the dominant height gives a quite erroneous impression of the quality of the locality. — Dominant height, therefore, is almost of as little use as a criterion of quality class as is mean height, especially in actual forests, where the quality of the stand, as a rule, differs widely from the normal — although under certain well-defined conditions they may both furnish some guidance in the assessment of localities.

Against Baur's method the following additional objections may be made: —

1. By this method for each species of tree, the quality classes will be determined independently of all other species, for which reason by this method no uniform classification, generally applicable to all localities, can be devised. Quality class III, established, for instance, on the data from Scots pine stands, by no means corresponds to quality class III obtained from Norway spruce stands, and both these in their turn differ radically from corresponding quality classes derived from beech and oak stands. For this reason it cannot be regarded as a satisfactory method of making a classification of *localities*.

2. By this method it is impossible to secure uniformity between different countries in regard to quality classes, even for the same species

[1] The letters refer to certain forest types. See page 37.

of tree. For instance, quality class III for the beech or spruce forests of Bavaria as determined by Baur's method does not correspond to quality class III of the beech or spruce forests of North Germany as determined by the same method.

It has been pointed out above as one defect of the strip method that it does not in any way guarantee that the normal growth curves arrived at graphically will reflect the rate of growth of any normally developing stand. There are some auxiliary devices for remedying this defect.

The directing curve method (Leitkurvenverfahren), introduced by C. Heyer (1846) and E. Heyer (1857), consists in collecting data from permanent sample plots, which are measured regularly at intervals of 5 years. By using the same graphical device as is employed in Baur's method, instead of individual points, shorter or longer series of points are obtained, depending on how many times the sample plots have been re-measured. The points of these series may be joined by straight lines, so that interrupted lines are obtained which may be used as guides either directly or as a basis on which special directing curves may be drawn. These directing curves, then, furnish guidance in the tracing of the final growth curves. Then the direction of the latter will not depend on unreliable limiting curves, and will be determined with all the greater accuracy the oftener the sample plots have been re-measured. This method, as is well-known, has been generally used by the Central European Forest Research Institutes for several decades past.

The index method (Weiserverfahren), is another auxiliary device originally invented by Huber (1824) and introduced by Th. and R. Hartig. This method is founded on the more or less correct assumptions that the dominant trees of a stand have, as a rule, been dominant trees also during earlier stages; that as the age of the stand advances trees do indeed constantly pass from the dominant class into the dominated class; but that the reverse case, i. e. trees which have once fallen into the dominated class once again developing into dominant trees, is only of rare occurrence. Starting off on the basis of these assumptions, sample plots are selected as usual, and the average tree or trees of the dominant class of these stands, defined by different investigators in different ways, are subjected to a so-called stem-analysis. All the normally developed stands are taken as representing the same growth series, when the growth of the average tree of their dominant class, as determined by stem analysis, shows a similar trend, and by their aid, accordingly, growth curves may be drawn. Various adaptations of this method have been used, besides that adopted by the Hartigs, for example by G. WAGENER, T. LOREY, A. SCHWAPPACH, BLOCK, Y. ILVESSALO (as a controlling device), etc.

Availing himself of m a t h e m a t i c o-s t a t i s t i c a l m e t h o d s WERNER CAJANUS has developed in his study: »Ueber die Entwicklung gleichaltiger Waldbestände» (1914) a unique auxiliary method. The foundation of the method is the stem distribution as it is obtained by classifying the trees of sample plots, on a basis of diameter at breast-height, into diameter classes with fixed intervals, expressed in centimetres. All the normally developed stands are taken to belong to exactly the same growth series, when the characteristics (mean value, number of stems, dispersion, asymmetry and excess) of their stem distribution series, based on the diameter of the trees, agree at one and the same age of stand, or the deviation from the mean value of any characteristic at that age amounts to no more than three times the standard error. This auxiliary method has also been used by Y. ILVESSALO.

All these auxiliary methods, even separately, but especially when supplementing one another, furnish very good guidance in tracing growth curves, and by their aid, the course of the latter can undoubtedly be traced with considerable accuracy. They are, however, of little avail for the classification of localities used for forestry. By their means, certainly, growth curves, determined with great accuracy, are obtained, but there is no limit to their number. All these auxiliary methods presuppose that the classification of localities has already been carried out by some means or other.

Methods based on the yield of stands, therefore, have failed to solve the problem of the classification of localities.

In the foregoing (page 8) allusion has been made to attempts to devise a natural system for classifying localities, which would not be dependent on graphical or mathematical abstractions. A natural system of classification is particularly necessary for sylvicultural purposes, whereas for the purposes of forest mensuration, even somewhat more artificial systems may work fairly well. Sylviculturally the different types of locality differ widely in value. To begin with the locality prescribes the species of tree to be grown. On the driest localities in Finland only the Scots pine stands any chance; on average localities the Norway spruce, birch and also the aspen grow satisfactorily, whereas *Alnus glutinosa* and still more so, the so-called hardwood species require the best localities in order to thrive satisfactorily. Furthermore, on different localities even the same species of tree requires widely different sylvicultural treatment. Thus, for instance, the treatment demanded by Scots pine forest varies widely, depending on whether it is growing on dry heath (Blomqvist's Class I), or on moist heath (Class II), or on hardwood forest land (Class III). The differences of treatment are also applicable in the use of methods of regeneration; methods of improvement cutting; in the growing of standards; in underplanting; and in the mixture of species; and these differences are really of fundamental importance. The proper treatment of Scots pine stands on pine moors shows a still greater contrast. In the interests of sylviculture, therefore, a natural system for the classification of localities is essential. Until such a system has been evolved, there is small hope of any very extensive, fundamental progress being made in the domain of sylviculture. A system of sylviculture, which takes no notice of localities, and at the present time sylviculture in most cases is of this type, must be abandoned and replaced by a natural system of sylviculture, based on locality classes. Also MAYR's grand idea of a universal sylviculture seems to be possible of realisation only on such a basis. The numerous, often very ingenious local sylvicultural methods that have been developed in various districts, especially in Central Europe, can only be made of general application with advantage, provided that the localities can be classified into classes which comprise localities biologically equivalent, and further, that the distribution of these classes and the natural classes of each local forest under consideration are known.

It is quite evident that the classification of localities for the purposes both of forest mensuration and sylviculture should be based preferably on the same principles. In this way the foundation would also be laid for the many investigations connected with forest statistics, especially for those having some bearing on forest yield, and the need for such a uniform system of classification will be all the more urgent the more international forest statistics become.

From all the arguments discussed above it can be stated that: —

1. A natural, uniform, universal and international system for the classification of localities utilised for forestry purposes, is important from the point of view of forest mensuration and valuation and of forest management generally, of sylviculture and forest statistics, as well as of forest policy, which to a great extent is based on the latter.

2. Such a system for classifying localities is indispensable also for all those forest investigations the result of which, in one way or another, is affected by locality.

3. This object, however, has not been attained by the methods considered above; on the contrary, it must be taken for granted that the attempts to solve the problem, based on such methods, have failed.

The Forest Types.

The Essential Principle of Forest Types.

Whenever the vegetation is sufficiently rank to induce a struggle and competition for space between the different individual plants, the latter combine to form more or less regular plant associations, which have a definite distribution and occurrence, and are in nature marked off from one anotherwith comparative precision. Thus there are in Finland *Agrostis canina* and *Nardus stricta* meadows with a definite floristic composition and occurring on certain well-defined localities; there are *Ledum palustre* and *Vaccinium uliginosum* moors; there are various rock plant associations, alpine associations, etc. In a like manner there exist forest plant associations, for instance, Scots pine forests on dry, sandy heaths with a rich *Calluna* vegetation, Norway spruce forests on moist lands with a rich *Myrtillus nigra* vegetation, etc. Each of these communities possesses a vegetation of a regular composition and occupies a locality of a definite character.

Since this is the case, nothing is more natural than to make use of the plant associations in some form or other in the classification of localities, and especially forest plant associations in the classification of forest localities, i. e. of forest land. What follows is an attempt to discuss the nature of forest plant associations from this point of view [1].

[1] The theory of forest types, which will be explained in the sequel, is really based on the classification of forest soils, formerly used generally in Finland and described above on pp. 7—8, as well as on the phytotopographical research which was instituted by J. P. NORRLIN in Finland. The present writer had his ideas first turned towards this theory in 1904—1906, while studying at the Forestry Institute at Evo. The director of this Institute at that time asked the writer to make a description of the surface-vegetation on dry heaths, moist heaths, etc. for the handbook upon which he was then

A primeval forest, undisturbed by man's interference, is exceedingly regular. For instance, on the Lena, in Eastern Siberia, pine forest is found on rather dry, warm and sunny slopes, and spruce forest in the moist valleys, while the larch occupies the rest of the forest land. On the vast stretches of land inundated by the river during times of flood, some shrubs, two species of alder, birch and spruce form bushes or stands, the distribution of which, with regard to the spring floods, is exceedingly regular. The ground vegetation of these forests is also very regular. Thus, the larch *(Larix Cajanderi)* forests that are found at 67 degrees of north latitude, occur in two main types, namely: — *Ledum palustre* forest and *Vaccinium uliginosum* forest, each of which possesses a vegetation of a definite composition, the former occurring on fresh and the latter on somewhat moister soils. The driest larch forests, however, are characterised by a *Vaccinium vitis-idaea* vegetation and the exposed hills by a *Betula nana* vegetation.

This degree of regularity is not met with in inhabited regions. Thus, in the southern half of Finland, especially in areas where burning for cropping purposes was formerly much practised[1], it is possible to find

engaged. The descriptions made are contained in the work by B. ERICSSON, »Metsänjako-oppi» (Forest Management), pp. 3—5. The impossibility of exactly determining the nature of these soil differences on the basis of the vegetation, led to the idea of amending the classification, which was done in the publication, »Ueber Waldtypen» (1909), written by the author. The name 'forest type' came originally from the forest ecological classifications used in Sweden, in which the classes were generally called forest types. The foundations of these systems of classification were different, however. In the best known of them, i. e. the one due to A. LUNDSTRÖM, the main classes were, 1) Natural forest, 2) Types derived from natural forest and 3) Retrogressive types. The stand types (Bestandestypen) described by MOROSOW in Russia, on the other hand, were unknown to the author and so have not had any influence on Finnish ideas of forest types. The breaking up of the Russian stands into types is based on the climate, the soil, the effect of man's interference, the ecological nature of the species of tree, etc. They have been mainly used for sylvicultural purposes, as also have the Swedish forest types, which, however, have not come into more general use.

[1] In ancient times and even until the middle of the last century, burning for cropping purposes was practised in Finland to a very large extent. The forest was felled in the beginning of the summer and left untouched in order to dry until the next summer, when it was burned over. The area was then simply ploughed by a primitive plough and harrowed by a stick-harrow. In the ground so prepared the grain was sown, after which the burned area was left to afforest.

Pinus sylvestris, Picea excelsa, Betula verrucosa and *B. odorata, Populus tremula* or *Alnus incana* forests on exactly similar localities, and more often than not, the stands are more or less mixed in character. Of the regularity of the primeval forest nothing remains except that the drier lands are mostly occupied by Scots pine forest alone, whilst all the common species of trees are found predominating on the fresher soils and the hardwood species only on the best localities. The ground vegetation also varies to a great extent.

The sole explanation of the difference between primeval and cultivated countries lies in the competition between the species of trees and the species of plants in general. In the primeval forest this competition has gone on without interruption for hundreds, almost thousands of years, but in regions within the bounds of civilization, it has occasionally been interfered with by felling, fire, burning for cropping purposes, etc. Some idea of the intensity of this competition may be gathered from the fact that according to Y. ILVESSALO, a single tree of Scots pine in a normally developed stand on the dry heaths of South Finland requires at the age of 25 years, an area of 6.46 sq. ft., at 50 years, 21.42 sq. ft., at 75 years, 41.01 sq. ft., at 100 years, 73.52 sq. ft., at 125 years, 118.94 sq. ft., and at 150 years, 162.32 sq. ft. Since the area occupied by a stand does not change, a diminution of the number of the stems inevitably follows as the stand advances in age. In dry heaths this diminution ranges from 6,716 to 268 stems per acre and yet the overwhelming majority of the individuals have perished before the stand has reached the age of 25 years. This struggle for room — in the first place for the space from which the plant derives its nourishment — goes on everywhere in nature; in given conditions on a given area only a definite maximum number of individuals of a given species can have their requirements satisfied.

When an area, burnt over for cropping purposes, begins to revert to forest, there is at first plenty of room and the composition of the seedling stand, which makes its appearance, depends largely upon chance factors, e. g. the character of the surrounding forest, the frequency of the seed years of the different species of trees, the weather conditions prevailing at the earliest stage in the life of the seedlings, etc. Before long, however, the clearing is covered with seedlings, and the struggle for space commences amongst them. In mixed forest perhaps growing on such a clearing, by the age of 25 years nothing definite may have taken place in the relationships between the different species of trees composing it, although the seedlings of Norway spruce, owing to their slower growth may have been overtopped by the other species. If the spot be visited after the lapse of 50 years one finds that the alder has begun to lag behind and that the spruce has gradually gained upon the other species of trees. By the age of 150 years the alder, as a rule, has disappeared and a large proportion of the birches and aspen has become over-mature. After the lapse of 300 years, the aspen and birches have entirely disappeared, and only old Scots pines and spruces, together with a young growth of spruce, are found on the area, the pine having failed to regenerate itself owing to the shade. In inhabited areas, before this final stage has been reached, this competition has been repeatedly disturbed and even interrupted by fellings, etc., the effect of which is that the forests there are never allowed to acquire the regularity of primeval forest. This development of forests towards the final (relative) stage of primeval forest is, however, discernible everywhere in those districts, where burning for cropping purposes has been practised, and the spruce forest stage is even met with in many places, for instance in the State forests, although other species of trees are still present to some extent with the spruce. — The more intensive the sylvicultural management of a forest is, the more disturbed will be the natural development of its composition according to tree species. When a forest is regenerated by natural reproduction, one or more definite species of tree will be favoured; when the regeneration is effected by sowing or planting, the species will be still more rigorously selected; while in the making of thinnings, preference may also be given to one species of tree or another.

Amongst the surface vegetation of a forest the natural competition is also now and then disturbed by cultural operations. In this connection, ground burnt over for cropping purposes again affords a good illustration. In the course of the years immediately following the abandonment of an area which has been cropped after burning, the number of the plant species increases very rapidly, reaching its maximum, about 105 species of vascular plants on the burnt and cropped areas north of Lake Laatokka (Ladoga), in 7 to 8 years, according to the investigations of LINKOLA (1916). After the lapse of that time, the clearing is covered with plants, and the competition enters its fiercest phase, and the biologically weaker species gradually perish. In 20 to 40 years the number of species has decreased down to about 70. After 60 years it is down to about 40, and at about the 70th year, the falling-off ceases and the number becomes stationary, somewhere between 30 and 40. Long before the forest has reached the age, when it can be utilised, only a select body of those species, which would have thriven on the area even if there had been no competition at all, survives and the vegetation acquires a more and more regular character. Even that vegetation which first makes its appearance on land burnt for cropping purposes (or on areas burnt by forest fires or on felled areas), shows differences according as the localities vary in quality. At first, it is true, a heterogeneous mixture grows on the cleared areas, of all those plant species whose seeds or spores have found their way to the areas, so far as they have any chance of thriving there. For the simple reason that the different kinds of locality supply the different plant species with very different vital requirements, the vegetation with an abundance of species, which makes its appearance on such spots, takes from the very beginning to a considerable extent a different composition according to the differences in the quality of the different localities, so much so as to become characteristic of the different localities. Step by step with the growing intensity of the struggle between the plant individuals, those species which on that locality are biologically weaker are gradually exterminated, the result of which process is that the vegetation becomes more and more regular. A battle of this kind is going on, not only in the ground vegetation and not only among the trees, but also in the different storeys of the vegetation. It follows from this fact that the ground vegetation is also very regular in mature stands in inhabited regions, in forests under regular sylvicultural management, so much so as to approximate to the regularity of the ground vegetation of a primeval forest.

The final issue of the struggle necessarily depends on the plant species engaged in the struggle and on the nature of the locality. Wherever the plant species engaged in the struggle are identical, the final outcome necessarily depends exclusively on the quality of the locality, so that the final results of struggles taking place on localities of equal biological value perforce must be the same plant associations. Such a state of affairs, however, is never completely realised, for the species available are so numerous that it is scarcely possible for the seeds or spores of all of them to find their way to the spot. The most dominant »locality plant species» (Standortsgewächse), however, occur in most cases everywhere in such frequency and abundance and are also so widely distributed that, as a rule, every particular clearing is always peopled by so numerous a colony of its characteristic species, that the plant association in question as a rule will assume a character typical of the quality of the locality — as a result of the more or less specialized requirements of the plants with regard to locality, of the struggle between the plants, and of the unconscious favouring of certain plant species by others. Thus it is possible, especially in mature forests, to distinguish quite definite plant associations characterised by plant species which are always, or nearly always present. There are, for instance, lichen pine forests, i. e. Scots pine forests, where the ground is covered with white *Cladina* vegetation accompanied by some characteristic dwarf-shrubs, herbs and grasses, and there are *Calluna* pine forests, *Vaccinium vitisidaea* pine forests, *Myrtillus nigra* pine forests. etc. In the ground vegetation of each of these varieties of forest there exists a stock number of plant species, which are always or nearly always present and from this stock number there leads an uninterrupted series through those which are often present down to those which are only very seldom present. Species belonging to different degrees of frequency may be present in varying

abundance. The features of a plant association are generally determined by those species which are present in the greatest abundance and frequency. Those species, however, which are present at a lesser rate of abundance, but are, nevertheless, always or nearly always present, are also, of course, equally characteristic of the association. Finally those species which, though they may be more or less rare, are met with, however, almost exclusively in the association in question, are also characteristic of that association. On the other hand, of course, the absence of certain plant species is also a very important feature in the delineation of a plant association, although the definite establishment of absence is more difficult.

All the plant associations or modifications of plant associations which occur in one and the same pine (spruce, birch, etc.) stand during its growth from the seedling stage up to maturity, and which form one continuous developmental succession, are referred to the same forest type. Moreover, to the same forest type are referred all those more or less diverging plant associations the divergence of which from the corresponding stage of the normal succession has been caused by some accidental factor, perhaps, for instance, owing to the fact that the forest has been rendered thin and full of gaps by fellings, or that the forest has been scorched by fires, or that the forest has been used for grazing, etc., provided that the difference is such as would disappear after the factor has ceased to operate. The species of tree may also be regarded, in the same way, as an accidental factor, the action of which alters as soon as it is replaced by another species of tree.

Consequently, all those stands are referred to the same forest type the vegetation of which at or near the time of maturity of the stands and provided the stands are normally stocked, is characterised by a more or less identical floristic composition and by an identical ecologico-biological nature, as well as all those stands the vegetation of which differs from that defined above only in those respects which — being expressions of differences due to age, fellings, etc. — have to be regarded as merely accidental and ephemeral or at any rate as only temporary. Permanent differences call forth a new forest type in cases where they are sufficiently well-marked, or a sub-type in cases where they are less essential, but, nevertheless, noticeable. In a forest type, therefore, as a rule, only those primary — climatic and edaphic — factors of the locality are reflected — which factors may be assumed to remain active, even when the locality is laid bare of all plants. [1]

Which of the various vegetational combinations have to be referred to the same and which to different types can be ascertained with certainty either by experiment, i. e. by taking a stand or part of a stand as a permanent sample plot and allowing it to develop as freely and regularly as possible, or, more quickly, by making comparative investigations directed in the first place to cases where the boundaries between different stands are as rectilinear as possible, as such boundary lines generally cannot coincide with the lines marking off one locality from another. Such rectilinear boundaries are very commonly met with everywhere in forests to which felling by compartments has been regularly applied. In practice, as a rule, recognition of the forest types does not present any great difficulties. For that purpose one must learn first to distinguish the different forest types with certainty in their most

[1] The secondary locality factors, above all the changes in the local climate (that of the stand itself), i. e. in light intensity, etc. and in the soil, brought about by the age, density, etc. of the forest covering, stamp the vegetation clearly with an impression peculiar to themselves. On the other hand, variations due to secondary locality factors such as the age and the quality of the stand, etc. may cause deviations in the vegetation of the forest types, which are only incidental, although at times very distinct, in character.

typical or normal form, i. e. as they occur in stands normally stocked and fairly mature, and after sufficient skill has been acquired, one has to train oneself in deciding to which normal type series any vegetation departing from the normal belongs. Special note must be taken of the stands in the immediate vicinity of the stand concerned and by devoting careful attention to such boundaries of the stand as appear to have been determined by factors other than those pertaining to the locality. This task is greatly facilitated by the fact that the differences in the vegetation of all the forest types of lowest productive capacity have a comparatively small range within the compass of one and the same forest type, and also by the fact that the influence on the ground vegetation of the different species of trees under the same conditions is comparatively insignificant. On the lands of highest productive capacity the difficulties are certainly greater, because the deviations shown by the vegetation on land of this kind are quite appreciable at the seedling stage and the pole stage, the stand being then at its densest, and at the time of maturity, as is clearly shown by the investigations of the writer into forest types in Central Europe (1909). Thorough training, however, will enable one to distinguish with accuracy the developmental successions of vegetations belonging to the different forest types even on the land of highest productive capacity, the more so as there generally is a sufficient amount of material at hand for comparison, for instance, parts denser or with more gaps than the rest of the stand, older or younger neighbouring stands on the same locality, or stands otherwise different in one respect or another. The determination of a forest type, even in extreme cases, is not more difficult than the determination of, let us say, the species of a plant which is imperfectly developed, which lacks flowers, and so on. That, too, requires training, but when the training has been acquired, it is comparatively easy to accomplish it with accuracy.

The dividing lines between the different associations of forest vegetation, as between plant communities in general, are fairly distinct and in any case so distinct that their recognition in practical survey work does not present any great difficulties. To illustrate their work, plant geographers nowadays make quite frequent use of mapping, and the mapping of forest vegetation associations, or, what is the same thing, of forest types, in other words, the mapping of forest soils on the basis of forest types, is not by any means any more difficult. Also the comparatively sharp dividing lines between the different plant associations are, as the present writer has already shown (1909), brought about by the competition between the plant species. This is quite obvious in such cases where two plant associations, both having one absolutely dominant plant species, come into contact with each other, for instance on the flood meadows of North Finland, where near the water level *Carex acuta* and *Calamagrostis phragmitoides* often occur in parallel unmixed zones, running side by side without overlapping each other. The locality, it is true, changes quite gradually from the water level upwards, without any distinct lines of demarcation, but the vegetation shows, nevertheless, a very marked dividing line. The reason for this is that *Carex acuta*, as can be seen, indeed, from some isolated scattered individuals, thrives everywhere in the *Calamagrostis* zone and even higher up, and *Calamagrostis*, in its turn, everywhere in the *Carex* zone. Over the whole area, however, of the *Carex* zone *Carex* is biologically stronger in the struggle than *Calamagrostis* and over the whole *Calamagrostis* zone *Calamagrostis* is biologically hardier than *Carex*. Both of them may live permanently side by side only on such spots where the conditions constituting the locality are so equal for both that neither can defeat the other. Such a locality, however, exists only on the narrow strip that forms the boundary between these two zones. — Where the vegetations are not so pure, but where several more or less dominant species live together and especially where the vegetation forms several storeys, for instance that of mosses and lichens, that of dwarf-shrubs, herbs, and grasses, that of bushes and that of trees, as is the case with forest-stands, often the dividing lines for the different species do not coincide and, accordingly, the boundary lines of such a plant association cannot be so clearly defined as in the above case. Here too, however, the same competition and struggle are, nevertheless, exerting their influence, and the intermediate zones, where personal judgment has the most marked effect on the locating of the boundary lines, are of comparatively small importance. — Moreover, it is one of the characteristics of plant associations that they recur in nature, as a rule, in forms very much like one another, so that they may, in consequence, be easily combined into collective units almost in the same way as individual plants which resemble one another, may be combined into plant species. Thus, it is quite possible to carry out a classification of plant associations. For reasons discussed above all the localities which are colonised by the same forest type must be regarded as representing mainly biological equivalents, and they are fairly easily recognised by the forest type occupying them. All these facts tend to prove that on a basis of forest types it is possible to work out a biological basis of classification of localities essentially independent of species of trees[1] — a basis which is necessary as a foundation for any method of classification of localities, whether based on the soil or based on the yield of stands, and once this foundation has been laid, work can be proceeded with according to either of these methods. The introduction of forest types need not mean any simplification in assessing the quality of forest localities as compared with how it is usually carried out in practice. Instead of simplification the aim of forest types is to achieve as natural, objective, and general an assessment of qualities as possible.

[1] This fact is of very great importance especially in such a country as Finland, where the original natural proportions of the species of trees have been changed to a very great extent, especially on account of forest fires and burning for cropping purposes, since the spruce has been forced to give way to the pine, birch and black alder. Now, however, as the burning for cropping purposes has been abandoned almost entirely, the spruce is occupying anew the areas belonging to it. The result is that now, in quite similar localities, here one and there another species of tree predominates, without any ordinary regularity.

The Forest Types of Finland.

As the forest types, especially when rather large regions are taken into account, are comparatively numerous, it is indispensable to arrange them in as natural a system as possible, so that those really closely related to one another biologically will also take their places in the system near one another. Systematisation of forest types, as well as the systematisation of plant associations generally is as yet in its infancy. The guiding principle of the system we are going to expound in the sequel is, that the forest types should be grouped together according to their normal form (as expressed by the plant association which is characteristic for a mature and normally developed stand) and in such a way that those forest types, which, in respect of their floristic composition resemble one another most, are placed nearest to one another, and also in such a way that, in establishing the more comprehensive classes, notice is taken of the requirements of the species of trees and of the plant species usually growing in them, the order being as follows: — the Scots pine as the most accomodating species, the moderately exacting species and the very exacting species. Further account is taken of the relative abundance of such physiognomico-ecological plant types as lichens, mosses, plants with herbaceous stems, dwarf-shrubs and bushes, and finally due attention has been paid to the general ecologico-biological character of the vegetation.

Regarding the nomenclature of the forest types, several devices are possible. They could be designated by the letters, A, B, C, etc., or by the Roman numerals, I, II, III, etc., or by combinations of these. These devices, however, are marred by the draw-back that they are difficult to remember and, in addition, the system would be disturbed by the addition of new types. For these reasons recourse has been had to the

method of naming the forest types from the plant species which are most characteristic of them, e. g. the *Calluna* type, *Myrtillus* type, etc. In addition, from the botanical name of the most characteristic plant species or group of plant species symbols have been derived for these forest types, as ClT for the *Cladina* type, CT for the *Calluna* type, MT for the *Myrtillus* type, OT for the *Oxalis* type, a method which was suggested to the author by Prof. Baron J. A. PALMÉN, from an analogous method with contractions used in geology (e. g. L. G. = Litorina-Grenze). It has, however, always to be borne in mind that a name like this is only a name for some definite forest type which, especially in its normal condition, is characterised by a vegetation association with a definite floristic composition.

The following pages will be devoted to a brief account of the main features of the vegetation of the normal forms of the forest types that so far have been differentiated in Finland. We preface it, however, with the statement that the forest types even of Finland still require a good deal of investigation and correction of details in regard to their botanical aspect in order to make their definition as precise as possible and to elucidate their variations. More detailed descriptions, together with lists of plants are to be found in the following publications: —

A. K. CAJANDER: Ueber Waldtypen. 1909. Acta forestalia fennica I and Fennia 28.

K. LINKOLA: Studien über den Einfluss der Kultur auf die Flora in den Gegenden nördlich vom Ladoga-See I, 1916 and II, 1921. Acta societatis pro fauna et flora fennica 45.

O. J. LAKARI: Tutkimuksia Pohjois-Suomen metsätyypeistä (Investigations of the Forest Types of North Finland), 1920. Acta forestalia fennica 14.

Y. ILVESSALO: Vegetationsstatistische Untersuchungen über die Waldtypen. 1922. Acta forestalia fennica 20.

A. PALMGREN: Zur Kenntnis des Florencharakters des Nadelwaldes. 1922. Acta forestalia fennica 22.

The following study may also be added: —

K. LINKOLA: Waldtypenstudien in den Schweizer Alpen. 1924. Veröffentlichungen des Geobotanischen Institutes Rübel in Zürich, 1.

The Dry Moss- (and Lichen-) Forest Class.

The general character of the vegetation is more or less xerophilous.

Lichen vegetation is nearly always present, forming on the driest heath a continuous cover. The moss vegetation stands almost in inverse ratio to the lichen vegetation. Herbs and grasses scanty. Dwarf-shrubs for the most part rather plentiful, most of them decidedly xerophilous. Bushes very few (*Juniperus communis*, a few willows). In most cases the forest-forming species is the Scots pine, less frequently some other tree.

The humus is thin, — on the driest heaths, very defective.

Cladina type (ClT): The ground, as a rule, greyish white, owing to the abundance of *Cladina* vegetation (*Cladonia alpestris* in particular). The moss vegetation rather scanty. Herbs and grasses very few. Nor are the dwarf-shrubs very abundant, but are interspersed among the lichens. The forest consists for the most part of Scots pine forest. — Occurs most commonly and in its most typical form on the dry sandy heaths of Lapland and the far north, but is also met with on the poorest and driest soils even of South Finland. A few varieties, differing from the true type, may be recognised. In fact, LAKARI has distinguished in the far north and in Lapland a sub-type rich in *Empetrum nigrum* and another rich in *Calluna*. The northern forests of the *Cladina* type differ considerably from those of South Finland. Accordingly, two geographically different, interchangeable sub-types may be differentiated. With regard to the forests of *Cladina* type in the south, is it to be noted that the lichen vegetation is far from being as luxuriant as in the north and *Empetrum nigrum* is present to an insignificant extent; furthermore, several of the more northern species (*Nephroma arcticum, Platysma nivale*, etc.) are absent. In their stead, *Convallaria majalis* and *Calamagrostis arundinacea* in particular occur more frequently and in greater abundance in the south.

Myrtillus-Cladina type (MClT): is a definite intermediate type between the *Cladina* and the *Empetrum-Myrtillus* types, fairly self-contained and characterised by abundant lichen and dwarf-shrub vegetation (*Myrtillus nigra* and *Empetrum nigrum* in particular) which is more conspicuous in this type than in the preceding one. Fairly widely distributed on the dry heaths of the far north and Lapland.

Calluna type (CT): Moss vegetation (*Hylocomium parietinum* and *H. proliferum, Ptilium crista castrensis, Dicranum undulatum* and *D. scoparium*, etc.) and lichen vegetation (mainly *Cladonia rangiferina*) are present in varying degrees of abundance, the former vegetation alternating with the latter in respect of predominance. Herbaceous and grassy vegetation is somewhat more abundant and richer in species than in the preceding types. Dwarf-shrub vegetation is abundant, *Calluna vulgaris* as a rule, being the predominant species. Of the bushes *Juniperus communis* is fairly common. In most cases the forest-forming species is the Scots pine, but the birch (*Betula verrucosa* and *B. odorata*) and Norway spruce occur commonly as admixtures, and sometimes as the dominant tree species.

The *Calluna* type is distributed all over Finland, taking up 8.3 per cent of the area of the economically productive forest land. In the southern half of the country, however, this type is more common than in North Finland, where there are forests, which, just as was the case with the *Cladina* type, represent an interchangeable sub-type, characterised by a more abundant lichen vegetation, *Empetrum nigrum*, etc.

On the Central European mountains forests are met with, although not very frequently, which approach nearly to, and may partly coincide with, the *Calluna* type of Northern Europe.

Empetrum-Myrtillus type (EMT): Moss vegetation dominant, including mostly the so-called feather mosses (*Hylocomium, Dicranum*, etc.) and a certain proportion of *Polytrichum;* lichens are common, but less abundant than in the MClT. Herbaceous and grassy vegetation rather scanty. Dwarf-shrub vegetation, dominated by *Myrtillus* is, instead, very common and accompanied, although not usually in equal abundance, by *Empetrum nigrum*. In most cases the forest is formed by the Scots pine, almost constantly intermixed with the birch (*Betula verrucosa* and *B. odorata*), frequently with the Norway spruce and often with the aspen (*Populus tremula*). Sometimes the birch and especially the spruce are dominant. Widely distributed on the moderately dry heaths of Northern Finland, taking up 26.0 per cent of the area of the economically productive forest land of the Province of Oulu. This and the next type are often combined into a separate sub-class: moderately dry moss-forests.

Vaccinium type (VT): Moss vegetation, including feather mosses mainly, is fairly continuous; lichens common, but, as a rule, of lesser importance. Herbs and grasses somewhat richer in species and more abundant than in the *Calluna* type. Dwarf-shrub vegetation rather plentiful, consisting mainly of *Vaccinium vitis idaea*, accompanied in varying degree by *Myrtillus nigra* and *Calluna vulgaris*. Juniper is very common. In most cases the forest is formed by the Scots pine, but the birch and the Norway spruce occur commonly in mixture, often also as the main forestforming trees; the last-named function is also sometimes usurped by the bushy *Alnus incana*.

Forests of the *Vaccinium* type occur on moderately dry sandy ground and on glacial ridges, sometimes even on moraine, and they occupy about a quarter of the economically productive forest land of Finland. A type so widely distributed naturally displays many intermediate forms. Apart from the fact that some of these approach more nearly to the *Myrtillus* type, others to the *Calluna* type, the *Vaccinium* type also falls geographically into two interchangeable sub-types, the one occurring in North, the other in South Finland, but the boundary line between them is not very pronounced. The former is characterised particularly by *Empetrum nigrum*.

On the Central European mountains, in the regions where the climate is the same as, or approaches to, that of Fenno-Scandia, there occur in many places forests of the *Vaccinium* type, which display a close agreement in quality with those occurring in Northern Europe. Even in the highest forest zones of the Alps, in South Tyrol in Brixen, for instance, the author has encountered Scots pine forests that, in the composition of their vegetation and also in their general character, agree very closely with the Scots pine forests of northern Europe. LINKOLA, too, has met with forests of *Vaccinium* type on the Swiss Alps, on the higher parts of which there occurs a forest type comparable, if not identical, with the *Vaccinium* type of North Finland, the *Empetrum-Vaccinium* type (EVT), and, on the parts at slightly lower elevations, another type which may be set on a par with the *Vaccinium* type of South Finland.

With the dry moss-forests have to be classed some forest types met with on the Alps and characterised by *Erica carnea*.

The Moist Moss-Forest Class.

The general character of the vegetation is more or less mesophilous.

The forest types belonging to this class are generally characterised by a fairly abundant or continuous moss vegetation (species of *Hylocomium, Dicranum*, etc.). The part played by lichens is quite insignificant. Herbs and grasses are present in somewhat greater degree and in the types approaching the next class in much greater degree than in the preceding class. Dwarf-shrub vegetation is fairly plentiful or plentiful, consisting for the most part of *Myrtillus nigra*; in some of the types, however, *Vaccinium vitisidaea*, is more prevalent.

As forest-forming trees all the less exacting species of trees may occur (*Picea excelsa, Betula verrucosa, B. odorata, Pinus sylvestris*, etc.) whilst the hardwood species, as well as more exacting bushes, are met with in types bordering on the next class.

The humus layer, as a rule, is well developed, having in a greater or less degree the characters of raw humus.

Hylocomium-Myrtillus type (HMT): This forest type is characterised by a continuous and exceedingly luxuriant feather moss vegetation. Lichens are scanty. Herbs and grasses are scanty, whilst dwarf shrub vegetation is more or less abundant, including especially *Myrtillus nigra* and, apart from that, *Vaccinium vitis idaea* and *Empetrum nigrum*. In most cases the forest consists of rather open Norway spruce forest, with an admixture of birch. Often the Scots pine is also met with, mostly in the form of standard trees. This forest type takes up 9.9 per cent of the economically productive forest land of the Province of Oulu, and it occurs especially on the upper slopes of the mountains of the eastern parts of North Finland, where it is markedly dominant. It is less prevalent on the mountains of Western Lapland, occurring, as a rule, on their moist, northern slopes.

Somewhere in proximity to this forest type, perhaps, may be classed some of the Norway spruce forests of poor growth occurring on the upper parts of the Central Mountains of Central Europe and having a rich moss and *Myrtillus* vegetation, in which *Calamagrostis villosa* is very common.

Myrtillus type (MT): The moss vegetation, as a rule, is abundant or continuous, but it is not as thickly luxuriant as in the preceding type, and its most important components are *Hylocomium proliferum, H. parietinum* and the various species of *Dicranum*, etc. The role played by lichens is very unimportant. Herb vegetation is more abundant and richer in species than in the preceding type, consisting mostly of quite common species. Grasses are comparatively few. The dominant *Myrtillus nigra* is nearly always accompanied by *Vaccinium vitis idaea*. In the natural state this forest type would always be covered by Norway spruce; but, owing to burning-over for cropping purposes, fires, fellings, etc., the Scots pine and birch occur very commonly as forest-forming trees, and, in tracts where burning-over for cropping purposes has been much practised, also the grey alder *(Alnus incana)* and Aspen *(Populus tremula)*. Hardwood species of trees, as a rule, are not met with, except in regions where grass-herb forest types prevail, and whence hardwood species of trees have strayed to this type.

The *Myrtillus* type is very characteristic of the southern half of Finland, of the economically productive forests of which, it takes up 38.5 per cent. The corresponding percentage for the Province of Oulu is 4.0, and this percentage, moreover, is met with in the main in the southern parts of the province.

In Central Europe, forests rich in *Myrtillus nigra* are widely spread and very common. They occur commonly even in the Swiss Alps. The *Myrtillus* type which is met with there from altitudes of 5,900 feet upwards, is, according to the investigations of LINKOLA, fairly parallel with the Finnish *Myrtillus* type. Analogous forests of the *Myrtillus* type occur also on the higher parts of the Central Mountains of Germany, whereas the forests rich in *Myrtillus nigra* that are common in the plains of Germany, seem, as LINKOLA has also recently established, to differ from these.

Oxalis-Myrtillus type (OMT): This type represents a certain relatively self-contained intermediate form between the *Myrtillus* and the *Oxalis-Majanthemum* types. Moss vegetation is fairly abundant, but much scantier than in the preceding type; lichens are of no significance. Grass vegetation is somewhat, and the herb vegetation, much more abundant than in the preceding type. Among the grasses and herbs, some more hygrophilous species, as *Oxalis acetosella* in particular, and *Melica nutans*, *Fragaria vesca*, etc., are also encountered. More exacting bushes (*Rubus idaeus*, *Daphne*, etc.) are often present. Among the common species of trees a sprinkling of hardwoods is often met with and sometimes they may even be dominant (e. g. the oak — *Quercus pedunculata*, — in Southwest Finland).

This forest type occurs on the more fertile lands of the southern half of Finland, being fairly common especially in valleys and on the lower slopes, although the areas covered by it are not very extensive.

On the Central Mountains of Germany the *Oxalis-Myrtillus* type is encountered mostly in the more fertile valleys at an altitude of 2,600—3,900 feet, and Linkola has observed forests belonging to, or approaching to this forest type in numerous places in the Swiss Alps at altitudes of from 5,425 to 6,250 feet.

Pyrola type (PyT): This is a forest type closely related to the preceding one, and it is characterised by a rather abundant presence of *Vaccinium vitis idaea*, whereas *Myrtillus nigra* is sometimes entirely absent. The different species of *Pyrola* and *Succisa pratensis* are common. This occurs especially on the clay soils of the southern parts of Finland. — This, as well as the preceding forest type, is sometimes set apart as a separate sub-class: Moist Forest resembling Grass-herb types.

On the mountains of Central Europe *Myrtillus* forests are often encountered, approaching grass-herb forests and rich in *Rubus idaeus* (RMT).

Grass-herb Forest Class.

The general character of the vegetation is more or less hygrophilous.

Lichens play a quite insignificant role. Moss vegetation scanty, although it consists of many species. Dwarf-shrubs, as a rule, do not occur or are present in small numbers. Grasses and especially herbs are comparatively abundant and rich in species, the presence of thin-leaved species being very noticeable. Shrubs may often occur fairly abundantly.

The Scots pine, as a rule, does not occur as a forest-forming tree. In the most typical cases the forest is formed by hardwood species of trees, but in the types as they occur in the northern countries, the Norway spruce and those broad-leaved trees which have light seeds are generally dominant.

The humus varies in thickness and is welldecomposed.

Geranium-Dryopteris type (GDT): A grass-herb forest type bordering on the moist moss-forests. Mosses are scanty or present to some

extent, especially various species of *Hylocomium*. Lichens are very scanty. Herbs are fairly copious, especially *Geranium sylvaticum* and *Phegopteris dryopteris* in varying amounts. Further, *Maianthemum*, *Rubus saxatilis*, *Angelica sylvestris*, various species of *Pyrola*, *Trientalis* etc., occur. Grasses are rather scanty (*Luzula*, *Calamagrostis* etc.). Dwarf-shrubs occur to some extent, especially *Myrtillus nigra* and *Vaccinium vitis idaea*. Shrubs are rather scanty (*Juniperus communis*, species of *Ribes*, *Rubus idaeus*, *Prunus padus*, etc.). — The forest is mainly mixed, consisting of Birch, Norway spruce, Scots pine and aspen. It occurs mainly on the most fertile slopes and in the most fertile valleys of North Finland and Lapland, especially on calcareous soils, but always on relatively small areas. It displays a good deal of variation.

Oxalis-Majanthemum type (OMaT): Mosses rather scanty (*Hylocomium triquetrum*, various species of *Polytrichum*, various species of *Mnium*, etc.). Among dwarf-shrubs, *Myrtillus nigra* and *Vaccinium vitis idaea* are common, but generally in small numbers. Grasses and sedges are not very abundant (*Calamagrostis arundinacea*, *Aira caespitosa*, *Melica nutans*, *Carex digitata* etc.), but the thin-leaved herbs (ferns, *Oxalis*, *Majanthemum*, *Convallaria majalis*, *Rubus saxatilis*, *Fragaria vesca*, various species of *Viola* etc.), are in greater abundance. If the conditions of primeval forest obtained, Norway spruce would be the only dominant tree species; but in the conditions prevailing in Finland, the birch (*Betula verrucosa* and *B. odorata*) is, in most cases, the forest-forming tree, and in addition, in tracts where burning-over for cropping purposes has been practised, the grey alder (*Alnus incana*) as well as the aspen (*Populus tremula*), besides which hardwood species of trees also occur. In Finland, its distribution is nearly the same as that of OMT, but it is less common.

Linkola encountered in many places in the Swiss Alps this forest type or a type closely allied to it, at an altitude of 5,250—5,575 feet.

Fern type (FT): The special feature of this forest type is the presence of thin-leaved ferns (various species of *Phegopteris*, various species of *Polystichum*, species of *Athyrium*, *Onoclea*), occurring in abundance, as well as by rather abundant and luxuriant vegetation of various kinds of other herbs and grasses. It is very often accompanied by slight symptoms of invasion by swamp conditions. One of the dominant trees is the black alder (*Alnus glutinosa*). This type is met with in the fertile valleys of the southern half of Finland, whereas in North Finland it occurs only in very favourable conditions.

This forest type or at least a closely allied type, is also encountered in the rather moist valleys in the Central Mountains of Germany.

Sanicula type (ST): This type comprises the most luxuriant grass-herb forests of Ahvenanmaa (Åland), on more or less calcareous soil. They have a very copious grass and herb vegetation, rich in species, but hardly any dwarf-shrubs, while more exacting shrubs are abundant and the species are numerous. The forest in most cases is mixed and the role of the hardwood trees and the black alder *(Alnus glutinosa)* is outstanding. Often these forests have much in common with meadows.

Aconitum type (AT): Comprises the most luxuriant grass-herb forests of Laatokan Karjala (Ladoga Carelia), occurring generally on calcareous soil. Their general characters are very much the same as those of the preceding type, but their floristic composition differs considerably. The distinguishing feature of this type is the tall *Aconitum lycoctonum*. The forest may have been mixed even from the very beginning, but, unlike the *Sanicula* type, the Norway spruce, according to LINKOLA, has played a notable part in the natural state of affairs. The significance of hardwood species of tree on the contrary is much less than in the *Sanicula* type, although the maple *(Acer platanoides)* and the lime *(Tilia ulmifolia)* occur very commonly and sometimes also the elm *(Ulmus montana)*.

Lychnis diurna type (LT) is encountered on sea-coasts. It is a forest type which is as yet only incompletely elucidated and which for the most part consists of stands of black alder *(Alnus glutinosa)*.

Nearly related to the *Oxalis-Majanthemum* type is a collective forest type which is wide-spread in Central Europe, i. e. the *Oxalis* type (OT), the resemblance of which to grass-herb forest is still more pronounced than that of the *Oxalis-Majanthemum* type; dwarf-shrubs are either wholly wanting or present to a very limited extent, while thin leaved herbs and grasses are relatively even yet more abundant. In Central Europe there are several other grass-herb forest types, amongst which in particular, the *Asperula* type (AspT) on fresh fertile land and the *Impatiens-Asperula* type (IAspT), which LINKOLA has encountered also in Switzerland — in fertile fresh and rather moist valleys — seem to be widespread. To these types belong also the grass-herb forest types of Denmark (*Mercurialis* type, *Circaea* type, etc.) described by BORNEBUSCH. — It seems that, from the purely botanical point of view, a great number of grass-herb forest types can be differentiated. Their differentiation would no doubt be important also from the point of view of forestry, but, as it would be difficult in practice to make use of too great a number of forest types, it is necessary to arrange the forest types which can be differentiated into several natural groups, which can be used as collective types.

With regard to Finland the following forest types may be added: —

Vaccinium-Rubus type (VRT): Represents as it were an intermediate form between the grass-herb forests and the dry moss-forests, and is encountered on the higher slopes of the hills north of Lake Laatokka (Ladoga). Forest forms approximating to this are also met with here and there elsewhere in South Finland, but they are of purely local significance.

Forests approximating to this type very probably occur on German mountains. LINKOLA describes a type approaching this, the *Vaccinium-Papilionaceae* type (VPT), which he has encountered in the Swiss Alps, viz. at Zermatt, and which occurs on fertile, rather dry slopes, especially on south aspects. There occurs, likewise, according to the same author, on southern exposures in Switzerland, a forest type allied to these, i. e. the *Brachypodium-Chamaebuxus* type (BrChT).

Spruce and Broadleaf-tree Peat-Moor Class (Marshes.) The general character of the vegetation of the spruce and broadleaf-tree peat-moor class is more or less mesophilous, and partly also hygrophilous. The proportion of the moss vegetation is variable, ranging from relatively scanty, though rich in species, to a complete covering, including only a few species. It consists of relatively exacting *Sphagnum* species (*Sph. strictum*, *Sph. squarrosum*, *Sph. Wulfii*, etc.) and certain species of *Polytrichum* (especially *P. commune*) in varying quantities. In certain types of this class there may even be a large number of other leaf-moss species (belonging especially to the genera *Mnium*, *Hypnum*, *Dicranum* etc.). The forest is formed by the Norway spruce or broad-leaved trees, whilst the importance of the Scots pine is negligible.

These peat moors occur on boggy land which is comparatively rich in nutrients and in which the water is as a rule more or less running or else in movement. They may be divided into two sub-classes, one of which being more exacting and corresponding to grass-herb forests, comprises a moss vegetation more scanty in individuals, but rich in species, and a herb and grass vegetation rich in species. In it the broad-leaved trees (among others also the black alder) dominate or, at least, enter into its composition more or less copiously in mixture. The other, less exacting and corresponding to the moist moss-forest class, has a moss vegetation which is copious but with fewer species, a grass and herb vegetation with fewer species, dwarf-shrubs in greater quantity, especially *Myrtillus nigra*, and the Norway spruce is the commonest tree present, being, in the natural state of affairs, probably the dominant tree without a rival. Both sub-classes embrace a number of different types, the occurrence of which and variations to a great extent depend on the soilmoisture.

Pine Peat-Moor Class. The general character of the vegetation of pine peat moors is generally clearly xerophilous. On the most typical pine peat moors, the moss vegetation is continuous, but less so in types occurring on wetter ground, and it contains for the most part, comparatively speaking, very accomodating species of *Sphagnum* (*Sph. fuscum*, *Sph. recurvum*, *Sph. acutifolium*, etc.), interspersed with other accomodating moss species (*Polytrichum strictum*, *Aulacomium palustre*, etc.) Lichens, especially *Cladonia rangiferina*, occur in some types to a certain extent. Dwarf-shrubs, as a rule, are fairly plentiful (*Ledum palustre*, *Myrtillus uliginosa*, *Calluna vulgaris*, *Betula nana* etc. being, in some types, the prevailing dwarf-shrubs, while, in types approaching spruce peat moors, *Myrtillus nigra* occurs to a marked extent). Herbs and grasses occur sparingly (*Eriophorum vaginatum*, *Rubus chamaemorus*, *Drosera rotundifolia*, etc.). The principal species of tree is the Scots pine, generally forming pure stands; in the more extreme types Norway spruce and birch are worth mentioning as being met with in mixture and even as the dominating species. Unlike the spruce peat moors, the Scots pine peat moors are most nearly related to the dry moss-forests. They occur on the more, or even very, infertile boggy ground. The ground water present is generally less active than in spruce peat moors.

In Finland the peat moor forest types have usually been dealt with in connection with other bog types, and therefore we shall not subject them here to closer analysis. With regard to them, the reader is referred to the study by A. K. CAJANDER: »Studien über die Moore Finnlands», 1913. Acta forestalia fennica 2, and Fennia 35.

No consideration has been given here to all those varying forest types which occur on lands inundated by rivers, on blown sand, on rocky ground, at the forest limit on mountains, as well as in the vicinity of tundras, as these forest types are mainly locally significant.

Forest types in their Relation to Forest Mensuration.

The first investigations into the bearing of the forest types upon forest mensuration were in many respects only of a tentative character.

The comparative measurements carried out by the author in the forests on both mountains and plains of Central Europe in 1906 and 1907 were of that character. They consisted partly of height measurements of dominant trees in mature, normally developed stands belonging to various forest types, and partly of measurements of the stumps of trees belonging to the dominant canopy class on areas, belonging to various forest types, to which clear-cutting by compartments had been applied. These latter measurements were taken, so as to ascertain the mean growth in basal area at stump height. Indefinite as these measurements were, they clearly pointed, however, to differences in the growth of the different forest types.

The growth investigations which were carried out by N. THOMÉ and P. MINNI (1908) and by J. SILFVERBERG and G. KARLSSON (1909) with special reference to two forest types, occurring in the Forest District of Evo-Vesijoki, i. e. the *Calluna* and the *Myrtillus* types, were also of this preliminary nature. Having taken sample plots in stands of all ages of a normal character and having plotted their timber volumes as points in a system of co-ordinates, where the ordinates stood for the

volume and the abscissae for the age, they were able to ascertain that the points arranged themselves so evenly as to make it possible to draw through, or in close proximity to them, a very regular curve, with extremely slight deviation. This fact alone clearly indicated that normally developed Scots pine stands belonging to the same forest type possess a very uniform growth, whereas the growth for different forest types on the average differed widely.

The investigations carried out by Y. ILVESSALO in 1914 in the State Forest of Salmi, which dealt with the *Myrtillus* and *Calluna* types, were of greater importance. They were based on 30 sample plots taken in regularly developed Scots pine stands, an equal number in each type. The sample trees were subjected to a complete stem analysis, and they were selected in the following manner: — The trees of the sample plots, which were a quarter of a hectare each in area, were grouped according to diameter, and, beginning with the thickest, were arranged in four classes, each containing 25 trees, then the next thickest were arranged into three classes, each of which contained 50 trees, and lastly the thinnest trees were arranged into classes, each containing 100 trees. The sample trees were selected from average stems of the first or predominant class. The growth ascertained in this way turned out to be markedly uniform for those stands of the same forest type, whereas different forest types varied widely in this respect. The investigations into the proportion between the breast-height diameter and the height of trees, carried out by Y. ILVESSALO in the Forest Districts of Simo and Kemi in 1915, showed that on an average, trees with the same diameter are much taller in the better forest types than in the inferior types, so that, for instance, in the *Myrtillus* type they are taller than in the *Vaccinium* type and in the latter, taller than in the *Calluna* type.

As all these preliminary investigations — including also those carried out by BJÖRKENHEIM in the Central Mountains of Germany in 1907 — had thus led to positive results, the Society of Forestry in Finland, which had received funds for the purpose from the Councillor of Commerce O. A. Malm Foundation, commissioned Y. ILVESSALO to carry out a more extensive investigation into the subject. The intention was to prepare yield tables for normally developed Scots pine, Norway spruce and birch stands in the southern half of Finland and for this purpose, the necessary sample plots had to be taken in normally developed stands of all ages, consisting of the forest species mentioned, even-aged and growing on land, where the conditions of swamp-invasion were absent. The sample plots had to be measured as accurately as possible and all the data that it is customary to record in yield tables had to be procured. Further, in each sample plot the mean tree of the 100 thickest trees per hectare had to be subjected to a complete stem analysis and a complete description of the vegetation had to be rendered. Finally, samples of the soil had to be taken from each of the soil horizons. The material thus collected from the sample plots had to be treated by mathematico-statistical methods. The particular aim of all this was to find out, whether the forest types were adapted to serve as quality classes in the preparation of yield tables, in which case the tables had to be prepared on that basis. The sample plots were selected by Ilvessalo himself during three successive summers, 1916, 1917, and 1918 and the number thus taken amounted to 467 in all. They were scattered all over the southern half of Finland, and they were distributed among the different forets types and species of trees as follows: —

	AT	OMaT	OMT	MT	VT	CT	ClT
Scots pine	—	1	15	65	77	70	13
Norway spruce	4	3	50	27	—	—	—
Birch	3	29	44	38	5	—	—
Aspen	—	—	5	2	—	—	—
Grey alder	2	7	1	—	—	—	—

For the sake of comparison, there were added to these, three sample plots in mixed stands and 3 sample plots in the *Hylocomium-Myrtillus* type. The number of the sample plots was sufficient to render possible the determination of the growth of Scots pine stands on the forest types OMT, MT, VT, CT and ClT, of Norway spruce stands on types OMT and MT, and of Birch stands on types OMaT, OMT, MT and VT. The rest of the sample plots were used as material for comparison.

From a forest mensuration point of view, this research led to the following results: —

For all species of trees, the mean diameter of the stems of a stand in every age gradation is greater, the better the forest type is. The different forest types differ markedly from one another, moreover, in respect of the current and mean increment of the mean diameter.

The better a forest type is, the greater is the dispersion of the stem distribution series, based on breast-height diameter.

The poorer a forest type is, the greater is the number of stems in a stand, for every tree species dealt with, at least from about 20 years of age onwards.

On the basis of the characteristics of the stem distribution series and by using forest types as quality classes it is possible, with the aid of statistical methods, to calculate theoretically the mean stem distribution series for the various age gradations of a stand. These stem distribution series differ considerably for the various forest types, giving, when portrayed graphically, lower and broader curves, the better the forest type is. The better a forest type is, the more rapidly and to greater extremes does the diameter decrease of the smaller and the diameter increase of the greater diameter classes take place, from which it follows that saw-timber grows much more rapidly and in greater quantity on better than on poorer forest types.

The better a forest type is, the greater is the volume of a stand for all the species of tree dealt with, at every age gradation. The better the forest type, the greater is the maximum of the current annual increment in volume (and also the increment itself, during most of the life of a stand) and the earlier it appears. The same is true of the mean annual volume increment.

The better a forest type is, the greater is the basal area of a stand of the same species of tree at every age gradation, also, the earlier do the current and the mean increments of the basal area reach their maximum — which is also greater.

The mean height in regular stands — although in individual cases there may be great variation — is on the average greater, the better a forest type is.

The height of the dominant trees of a stand for every species of tree dealt with (except the Scots pine on the *Oxalis-Myrtillus* and *Myrtillus* types) and for every age gradation, is greater, the better a forest type is, while the current and the mean height growth reach their maximum — which is also greater, — earlier, the better a forest type is.

The better a forest type is, the greater is the breast-height diameter of the dominant trees of a stand at the same age gradation; the greater is the maximum of the current diameter growth, which occurs as early as the early seedling stage; and the mean diameter growth is always greater on the better forest types than on the poorer ones.

The volume of the dominant trees of a stand, for the same age gradation, is greater, the better a forest type is; the current and mean volume increments at every age gradation, is greater on the better forest types than on the poorer ones.

The divergencies among the different forest types in respect of the various aspects of the growth of the dominant trees of a stand (as well as in respect of the mean diameter of a stand) have also been mathematically established according to the theory of probability. In the same manner it has been proved that, in regard to growth, the behaviour of the same forest type is very similar in different parts of the southern half of Finland.

From these results Ilvessalo came to the following conclusion: —

Since, therefore, growth in all its aspects is different for the different forest types, while for the same forest type it differs within comparatively narrow limits, the forest types, being uniform, natural and relatively easily distinguishable quality classes, are well-suited to serve as a basis for the classification of forest soils, for forest mensuration in general and for yield tables in particular.

Since the research had led to these singularly positive results, the construction of growth tables on the basis of forest types could be begun without hesitation.

It may be mentioned that, according to the yield tables thus prepared by Y. Ilvessalo, the volume of regularly developed Scots pine stands for different ages is, on the average in cubic feet per acre, over-bark, as follows: —

	OMT	MT	VT	CT	CIT
10 years	272	186	143	100	—
20 »	1,000	857	629	343	43
30 »	2,001	1,929	1,272	672	143
40 »	2,972	2,858	1,914	1,072	243
50 »	3,987	3,715	2,529	1,486	443
60 »	4,915	4,472	3,129	1,829	657
70 »	5,787	5,187	3,744	2,186	886
80 »	6,544	5,816	4,272	2,543	1,143

	OMT	MT	VT	GT	CIT
90 »	7,145	6,330	4,687	2,901	1,400
100 »	7,645	6,744	5,015	3,172	1,629
110 »	8,002	7,030	5,230	3,429	1,886
120 »	8,230	7,187	5,358	3,629	2,115
130 »	?	?	5,458	3,801	2,343
140 »	?	?	?	3,929	2,572
150 »	?	?	?	4,029	2,786

The number of merchantable trees per acre with a diameter of at least 11 inches in normally developed Scots pine stands at different ages proved to be, on an average, as follows: —

	OMT	MT	VT	CT
50 years	6	—	—	—
60 »	26	9	—	—
70 »	58	26	5	—
80 »	93	53	17	—
90 »	116	81	35	—
100 »	129	100	53	2
110 »	141	110	64	7
120 »	152	118	72	15

The »Growth and Yield Tables for Scots pine, Norway spruce and Birch Forests of the Southern Half of Finland» (1920) by Y. Ilvessalo differ from any growth tables published hitherto in the following points: —

1. Forest types have been used as quality classes, and

2. on this account, the quality classes are the same for every species of tree dealt with in the growth tables (see. p. 16), for which reason it is possible to make comparative calculations, for instance, as to the profitableness of growing the different species of trees on the same area of ground.

They are further characterised by the fact that: —

1. Unlike the earlier growth tables, it has been possible in these to treat the data of measurements for each quality class, i. e. forest type,

quite apart from the data from the rest of the forest types, and thus the series of figures in the tables (the growth curves in the diagrams) represent the mean values for the sample plot data of the particular forest type which happens to be under consideration, and therefore, they illustrate the growth of each forest type by itself. With regard to the importance of that fact we refer to what has been said on p. 14.

2. The continuity of the growth series has been checked by the index method and the growth in all its aspects has been tested by the aid of statistical methods (see p. 18).

3. These tables show the distribution of the trees by breast-height diameter classes with 2 centimetres' intervals, for each age gradation of the stand, and this is very important in determining the value increment of a stand, since the value of a stand, besides depending on its timber volume, also depends essentially on the thickness of its trees.

The importance of forest types in forest mensuration is demonstrated also by a study by E. Lönnroth (1925), the scope of which includes the development of normal, even-aged Scots pine stands on the *Calluna*, *Vaccinium* and *Myrtillus* types, with special reference to the distribution of the trees by biological tree-classes. The study was carried out on 30 sample plots in the southern half of Finland, selected with the utmost care and with particular regard to the purity of the forest types and to the normality of the stand, so far as this was possible by ocular estimation. In carrying out the study, the whole of the sample plot data were collected first and only when all the material had been collected, did the working up begin, nor was a single sample plot eliminated from the original material. This study disclosed quite remarkable regularity in the structural development of the stands. From the point of view of forest mensuration, the following facts are of special importance: —

Within the limits of the uniform regularities exhibited in the development of stands on the different forest types, the forest types displayed amongst themselves characteristic variations in several important attributes, connected with forest biology as well as with practical forestry, for instance, in the relative rapidity of their development, as well as in their averages, in their distribution series of variables, irrespective of whether the classifications were effected on a biological or mechanical basis.

It is very remarkable with regard to several characteristics which bear on forest mensuration, that the sample plot data of the different forest types furnish wellmarked, uniform series, which do not overlap one another, but on the contrary, run on separate courses even with considerable blank intervals between them. Among such characteristics may be mentioned: — the number of stems, basal area, volume per unit of area, mean height, dominant height and mean diameter.

Finally, it is worth mentioning that the smoothed values obtained, coincide as closely with the corresponding values reached by Y. Ilvessalo and described above, as is ever possible in two studies carried out on entirely different bases, with different objects in view and based on different sample plot material.

The investigations conducted by Ilvessalo and Lönnroth have shown that the growth of the normally developed stands of any forest type is uniform to an extremely high degree, provided the species of tree is the same. Further, they have shown that, although, of course, overlapping variations may occur between the different forest types in respect of different characteristics which, as is well-known, may vary considerably independently of one another, nevertheless, the different forest types differ quite markedly from one another in regard to the various aspects of growth. They have shown that the purer in regard to type and the more normal (see p. 3) the sample plots selected are, the more definitely can the growth and development series of the different forest types be determined and the more distinctly do they differ from one another. Accordingly, the forest types have proved that they are capable of satisfying to a very great extent the demands that may be made on a method of classification of localities from the point view of forest mensuration.

As has already been mentioned above, the investigations of Ilvessalo show that stands of the same forest types in different parts of the southern half of Finland have a similar growth, and certain investigations of a preliminary nature even tend to prove that the growth of Scots pine stands belonging to nearly the same forest type does not exhibit at least any noteworthy differences between South Finland and even the Alps (Evo in South Finland and Brixen in the Southern Tyrol having been compared).

Forest Types in Relation to the Soil.

If the assumption be valid that localities occupied by the same forest type represent areas, where the combined action of climate and soil is equivalent, it follows that in regions with an identical climate the presence of the actual forest types and, accordingly, the differences in the biological value of the localities must depend upon differences in the properties of the soil.

In order to throw some light on this matter Y. ILVESSALO, as has already been mentioned in the previous chapter, took from his sample plots located in a climatically rather uniform region, samples of soil, the analysis of which was made by J. VALMARI. In this way the loss on ignition, the amounts of nitrogen, of electrolytes, of phosphoric acid, of potash and of lime were determined. The number of samples analysed, taken from 175 sample plots, was about 600. The results are shown in the following table, in which the figures refer to the amounts in a surface layer, 8 inches deep, expressed in pounds: —

	Per 100 sq. yards		Per acre			
	Loss of weight on Ignition	Amount of Electrolytes	N	P_2O_5	K_2O	CaO
AT	718	219	826	52	154	736
OMaT	672	296	874	46	118	323
OMT	549	301	595	90	89	271
MT	469	189	446	167	82	231
VT	381	103	317	271	82	183
CT	412	159	284	198	79	125
ClT	228	83	158	270	97	85

These figures thus disclose a considerable degree of parallelism between the series of forest types and the constituents of the soil, and they reveal, further, how important each of the constituents examined is for the forest production of a locality. It may be observed that phosphoric acid and potash are all but insignificant. The amount of potash, to be sure, is usually somewhat greater for the most productive forest types, but the difference is not particularly striking, and, moreover, the amount of phosphoric acid varies to a great extent in a direction opposite to that of the yield capacity of the soil. On the other hand, the amount of lime exhibits an exceedingly wellmarked parallelism with the yield capacity of the soil. Further, the evident rise and fall of the amount of lime, simultaneously with the yield capacity of the soil, has an effect on the variations in the total amount of electrolytes. Equal regularity of behaviour is displayed by the loss of weight on ignition, which at once reflects the amount of humus in the soil. Intimately connected with the latter is the amount of nitrogen which also shows a wellmarked relationship to growth.

With the aid of the yield tables by ILVESSALO, VALMARI gives the following instructive table, based on his analyses, in which table MT is taken as 100, as the basis for comparison: —

	Relative Current Annual Increments in Scots pine stands 75 years old	Relative Current Annual Increments in Birch stands 60 years old	Relative amounts of CaO (In an 8 inches deep surface layer)	Relative amounts of N (In an 8 inches deep surface layer)
OMaT	—	185	140	223
OMT	115	117	117	137
MT	*100*	*100*	*100*	*100*
VT	83	83	79	71
CT	52	—	54	64
ClT	27	—	36	34

In order to make clearer the dependence of the yield upon the constituents of the soil, Y. ILVESSALO calculated the magnitude of the correlation between the yield and the amounts of the soil constituents, directing his calculations, since growth varies with age even in the same forest type, to Scots pine stands of middle age, taking into account all the sample plots in such stands, and adding to them, by the use of a suitable method of conversion, all the corresponding sample plots in spruce and birch stands. The correlation proved to be as follows: —

Loss of weight on ignition	r = 0.435 ± 0.078
Total amount of electrolytes	r = 0.407 ± 0.081
Amount of nitrogen	r = 0.736 ± 0.056
do. of Phosphoric acid	No correlation
do. of Potash	r = 0.214 ± 0.091
do. of Lime	r = 0.612 ± 0.069

With reference to these figures, it is worth remembering that lime as such is an important nutrient for plants, and exercises, besides, a considerable influence on the physical properties of the soil. It has a particularly powerful influence also on the chemical reactions in the soil and thereby on the availability of nitrogen, i. e. on the processes whereby the nitrogen is transformed into a form suitable for plants. Regarding the nitrogen correlation it should be remarked that the nitrogen is determined according to the total quantity present, which, however, does not furnish any exact criterion of the amount of nitrogen which is actually available for plants.

Aaltonen has recently investigated the decomposition of nitrogenous compounds in the forest soil and he has paid attention especially to the nitrogen actually available for plants. He has established that the forest types in this aspect also clearly differ one from another. The higher the yield capacity of a forest type is the greater is the amount of nitrogen as ammonia, nitrogen as nitrates, as well as total nitrogen in the soil.

The percentage of total nitrogen (calculated as compared to the humus) in the humus layer is, according to Aaltonen:

Forest type	CT	VT	MT	OMT	OMaT
%	1.495	1.666	1.796	2.234	2.795

The nitrogen as ammonia and the nitrogen as nitrates of the samples was determined immediately after taking the samples and again after

keeping them for 2 months. In the samples taken from the humus layer the proportion of mobilized nitrogen (nitrogen as ammonia and nitrogen as nitrates) in the total nitrogen (all calculated as compared to the humus) is as follows:

Forest type	CT	VT	MT	OMT	OMaT
Determination immediately, %	0.220	0.335	0.383	0.484	0.551
» after 2 months, %	1.074	1.207	1.819	2.868	4.425

In the absence of the requisite apparatus, Valmari had to leave such an important factor as soil acidity without exact determination. In this connection, however, V. T. Aaltonen carried on the work by determining the hydrogen-ion concentration in a total of about 800 humus samples taken from different parts of the country, including farthest Lapland. It appears from this research work (1925) that the humus layer of forest soils is in Finland usually more or less acid. The characteristic of acidity, P_h, is, however, least in dry moss-forests, somewhat greater in moist moss-forests and greatest in grass-herb forests, for which the reaction sometimes may even be neutral. Taking into account the whole of Finland, the mean values for P_h in these forets type classes are as follows: —

Grass-herb forests	5.1 ± 0.10
Moist Moss-forests	4.7 ± 0.05
Dry Moss-forests	4.1 ± 0.05

The averages for the most prevalent forest types in the southern half of Finland, which part is fairly consistent in regard to climate, are, according to Aaltonen, as follows:

	P_h
OMaT	(5.0) [1]
OMT	5.2
MT	4.8
VT	4.6
CT	4.2
ClT	3.6

[1] The material for this type is too scarce, consisting only of 5 samples.

Since the acidity of the soil and especially of the humus exerts an influence on the soil leaching process by water percolation, the so-called podsolation of the soil, it is very likely that there is a sort of connection between the process of podsolation and the forest type. In fact, the investigations carried out by Tamm in Sweden (1920) point in this direction. Regarding the forest types which he dealt with, mainly in the form in which they were distinguished in Finland in 1909, without taking into account the later development of the system of forest types, Tamm reached the following conclusions: —

»The investigations carried out have revealed that the different forest types influence the leaching process in the soil caused by water percolation, to markedly different degrees, due to the quality of the humus layer which they produce. The strongest leaching action is exercised by the *Myrtillus* type, then by the *Vaccinium* type, while the weakest influence is exercised by the *Cladina* type. The *Oxalis-Maianthemum* type is an intermediate type, which in all probability exerts a stronger action, the more it is mixed with *Myrtillus*, and for that reason, possesses a more decided raw humus.»

The work on this subject has not yet passed the preliminary stages, but the investigations carried out so far tend to show that the forest types reflect the properties of the soil so clearly that they satisfy, at least to a very great extent, the demands made on p. 12 for a system of classification by which localities could be grouped naturally, if only in broad outline; and that they in addition afford a means whereby the systems of classifying localities, both that based on the properties of the soil as well as that based on the yield of stands, can be brought into harmony with each other.

At the same time, as those properties of the soil which are important for plant life, especially the physical properties of the soil, are more and more taken into account in future research work, it will become necessary to treat them more and more in combination with one another in each individual case, for the poor yield capacity or inferior biological value of a locality is incomprehensible, if it contains a very high proportion of nitrogen, since the result of that ought to be a high yield capacity, unless the nature of the other properties of the locality and their relative proportions are also ascertained. Among the latter there may be a number of growth factors, which, because they vary, to a great extent, independently of one another, may each be far from the optimum which harmonises with the optima of the other factors (Schimper). Moreover, the wider the geographical regions over which investigations are to extend, the more necessary will it be to take into account the changing character of the climate, i. e. to consider the properties of the soil in their relation to climate. It seems to be the case, that the same forest type becomes more exacting in regard to soil requirements the more unfavourable the climate is. In addition the same homogeneous sample plot must be investigated in many spots, because even on the most homogeneous of areas, the locality characteristics seem to vary to a great extent. — It is particularly necessary, for the elucidation of problems in connection with the plant nutrients of the soil, to employ also in forest soil investigations the method of experimenting with pot-cultures, which has recently been developed to a great extent by Mitscherlich.

By continous investigations directed towards these problems, a reliable foundation, no doubt, can be established on which to base measures for improving the yield capacity of the land, and in the first place, forest land.

Forest Types in Relation to Plant Biology.

The plant biological investigations on the various forest types are also in the initial stage. The following main features of these may be mentioned here.

As has appeared from the general discussion on the forest types, the behaviour and growth of the different species of trees differs markedly on the different forest types. The most exacting species, the so-called hardwood species, cannot thrive at all on soils of poorer productive capacity, whilst the most accomodating of them, the Scots pine, can grow on the best soils more or less abnormally. The occurrence of the species of trees on the various forest types is illustrated by Ilvessalo's sample plot data (p. 44). Normally developed Scots pine stands, suitable for sample plot purposes, were found in the greatest number on the types MT, VT, and CT, Norway spruce stands on types OMT and MT and birch stands on types OMaT, OMT and MT. Even on those forest types on which a certain tree species does occur in the form of stands, its growth, as has been pointed out above (pp. 46—47), varies greatly from type to type. This is, to be sure, a matter relating to forest mensuration, but at the same time, naturally, and even essentially relating to plant biology. Indeed, it can be asserted that the growth of trees (plants) is one of the most sensitive indicators of the biological value of a locality. Similarly, the division of the trees of a stand into classes, according to their development, which is referred to above (pp. 48—49) and with regard to which the various forest types differ considerably from one another, is a purely biological phenomenon.

HEIKINHEIMO (1915) has demonstrated that the capacity of broad-leaved trees for producing coppice shoots differs distinctly for the various forest types. As regards the regeneration of the ground vegetation, investigations into the variations of that on the different forest types are being worked upon at KUJALA.

It has been pointed out in the foregoing that the forest types differ from one another in respect of their ecologico-biological structure, and this can be used among other things as a basis in grouping the forest types into larger classes. Thus the hardwood forest types are more or less hygrophilous with regard to their general structures, whilst the dry moss-forest types have a xerophilous character, the moist moss-forests taking up an intermediate position. The Scots pine peat-moors are more xerophilous than the Norway spruce peat-moors.

LINKOLA has established that the forest types differ from one another also in respect of the so-called biological spectrum (RAUNKIÆR). On the basis of his investigations carried out in Switzerland he has produced the following table of percentages: —

	Phanerophytes	Chamaephytes	Hemicryptophytes	Geophytes	Therophytes
Dry moss-forests					
EVT	18	25	50	—	7
VT	19	22	53	—	6
Moist moss-forests					
MT	18	18	58	2	4
OMT	17	11	66	5	1
Grass-herb forests					
OMaT	9	9	74	7	1
OT	17	5	58	16	4
BrChT	28	4	55	12	1
VPT	15	14	66	—	5

On the basis of his investigations carried out in Finland, LINKOLA has drawn up the following table of the biological spectra: —

	Ph.	Ch.	H.	G.	T.
Dry moss-forests					
CT	21	32	35	9	3
VT	19	24	40	12	5
Moist moss-forests					
MT	17	17	46	15	5
PyT	14	14	59	10	3
OMT	22	11	48	15	4
Grass-herb forests					
OMaT	16	6	57	18	3
AT	13	5	60	18	4
FT	14	4	58	20	4
VRT	17	7	57	12	4

On the basis of these facts, LINKOLA is of the opinion that the different forest types and especially the forest type groups, exhibit in regard to their biological spectra quite striking differences, particularly in respect of the proportion of the Chamaephytes, but also to some extent in respect of the proportion of Hemicryptophytes and Geophytes. The spectra of the same type in Finland and in the Swiss Alps are similar in a very high degree, which similarity in all probability would be still greater, had not some slight discrepancies existed in the methods of making the determinations (the data for Finland were collected in 1914 and 1915 and those for Switzerland in 1923) and had the data collected in Switzerland been more ample. The most specific characteristic of the biological spectra of the different forest types seems therefore, in the main, to depend upon the Chamaephytes which they contain. According to the proportion of Chamaephytes, the forest types — leaving out of account the peat-moor forests — fall into three groups: — dry moss-forests, for which the percentage of Chamaephytes is 22—32 (generally more than 20), moist moss-forests, for which it is 11—18 (10—20) and grass-herb forests, for which it is 4—9 (for VPT, which is also peculiar in other respects, 14). This state of affairs will be still more apparent, if the frequency and the abundance of the Chamaephytes in the different forest types are also taken into account. — Further, Linkola points out that the forest types are characterised also by their pheno-ecological spectra (Gams). Thus in the forest types of dry moss-forest, the summer aspect is absent or it is only incompletely developed, whereas it is very conspicuous in the hardwood forests.

By his fundamental investigations in 'hardwood-meadows' in Ahvenanmaa (Åland), and by subsequent investigations of the same nature, A. Palmgren has, simultaneously with certain Swiss botanists, but quite independently of them, evolved an exact phytogeographical research procedure of his own. After Palmgren had worked out his so-called constitution curves for the above-mentioned 'hardwood-meadows' in Ahvenanmaa (1917), Y. Ilvessalo (1922) constructed, on the basis of the data he had collected from his sample plots, the constitution curves of the different forest types, which differ considerably among themselves. In the study mentioned above Y. Ilvessalo,

making analogous investigations to those carried out by Hult in North Finland (1881), has also produced diagrams of the morphological structure of the different forest types, which are very characteristic for each type, and has determined by statistical methods, so-called minimum areas for forest vegetation — an expression introduced into the science by Palmgren (1917) — and these appeared to be of markedly different size for different forest types.

In this connection it is appropriate to consider briefly also the number of plant species in the forest types as such, the importance of which factor for the characterization of localities and plant associations, including the forest types, has been especially emphasized by Palmgren. The result, of course, will vary, depending upon whether only the plant species of a forest type as it occurs in its normal form, or the plant species of all the forms in which a forest type actually occurs, are taken into account; whether only the proper species of a type are noted or also those species occurring occasionally; and further on the number of sample plots, etc. With this reservation, the following table on the proportional number of species in the forest types is presented, in accordance with Linkola (the *Myrtillus* type as the basis of comparison = 100): —

Forest Types	In the Swiss Alps	In Laatokan Karjala (Ladoga Carelia)
AT	—	281
OT	249	—
OMaT	180	190
OMT	144	131
MT	100	100
VT	71	74
CT	—	66
EVT	62	—

In the point under comparison the forest types show a degree of similarity between the Swiss Alps and Laatokan Karjala in Finland, which one could hardly expect to be greater.

Even the investigations carried out up to date show that each of the diffeient forest types has a very distinctive plant biological nature, and that a field for research is opened out here which is of as great importance for phytogeography as for sylviculture.

Forest types in Relation to Sylviculture.

The treatment of forest-stands is based upon forest-biology, mainly indeed on the biology of the trees, but also to a very great extent, on the biology of the vegetation of the stand as a whole. It may, therefore, be presumed that the obvious biological variations which are expressed by the vegetation according to the forest type, will also cause differences in the most appropriate treatment for the different forest types. Investigation on this point is, to be sure, still in the preliminary stage, but the main points already stand out quite clearly.

What has been said in the previous chapter concerning the variations in the occurrence and development of the various tree species on the different forest types has a direct bearing upon the selection of the species of tree, confining that selection within relatively narrow absolute limits, and still narrower limits in such cases, where the prospective value of growing the different species on the forest types is calculated by means of yield tables. It may be mentioned as a case in point, that, according to the preliminary investigations carried out by the author in Germany in 1906 and 1907, the *Asperula* type is the forest type on which the cultivation of oak is most profitable.

The same investigations have shown that various methods of regeneration on the different forest types lead to results differing considerably. The methods most generally applied to the forests investigated were clearcutting by the compartments system (Kahlschlag), the regeneration by the group system (Gruppenweise Verjüngung), as well as the Schwarzwald selection system (Schwarzwälder Femelschlag), so that it was chiefly these which were compared.

The use of clearcutting in all hardwood types (especially in IAspT, AspT and OT) meets with considerable difficulties due to the fact that as soon as a stand has been clear-cut, the area becomes covered with tall, dense weed-vegetation, under which the young newly-planted seedlings — sowing, as a rule, is quite out of the question, except in the case of the oak — entirely disappear during the first years of their life. The weed vegetation is most luxuriant in the IAspT, in which it is often exceedingly dense and tall. Even where the weed vegetation is mown or otherwise cut down, a considerable proportion of the tree seedlings succumbs and afterplanting (beating-up) is nearly always necessary. The application of clearcutting to the moist moss-forest types is a much easier matter. Only on the RMT is *Rubus idaeus* sometimes destructive to young spruce plants, but, as a rule, no special measures are needed for their protection against weeds. Still less is it necessary on the dry moss-forest types.

The regeneration by group system likewise leands to widely different results on the different forest types. It leads to good results even in the most luxuriant hardwood forests, as far as those species of trees are concerned the seedlings of which are able to endure stronger shade than the dominant weeds and which, accordingly, permit of the use of regeneration gaps of so small a size or with so many old trees left, that the weed vegetation cannot gain the upper hand. Tree species of this type are *Abies pectinata* and the beech, whereas it is of no use trying to regenerate spruce naturally on the hardwood forest types by means of the group system. Moreover, the regeneration of the beech often fails, where the gaps have been cut in such a way that they are exposed too much to the sun, in which case they will be invaded by *Sambucus racemosa*, etc. On the other hand, in the forest types bordering on moist moss-forests, i. e. OMaT and OMT, the regeneration even of the spruce by means of the group system is fairly successful and it is particularly successful on the MT type.

With regard to the Schwarzwald selection method, it can be briefly stated that in the hardwood forest types, it is more successful the more beech and especially *Abies pectinata* enter into the composition of a stand. In such cases, very slow regeneration methods can be employed and, accordingly, the young plants can be kept heavily shaded all the time. In the case of moist moss-forests it is more successful the more these contain spruce, which in most moist moss-forest types regenerates excellently by natural reproduction. — Being less applicable to Scots pine forests, the Schwarzwald selection system, as a rule, is not employed on dry moss-forest types.

With the exception of a minor research work carried out by the author in the State Forest of Evo (1909) and one by G. Hj. Enroth in the military fief-lands of Finland (1915), no investigations of much importance into the forest types in their relation to sylviculture have yet been made in Finland. It is, however, universally accepted and is everywhere borne out by experience, that the natural regeneration of the Scots pine, especially when the shelterwood compartment or shelterwood strip system is employed, is most successful on soils of the *Vaccinium* type, and that it is more difficult away from this type in both directions, — on the more productive types, especially on account of increasing weed vegetation, on the poorer types by reason of the greater aridity, infertility, etc., and also by reason of diseases and noxious insects due to these last-mentioned factors, although the *Myrtillus* and the *Calluna* types allow of a fairly successful natural regeneration of the Scots pine. Under the shelterwood compartment or the shelterwood strip system, or under the Schwarzwald compartment selection system, the regeneration of the Norway spruce is most successful on types OMT and MT. — Thinnings are also influenced by the forest types, and the systems of high forest with standards and underplanting are wholly justified only on the most productive forest types. In many respects a special kind of sylviculture is required for the forests of the *Hylocomium-Myrtillus* type in North Finland, which have been investigated by Heikinheimo and Lakari. A special treatment is also required for Scots pine peat-moor and Norway spruce peat-moor forests.

As a special case, it may be mentioned that, according to the investigations of L. Ilvessalo (1917) on areas cut by compartments, the poorer the productive capacity of a forest type is, the more time does the forest take to regenerate itself and the more uneven-aged are the stands, even in the case of the most even-aged stands which have grown up by natural regeneration.

On the basis of the investigations into the forest types in relation to sylviculture so far carried out and of what is otherwise known concerning them, the conclusion seems to be justified that they conform to a great extent to the principle of classification, which is essential for further sylvicultural development and which has been emphasized on pp. 19—20.

Application of the Forest Types in Practical Forestry.

As a result of the important bearing of the forest types on forest mensuration and sylviculture, it follows that they can confidently be used with advantage as a basis for the organisation of forestry as a whole.

After the forest types had become generally known and especially after the growth and yield tables by Y. Ilvessalo had been published, the forest types obtained a wider and wider application in Finland as a basis for working plans, either by basing the entire working plan together with growth forecasts and instructions as to treatment upon them or by making use of them at least in map explanations. Without entering into the details of this question, two of the principal applications under this head may be mentioned.

Being of the opinion that the methods of assessing the quality of localities employed up to that date were too arbitrary, and after some forest inspectors and surveyors had made a tentative use of the forest types in their work since 1911, the Board of Forestry in Finland gave instructions as early as 1914, according to which notice had to be taken of the forest types in the State forest administration. In the interests of the forest types this was somewhat premature, because by that time, the forest types, especially of North Finland had been only too incompletely investigated, and a certain amount of confusion resulted.

Thus the *Empetrum-Myrtillus* type of the far north was quite commonly identified with the *Vaccinium* type, and so forth. Gradually, as a knowledge of the forest and moor types has been gathered and confirmed, they have as a result been utilised more and more consistently in the administration of the State forests. Instead of classifying forest soils according to their yield into economically productive forests, forests of poor growth, and waste lands, in accordance with the more or less subjective judgment of each surveyor, as was formerly the case, they are now classified in the service into these main classes on the basis of the forest and moor types. As the yield of the different forest types is different and as sylvicultural operations, too, are dependent on the quality of the localities, in the interests of a clearer survey the data dealing with the various tree species, age classes and the growing stock were arranged according to the following forest type groups: — hardwood forests, moist moss-forests resembling hardwood forests (OMT and PyT), moist moss-forests, moderately dry moss-forests (VT and EMT), dry moss-forests proper, economically productive spruce peat-moors and economically productive Scots pine peat-moors. When, however, a forest type group contains forest types, which differ considerably in respect of yield, as the *Myrtillus* and *Hylocomium-Myrtillus* types belonging to the moist moss-forests proper, the tables recording the species of tree, age class and growing stock are prepared for each of these forest types separately. In drawing up working plans, the sylvicultural operations are laid down in the first place in accordance with the forest type and quality of the stand. — It may be mentioned further that the General Forest Survey, which will be described later on, was initiated also with the special object in view of organizing the State forestry. The intention was to acquire homogeneous statistics speedily regarding the situation in the State forests in respect of the forest types as such, as well as in respect of the species of trees, age classes, growing stock, merchantable standing crop and growth in its various aspects, — all with reference to the forest types, with the ultimate object of basing the local working plans of the different Forest Districts on these statistics.

As another instance of the application of forest types, which has, however, been carried out quite independently of the establishment of forest types as effected in Finland, may be mentioned the system of management of the forests on the large estates of the Prince v. Schwarzenberg in Czecho-Slovakia. As the result of his visit to these forests in 1924, Councillor of Forestry Dr. O. J. Lakari gives the following description: —

»The landed property of the Prince v. Schwarzenberg amounts in all to 250,000 hectares (628,400 acres), of which area 135,000 hectares (333,935 acres) are taken up by the forests. The first working plans for these forests were drawn up in 1859 and ever since they have been treated methodically with a view to preserving continuity in forest economy and raising the yield. In the course of time the sylvicultural methods have varied, but, especially during the last decades, the sylviculture in the forests has developed into a peculiar and unique method of forest management, the so-called 'stand and locality system' of management, i. e. the sylvicultural operations are planned in accordance with the quality of each stand and locality. In this forestry no rigidly fixed modes of treatment and cutting, such as have proved to be appropriate under some conditions and which are often recommended in the professional literature as sylvicultural operations suitable for universal application, are observed. On the contrary, the tendency is to make the cuttings in the stands on every variety of locality in accordance with that method of cutting which, according to the experience acquired, has led in such stands to the best economic results. The Chief Director of the forest administration on the estates of the Prince v. Schwarzenberg, Dr. Franz Heske Sr., who has recently retired, in the course of the many decades during which he had charge of the administration of the forests on these estates, always especially strove to place the organization on a scientific footing.

The result of this systematic and methodical sylviculture, practised for many decades, has been that the forests of the Prince v. Schwarzenberg furnish a splendid example of exemplary forestry. This is shown also by the fact that the growing stocks approximate over wide areas to the normal figures given in yield tables, whereas in the other private forests bordering on those of the Prince v. Schwarzenberg, the growing stock on corresponding forest soils and in corresponding age classes is considerably less, often being only a small fraction of the growing stock of normal stands.

At the time of my visits to the forests of the Prince v. Schwarzenberg the forester, Dr. Franz Heske Jr., kindly favoured me with the following information on the quality of the forest lands of the Böhmerwald and on the management of the stands on the different kinds of forest soils: —

The forests of the Böhmerwald can be divided into the hardwood forest group and moist moss-forest group, and within these the following types can be distinguished: —

The best grass-herb type (*Asperula-Impatiens* type and those approaching it), corresponding to the locality class I;

the *Oxalis* type, corresponding to the locality class II;

Oxalis-Myrtillus type, corresponding to the locality class III;

Myrtillus type, corresponding to the locality class IV, and

the poorer *Myrtillus* type, corresponding to the locality class V and occurring on the higher slopes of the Böhmerwald.

These forest types differ from one another not only in respect of the ground vegetation, but also in respect of the yield per acre, the height of the trees, the mean diameter of the stems and the number of stems per acre. Thus the growing stock at the age of maturity is considerably greater in the better than in the poorer forest types, whereas the number of stems per acre at the same age is less in the better than in the poorer forest types. Further the size and the height of stems in stands of the same age are greater in the better than in the poorer types.

The difference between the different forest types is indicated by the bark of the trees: — in the better forest types the bark is smoother, and lichen is present in relatively smaller abundance, whereas the bark in the poorer forest types at corresponding ages is rough and rugged and lichen covers it more abundantly.

In giving an account of his observations on, and experience with, the classification of the above-mentioned forest lands and the forest

types, Dr. Franz Heske Jr. further remarked: »It is true that in this connection no investigations have been made here of so systematic and accurate a nature as those carried out in Finland; but our system of forestry, which is one of long standing, and the actual operations carried out over a long period in agreement therewith, provide examples in sufficient number to justify the contention that, in the Böhmerwald, the fundamental principles of the system of forest types have been completely substantiated.»

In addition to the differences from the mensuration point of view there have also been established in these forests sylvicultural differences in different forest types. Thus the thinnings are carried out in a different way in the forests of different forest types. On poorer forest types, where the natural thinning is slower, the thinnings are carried out more lightly. On better forest types the natural thinning takes place relatively early and heavily, for which reason the thinnings in these are carried out earlier, more often and more heavily. Even so the partial clearance is commenced earlier on better forest types.»

The Forest Types in Their Relation to Other Vegetation Types.

Just as forest types may be distinguished in the forest, so, in the same way, moor types may be differentiated on moors.

If it be true that the nature of a forest type is not determined by the kind of soil (e. g. sand, clay, etc.) which it occupies, but depends on the total value, biologically, of the locality, and originates as the final result of the combined action of all the primary climatic and edaphic factors on the vegetation, the assumption must also be true that, if a moor is drained, so as to assume in respect of moisture, too, the characters of ordinary forest soil, its surface will be occupied by that forest type which corresponds to the total biological value of the locality, in spite of the fact that the soil consists of peat. Since, further, the moor type and the forest type on peaty soil are determined by exactly identical locality factors and the existence of the former as compared with the latter, depends only on its higher degree of moisture, the assumption is warranted that each moor type, when drained, will be turned into a definite forest type. That this is really the case the investigations of Tanttu (1915) have proved.

Tanttu has investigated the moors which have been drained in Finland since the middle of last century, partly »in order to reduce the danger from frosts», partly for agricultural purposes, but which even in the latter case, in the absence of tillage, have been reconverted to forest. The results attained by Tanttu's investigations can best be shown in the form of the table between pp. 68 and 69, which illustrates the gradual changes undergone by treeless marshes as a result of drainage.

The table is not complete, because all the moor types known are not represented among the drained and reconverted moors of Finland. The identification of the original moor type on the basis partly of the surrounding moor, partly of the botanical character of the peat, is not always easily effected with accuracy. On account of the scarcity of the material available, recourse has often had to be had to less typical cases, besides which, the distinguishing features of some of the moor types obviously require revision. The general drift of the development, however, stands out quite distinctly and appears to be very regular: — as a result of drainage, the moor types develop into forest types. Since, moreover, as the investigations of Multamäki (1923) have shown, the rate of growth on the forest types on peaty soils is, generally speaking, at least chiefly the same as for the corresponding forest types on mineral soils, a basis is provided for calculating, with the aid of Y. Ilvessalo's yield tables, the prospective value of draining moors, especially as far as drainage for forestry purposes is concerned. The more recent drainage operations which have been carried out methodically, especially on State lands, could not be taken into consideration in connection with investigations of this type, because it requires a longer lapse of time before the final results are evident. Where a drained moor is once again

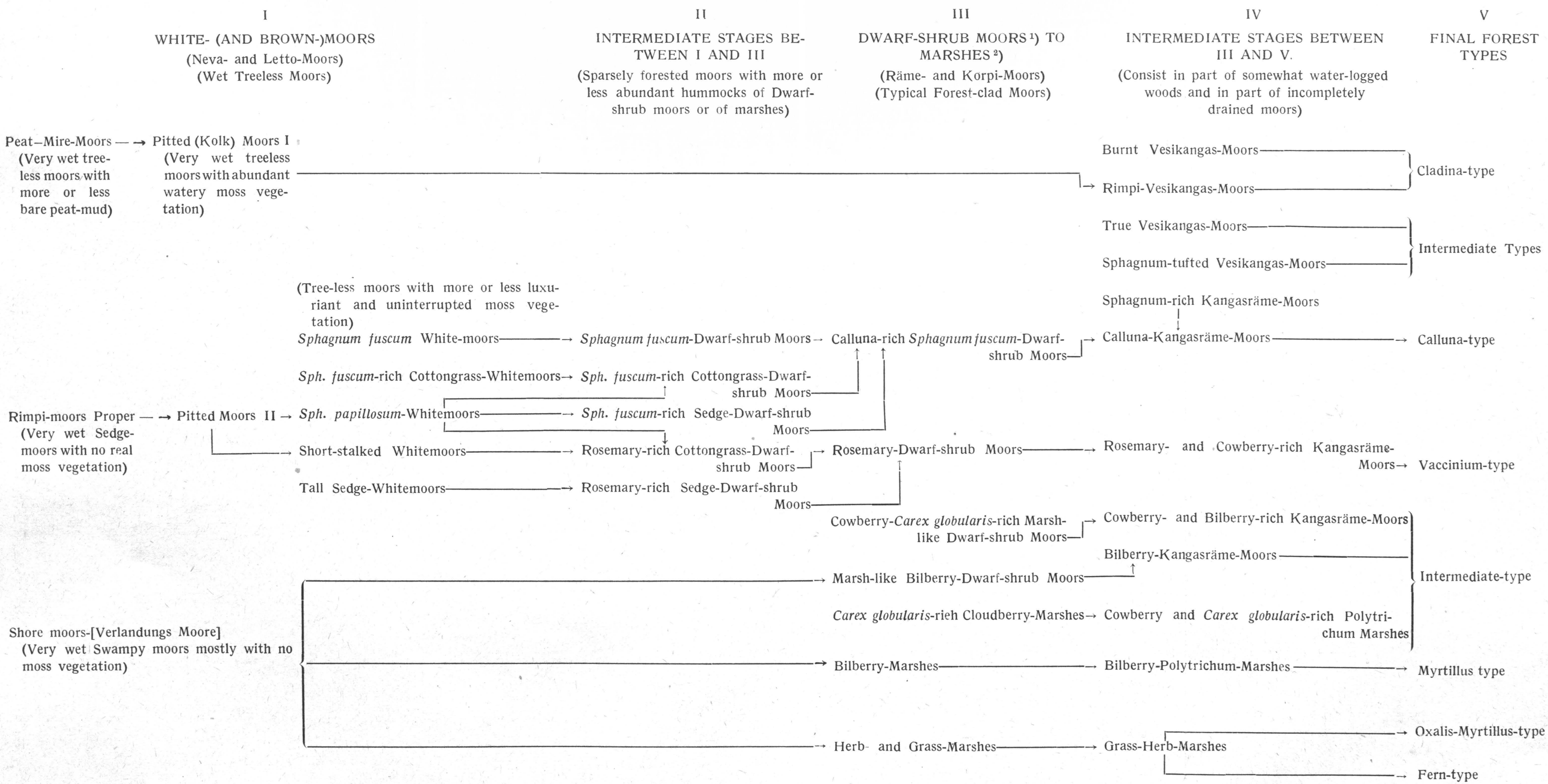
invaded by water, for instance, as a result of a stoppage of the drains, the development takes, as observations tend to show, a course the reverse of that indicated by the above table.

On meadows it is also possible to differentiate meadow types, and, since the so-called natural meadows in northern countries have previously been for the most part either moors or forest land, the determination of the corresponding moor type, considered collectively, or of the forest type is also within the bounds of possibility, and, by reducing moors, too, to the corresponding forest types, a common basis for assessing the quality of forests, moors and meadows, may be obtained. Finally, although caution is necessary and only where tilled fields, in comparison with forests, are of relatively small extent, and by making use chiefly of collective types, the determination of the original forest type of cultivated ground, too, may be attempted. In this way the cultivated lands would also find their place in the same system of classification for the assessment of quality. Attempts in this direction have been made, especially by Lukkala (1919) and Linkola (1922), and the task may not be impossible of solution, but, as yet, it requires more detailed investigations, probably also special experiment. It is evident that a uniform and objective system of assessing the quality of all the productive land would be of the greatest importance both from the practical and scientific point of view.

Employment of Forest Types for Statistical Purposes.

Almost as soon as the forest types had been elucidated to some extent, their application to the collection of forest statistical data was begun, partly in transforming existing forest maps, where they were detailed enough or were easily supplemented, into forest type maps by colouring the map areas in accordance with their forest types. This was the procedure adopted by the present writer with regard to the map of the forests of the town of Heinola this map has been published in a study

THE CHANGES IN MOOR TYPES AS A RESULT OF DRAINAGE



[1]) = Pine Peat-moors (see p. 41).
[2]) = Spruce and Broadleav-tree Peat-moors (see p. 41).

by LUKKALA (1919)]. On such areas marked on the maps in conformity with the forest types, statistical investigations may readily be based. TANTTU and other State foresters on special drainage work dealing with the drainage of bogs have worked out type maps of moors of the same description. The model map by TANTTU is published in a work by the present writer »Studien über die Moore Finnlands» (1913). Mapping work, however, even when it is done to supplement existing maps, takes much time, for which reason in forest statistical investigations in Finland, estimation by line survey is usually adopted.

Thus in the summer of 1917 LUKKALA and MULTAMÄKI carried out a kind of estimation by lines in the provinces of Savo and Karjala (Carelia), their method of procedure being as follows: — The highroad system in these provinces was previously divided on a map into portions of equal length; from the extremity of each of these portions a traverse was made along a straight line, at right angles to the highroad. The return journey to the highroad, ending at another point on the road, was made along a line, either at right angles to or parallel with the original line of traverse. The number of such traverse lines was 66 in all and the sum total of their length was 903 $^1/_2$ miles. In order to prevent curvature of the traverse-lines, the traverses were made with a compass and a rope, trailed by the compass bearer behind him, as indicators of the direction. On each map-area covered by the traverse-line the vegetation type (forest, moor and other such types), species of tree, age of the stand, density, growth, etc. were recorded; finally, in order to arrive at the necessary reducing factors, the length of line lying within each map-area was also recorded. — Research work of the same kind was carried out by the same investigators in Ahvenanmaa (Åland) in 1918 and by Multamäki in the western parts of the far north of Finland in 1919. As early as in 1912 W. CAJANUS, at the instance of the Finnish Forestry Association Tapio, carried out a regular estimation by strip-survey in two parishes of the central parts of the province of Häme, namely in Sahalahti and Kuhmalahti. The strips ran perpendicular to the principal features of the landscape. They were 32.81 feet (10 metres) wide and separated from one another by a distance of 546.83 yards (500

metres). Along these strips all the trees were measured for each map-area separately; the forest type, species of tree, age of the stands, etc. were recorded and the growing-stock per acre was estimated ocularly, on the basis of 240 sample plots, which were also used to check the ocular estimation mathematically. Cajanus had to leave the office-work unfinished and it was completed by Y. ILVESSALO, who published the results of the investigation in 1923.

After a great deal of preliminary work had thus been carried out, the time was ripe for making a general survey by means of lines extending over the whole of Finland. The immediate occasion for this arose from the fact that the Tax Committee of the State stood in need of reliable material on which to base the reform of the taxation levied upon forests. This work was started by LAKARI in the autumn of 1921 and it was carried out by Y. ILVESSALO in 1922—1923. The survey lines were traced at right angles to the general direction of the watercourses, glacial ridges, etc., and thus, in a SW—NE direction, at a distance of 16.16 miles from one another. The lines thus traced were 39 in all and their total length was 9,306 miles, or excluding water-surfaces, 8,066 miles. The growing-stock and the annual increment of the stands, both per acre, were estimated ocularly from area to area, but, in order to test these estimates and to procure data for control calculations, a complete sample plot with an area of 10.94 × 54.68 sq. yards (10 × 50 sq. metres) was laid down along the strips at every 1.243 miles (2 km), and another with an area of 10.94 × 109.36 sq. yards (10 × 100 sq. metres), in which all the trees of sawtimber size were measured. In each map-area, the kind of soil, vegetation type (moors and meadows by collective types), species of tree, age of stand, density, etc. were determined and recorded. The preliminary report recently issued under the title »The Forests of Finland. The Forest Resources and the Condition of the Forests» (1924) gives a very exact insight into the present condition of the forests of Finland, their forest types, composition, growing stock and growth. It is of paramount importance that the actual present growth of the forests should be ascertained, for a precise knowledge of this is indispensable for determining the balance between production and consumption in the forests. This, in its turn, is of the utmost economic importance for Finland. By this survey, statistical information is gained concerning a number of other interesting, and also to some extent economically important, circumstances, such as, for instance, the relationship obtaining between the forest types and soils, between the species of tree and forest types, the system of felling, etc. in the different parts of the country and in the forests under the different classes of ownership. Apart from this, however, since the General Survey has revealed the proportions of the forest types in the different parts of Finland and since the normal yield of the different forest types in the southern half of the country was already known from the growth and yield tables by Y. Ilvessalo, it is possible to determine, what would be the yield of the forests of the southern half of Finland, if they were in a normal condition. Further, as soon as the growth tables in course of preparation for the northern half of Finland are finished, the same will be true also with regard to North Finland. Finally, as it is roughly known into which forest types the different moor types are converted, it may also be calculated by what proportion it would be possible to increase the total yield of the forests, by draining all the moors of Finland capable of being drained, i. e. in the first place those moors which would be converted, when drained, into the grass-herb, the *Myrtillus* or the *Vaccinium* types.

Significance of the Forest Types in the History of Settlement and Culture as well as in Relation to Colonization Policy.

The statistical investigations into the distribution of the forest types carried out in Finland in the course of recent years have revealed that the various forest types are very unevenly distributed over the different parts of Finland. Whilst in some districts the most unproductive forest types predominate almost exclusively, in others the most productive forest types are very abundantly represented along with the less productive types.

Even the preliminary report of the General Survey published by Y. Ilvessalo shows that, taking the *Vaccinium* type as the average

locality class, the forest soils superior to the average, equal to the average and inferior to the average are very unevenly distributed over the various provinces, the distribution, expressed in percentage of the total area of forest land being as follows: —

Province	Superior to Average	Average	Inferior to Average
Ahvenanmaa (Åland)	75.4	12.4	12.2
Turku-Pori	44.0	34.2	21.8
Uusimaa	63.5	25.9	10.6
Häme	58.3	29.9	11.8
Viipuri	33.9	47.6	18.5
Mikkeli	47.7	40.7	11.6
Kuopio	50.0	31.7	18.3
Vaasa	36.9	33.2	29.9
Oulu	5.9	21.7	72.4
For the whole country	28.4	29.5	42.1

The provinces of Ahvenanmaa and Oulu are thus almost the exact opposite of each other.

From the geographical point of view, however, the provinces are very different in different parts. This will be borne out by comparing the south-west coast and archipelago of the province of Turku-Pori with the interior of the province of Satakunta (the backwoods of Parkano) in the north-east part of the same province; the districts of Sortavala and Impilahti in the province of Viipuri with the watershed region of Loimola; Maaninka, Lapinlahti and the parish of Kuopio with Rautavaara and Ilomantsi in the province of Kuopio; and so forth. A closer examination reveals that there are regions in Finland which are relatively fortunate with regard to forest types and others which are relatively unfortunate in that respect.

In view of the differences in the yield of the various forest types, their uneven distribution is of the greatest moment in the economic life of Finland. Forestry and the wood-manufacturing industries are so very important for Finland that the distribution of forest soils differing in yield capacity must bear on the economic life of the country as a whole.

The influence of the forest types, however, is not confined to this alone; on the contrary, as LINKOLA (1922) has explained, their significance in agriculture, too, is of the highest importance. Linkola calls attention to the following facts with regard to Finland: —

1. In Finnish farming forestry and agriculture are so closely bound together that the yield of the forests largely contributes to the total returns from the farm.

2. Since the herb and grass vegetation of forest lands increases in abundance and luxuriance from the poorest dry moss-forest types to the most productive grass-herb forest types, the differences in the distribution of the forest types will greatly affect the yield of forest land as pasture land, such pasture land being, as a rule, indispensable for Finnish farming.

3. As woods kept for grazing purposes, the different types of forest land will also vary in utility, probably in the same order as that mentioned in the last paragraph.

4. Since uncultivated meadows on mineral soil have been reclaimed from forest, either by clearing the ground directly of the wood, or by first burning it over for cropping purposes, their yield is quite obviously influenced in a great measure by the forest type which originally occupied the place, nor is that influence small even when such meadows are systematically cared for. — Roadsides and fences on the most productive forest types are covered with a far more luxuriant grass vegetation than on the poorer types and furnish the smaller cattle-feeders with a considerable part of their hay supply.

5. In view of the great importance attached to the raising of crops on burned-over clearings, as recently as some fifty years ago in most parts of South Finland and even yet in some frontier parishes of East Finland, it is of interest to point out that the annual crops on burned-over clearings quite obviously depend upon the forest type of the area, and further, that on burned-over clearings on the most productive forest types, more crops can be raised in succession than on those on the poorer types.

6. Further, the returns from land newly brought under the plough are closely related to the forest types which occupied the area and this is clearly evident even on cultivated fields of long standing. It is true that their yield capacity can be raised by various methods of land improvement, especially by manuring, but it cannot be denied that the poorer the original forest type was, the greater is the expenditure required in order to realize the same results. — Stoniness and other similar factors may account for some exceptions to the general rule.

In view of the importance of bog cultivation, it is reasonable to add that, as appears from the investigations of LUKKALA especially, there exists a considerable amount of correlation between the quality of forest soils and that of moors, especially when the latter are of small size or when the fringes of the larger ones are considered e. g. where the forest soils belong to better forest types, the moors, too, are better in quality and *vice versa*. On survey maps, important inferences can be drawn from the frequency of occurrence of spruce peat-moors as to the quality of the surrounding forest soils, as far as yield capacity is concerned. It is a phenomenon generally observed that, where better forest types prevail, the moors, meadows and arable land are also relatively better than elsewhere. In isolated cases, exceptions can easily be pointed out, for instance in the districts round the coast and in the belt of islands, where moors are few and where all the better forest soils and natural meadows have been brought under the plough, so that only the rocky ground and the most infertile areas are available for the growth of wood. It may, however, be stated as a rule which obviously holds good in a general way, that in the more fertile districts, both the forest soils and the moor, meadow and arable soils are on an average more productive than in the most infertile districts. As some typical examples in Finland may be considered the valley of the river Kokemäenjoki in the vicinity of Nokia and Karkku, compared with the backwoods of Parkano, or Maaninka in comparison with Rautavaara, and so forth.

The same evidence regarding the relative fertility of soils is disclosed by an analysis of the occurrence and distribution of the more exacting plant species. In this connection there exists a mass of material, collected by botanists in the course of a period of time extending over a century, which has accumulated from year to year, although, as yet, when the whole of Finland is taken into account, it is rather heterogeneous. By plotting on a map of Finland all the places, where the more exacting plants are known to occur, the fact is revealed, as the investigations of Lukkala and Linkola have shown, that these places are concentrated in the greatest numbers in certain districts, whereas in other districts they occur much less frequently, while in others again, they do not occur at all. These results agree, broadly speaking, with those reached by an investigation into the vegetation types, consequently, each method can best be used to supplement the other. In comparing the results, apart from the great variety of the data relating to the habitats of plants, it is necessary to take into account the lines of the post-glacial migration of plants into Finland, as well as the fact, thoroughly established by the investigations of Palmgren, that the ranks of the migrants grow thinner and thinner as the distance from the starting-point increases, and as suitable habitats become rarer. It may be of special interest to note that just as forest, moor, meadow and arable lands are found to vary in respect of productive capacity with a fair degree of similarity, so it may be remarked that, if the more exacting species among the forest plants, moor plants, meadow plants, rock plants, shore plants, aquatic plants, etc. are plotted on maps, each group on a map of its own, these maps will look very much like one another. That is to say, in the same districts where the most exacting forest plants cluster together, the most exacting meadow, moor, rock, aquatic and other plants are also concentrated. Accordingly, as Lukkala in particular has shown, investigations of this type also throw light on the *general* fertility of different districts.

As early as in 1916 the present writer was in a position to establish, on the basis partly of the knowledge of the places where exacting plants occurred and partly of preliminary investigations into the distribution of vegetation types, that in Finland it is possible to differentiate several regions, which, because of the presence of grass-herb forests and hardwood species of trees, may be called grass-herb forest centres. These

centres are characterized by a more than ordinary fertility of the soil. A series of transitional stages occurs leading from such centres to areas which in this respect are the antithesis of these. Further, it was established that this variation in the distribution of soil fertility has been a very influential factor in the history of colonization in Finland, and continues to be so. As examples of such grass-herb forest centres, I specially mentioned the centre of Ahvenanmaa and South-West Finland, the centre of the basin of Lohja, the centre of Pirkkala (Tyrvää — Ikaalinen — Längelmäki — Vanaja), the centre of Hollola (the districts around lake Vesijärvi, the southern part of lake Päijänne and the upper course of the Kymijoki), the centre of the Vuoksi, including the district round Viipuri Bay, the centre of Sortavala, extending as far north as Ruskeala and the somewhat less well-defined grass-herb forest centre of Kuopio. Besides these centres, districts resembling grass-herb forest areas quite commonly occur on the south coast and to some extent also on the coasts of the Gulf of Bothnia, one mid-way between the centres of Pirkkala and Hollola, another in the vicinity of Mikkeli — Lemi, and so on. As the direct antithesis of grass-herb forest centres, there exist extensive areas belonging to opposite types, not only in the northern, but also in the southern half of the country, e. g. on Suomenselkä, Maanselkä, and Savonselkä watersheds, on the watershed of the basins of Kallavesi and Pielisjärvi and on other main watersheds in general. The settlement of Finland has to a very great extent depended upon this unequal distribution of fertile land. It made its influence felt as early as the times, when fishing and hunting were the most important means of subsistence of the people, for game and even fish are most abundant in the most fertile districts, provided they have not been exterminated by unrestricted trapping and fishing; and the influence increased after cattle-breeding and agriculture had become the chief industries. Thus, the earliest centres of settlement of the Carelians were actually situated mainly in the grass-herb forest centres of the Vuoksi and Laatokka, those of the Tavastians in the centres of Pirkkala and Hollola and the Swedish settlement was concentrated in the grass-herb forest centres of South-West Finland and of the coast in general, so far as it had already risen from the sea. From the most fertile centres, culture spread step by step to those districts ranking next in fertility. Thus Kuopio was settled earlier than the districts of Pieksämäki, although they are further south, and so on. The most thinly populated districts in Finland are, as a rule, those most infertile ones, which, set apart as common lands, have been taken possession of by the State, and for the most part they offer the worst possibilities to the cultivation already existing. Very near to this worst type come such districts like Rautavaara, Ilomantsi, etc. in which the majority of the farms, being more or less suited only for growing forests, have passed into the possession of timber companies, whilst the State farms and old manors, etc. are located for the most part in the most fertile districts.

Subsequent investigations, especially those carried out by LUKKALA and LINKOLA, have in the main confirmed the above statements, at the same time adding to our knowledge new points of view and new details. On the basis of investigations carried out by himself, Prof. LINKOLA said in his inaugural lecture at the Finnish University of Turku (1923):

»But what about that exceedingly important problem: — Is it really possible to establish that forestry and agriculture are more remunerative and more profitable in those fertile districts than in the infertile ones? Yes. With regard to forests, this is due to the fact that in a fertile district, an acre of forest land, for instance, yields, on an average, within the same period of time, a much greater quantity of wood than, on an average, an acre of forest land in an infertile district. It is true that in agriculture this fact is only to a small extent reflected in the figures for the crop yield, but more because of the fact that in the more fertile districts, the same crop yield is certainly secured with less expenditure than in the infertile ones, with less manure and with less toil. The last-mentioned point is partly due to the fact that the soils of the fertile districts are more easily worked up by means of modern machines than those of the infertile districts. On fertile land, clay is of widespread occurrence, whereas it is rare or wholly absent on infertile land. Even climate favours the fertile districts more than the infertile ones, owing for instance to summer frosts being less frequent.

»This greater financial return from agriculture on those fertile lands is indirectly reflected in several different ways.

»At first, material prosperity in a fertile district is greater than in an infertile one. As a consequence of this, the tax-paying capacity of the farming population is greater, the buildings are better, the furnishing of the houses more complete and the people, moreover, are obviously better dressed than in an infertile district. I even venture to put forward so prosaic a hypothesis as this, that the mean weight of the farming population of a fertile district is greater than that of the farming population of an infertile district. In any case, thin, often quite hungry-looking persons are much commoner phenomena in the infertile than in the fertile districts of our country.

»On material welfare — although not on bodily weight — rests, generally speaking, the vigour of intellectual pursuits. Quite apart from the fact that the agricultural population of a fertile district takes a much livelier interest in the progress of agriculture, the more general intellectual pursuits are also most vigorous in such a district. For instance, it is quite evident that the sending of children to the higher schools is here more common than elsewhere.

»It has to be confessed that in many of the points discussed above, the differences among districts of different fertility have been obliterated to a great extent in recent times, especially in South Finland. They still exist, however, to an appreciable extent. They are most marked in the central and northern parts of the country, which could show many fine examples to illustrate my point.

»A rather pronounced exception to the general features delineated above is supplied by the conditions in South and Central Carelia. Even in very fertile parts of these regions, the population is still indigent and the conditions are in a comparatively primitive stage. The reasons for this state of affairs are of a historical nature. Under the Russian rule the population were heavily oppressed. The temper of the population suffered much on account of serfdom and other abuses, and now, the revival takes time.

»Although exceptional conditions do occur, we can state with certainty that it is a fact that the hypothetical degrees of fertility, visible on maps drawn on a botanical basis, are confirmed and verified in several indirect ways. Undoubtedly they also deserve attention from the practical point of view.

»The greatest practical significance of the degrees of fertility thus established probably consists in their capacity to supply an exact basis for the organization of our economic life on a really rational foundation. They indicate that agriculture should be concentrated, less inconsequently than has hitherto been the case in practice, in certain naturally favourable districts, which fortunately exist, even in abundance. It would be advisable, especially in such districts, to make the methods of cultivation more rational, so as to raise the yield to as high a level as possible. With regard to colonization and expansion of the land under cultivation, the observed degrees of fertility raise the serious question. — Should not land reclamation be directed to the really fertile districts, where cultivable land, not yet brought under the plough, exists in plenty; should we not beware of directing it to barren wildernesses?»

The same is the case in other countries. Thus LINKOLA records his observations in the Swiss Alps: —

»Then I often had occasion to pay attention to the fact that such pastures, as had obviously been cleared on places that had been occupied by forests more or less rich in dwarf-shrubs and more or less infertile, displayed considerably poorer growth of grass than the pastures on places previously occupied by hardwood forests or forests resembling these. Among other things, the former pastures showed a greater tendency to revert to dwarf-shrub. On the slope of the Gürmschbühl-Mettlen Alp, in the vicinity of the Wengern Alp, I observed how the luxuriance of the pasture grass increased markedly as I descended lower down and was greatest at that altitude, where the *Oxalis-Majanthemum* type prevailed in comparative abundance. Further, my observations led me to believe that unmanured and unwatered meadows could be mowed every year only in such cases, where they had been cleared on fresh and rather moist hardwood forest land, possibly also on fairly luxuriant land of the *Oxalis-Myrtillus* type; land more infertile than that is in all probability used mainly as pasture land only. Further, with regard to cultivation for crops a similar state of affairs may be demonstrated. Thus, for instance, certain observations, though quite incidental ones, indicate that in recent times, cultivation for crops in areas, where better forest types are wanting or are (and were formerly) comparatively scarce, has declined or has been abandoned. In any case the area under the plough in such regions is very small and all cultivation for crops gives the impression of greater or less poverty. As to the age of civilization, it may be stated that the main tendency was for the earliest civilization, provided there were no very difficult topographical conditions to prevent it, to spring up on lands of the best forest types — in valleys containing more or less luxuriant hardwood forests and on the slopes of these valleys covered by the same forests (so-called »Kulturstufe und tiefere Montanstufe»). The farm homesteads on more infertile ground and higher up on the mountains are of a later period; but even in these higher districts, civilization has, as may be inferred from the topographical conditions, selected the best forest types available. Here and there my observations lead me to believe that the prosperity of the people and their general standard of culture stand in definite relationship to the conditions in the different districts with regard to forest types, although the different linguistic territories of Switzerland are not directly comparable with one another. In the points discussed here, considerably different conditions, unknown to me, seem to prevail in the most continental parts of the Middle Alps (see Braun-Blanquet 1917, p. 5). The same is, perhaps, true in districts with a strongly suboceanic character.»

The above discussion has undeniably revealed an extremely productive field for investigation, which will enable us to appreciate, from an important, but hitherto comparatively neglected point of view, how ancient civilization, cultivation and intellectual culture have developed up to the present time, in different countries and different districts. From the practical point of view, also, it will furnish guidance of very great value in any future activity in connection with these matters. The unequal distribution of fertile land has, moreover, led to an investigation into the circumstances which, in those natural conditions generally prevailing, have brought about this uneven distribution of fertile land — a subject to which hardly any attention has hitherto been paid. This research field seems to disclose great possibilities.

The Use of Forest Types in an Examination of Changes in the Quality of Localities.

Localities are not for ever of a permanent fixed character. Their present state is only relatively stable. There are on record, for instance, a number of cases in which a forest soil under management has changed in respect of its yield capacity.

The commonest phenomenon of this type in Finland is swamp-invasion. In the northern countries invasion by swamp conditions has been taking place on a very large scale. According to the General Survey conducted by Y. Ilvessalo, peat-moors, all of which have grown up, as is well-known, during the post-glacial era — within a period of less than 10,000 years — take up 35.7 per cent of the total land area of Finland. It appears from the investigations by Backman, extending over many years, that at least 95 per cent of the moors of Central Ostrobothnia would now be natural forest land, had they not been invaded by swamp conditions, and his investigations indicate a similar figure for those districts of the Carelian Isthmus most extensively invaded by swamp. It may be regarded as certain that the bulk of the peat-moor land of Finland is forest land invaded by swamp, and invasion of dry land by swamp is still going on. On the other hand, the investigations of LUKKALA (1920) in particular have shown that, on large peat-moor regions, the moisture conditions are undergoing for some reason or other incessant changes. Thus on a given area of moor, *Sphagnum* may grow rapidly and before long such an area of moor may have grown above the adjacent parts, to which the water will then flow and render them water-logged. The surface of the peat-moor growing in height may reach the level of the upper surface of the barrier dividing the moor from dry land, and when this is overflowed by the waters of the peat-moor, the result is that the dry lands, below the level of the moor's surface, are gradually turned into moor, whilst the peat-moor the water of which has found an outlet, becomes drier at the surface and begins to grow forest in those cases, where it has been devoid of wood or its forest growth improves in those cases, where it is already forest-clad, — in accordance with the moor and forest type succession series indicated in the table between pp. 68 and 69. As has been explained above, a moor can by drainage be made to grow forest or to improve its forest growth, the ultimate limit of improvement being the corresponding type of forest land free from swamp-invasion, while in cases, where drains become clogged and the moor begins to suffer from excessive water, the development from type to type takes a reverse course.

Many circumstances indicate that, in the northern countries, apart from the fact that vast areas of dry forest land have been invaded by swamp, impoverishment of the soil has taken place on certain sites, partly due to the fact that rain water, and water melted from snow percolating through the soil, carries with it materials in solution and very fine particles in the form of silt, and partly to the fact that water flowing along the surface carries such material from land higher up to low-lying ground, to watercourses and thence to the sea. In our climate these processes are scarcely counterbalanced by the phenomena of weathering, which give rise to new food materials for plant-growth. As a matter of fact, the investigations of AUER, carried out in 1922 in the mountain region of Kuolajärvi and Kuusamo, have shown that such moors there as are ancient forest lands invaded by swamp, contain in

their bottom layers better kinds of peat than the kinds of peat originating nowadays on forest soils invaded by swamp conditions in the districts in question. This fact seems to indicate that on the mountains of Kuusamo and Kuolajärvi, impoverishment of the soil has taken place. Likewise the latest investigations of PALMGREN (1925) carried out in Ahvenanmaa tend to prove that the higher parts of the main island are nowadays more infertile than they probably were, when they rose from the sea, and PALMGREN has previously (1912) pointed out that the coasts of the Gulf of Bothnia are more fertile than the interior of Ostrobothnia. In agreement with this view is the fact that in hilly and mountainous districts, the tops of the hills and mountains are on an average the most infertile parts and the slopes and the valleys the most fertile ones. This phenomenon is in evidence on a large scale in the case, pointed out above, of the watersheds of Finland, especially the larger watersheds, which are more infertile on the whole — sometimes even very markedly more infertile — than the ground in proximity to the watercourses. The grass-herb forest centres described above are located alongside watercourses and on the coast.

Many factors may tend to accelerate to some extent these processes which are in reality very slow. The felling of trees, in so far as this is confined to utilizing the trunk, is probably of little consequence in this connection, because the wood of the trunk does not contain the so-called mineral ash in any great quantity. Fires have a greater influence, especially if they take place in very dry seasons, and reach to any great depth. Trees extract from the soil through their root-systems, partly even from a considerable depth, mineral matter, which is partly stored in the roots, trunk and branches and partly returned in the form of leaves and other fallen material to the ground. This material, as the result of burning by fire, is turned into ashes, containing mineral matter which is easily washed away by rain water and water melted from the snow. As an outstanding example of this may be mentioned an operation, which tradition records as having been practised in Ostrobothnia in olden times, namely that of burning the forests, especially the State forests, in order to improve the growth of the grass on the adjacent moors, because the mineral ash material produced by combustion was to a great extent carried by the water from the forest land to the moors, which, being as a rule, at lower elevations, were fertilized in this way. Even more impressive than the influence of forest fires is that of burning-over for cropping purposes, because here a further factor must be taken into account, namely the fact that as many crops are raised in succession from the ground burned as it is capable of producing, nothing, however, being done in any way to fertilize it. The continuous use of forest lands as pasture and enclosed pasture has much the same effect, wherever they are not fertilized or otherwise managed rationally. Burning-over for cropping purposes and grazing in Finland have largely supplemented each other, for it is usually those areas and forests burned-over for cropping purposes which have generally been used as pasture lands, until the time has come for them to be burned-over once more for cropping purposes, while in many places forest has been burned-over for the sole purpose of improving the pasture lands, since the ash material produced on the ground by the burning, enhances the growth of grass and herbs on the area for many years. As a matter of fact, some of the investigations carried out by Multamäki in Savo and Carelia seem to indicate that certain intermediary forms between MT and VT, occurring in districts, where burning-over for cropping purposes has been much practised in the past, were originally represented by a distinct *Myrtillus* type. Owing to continuous burning-over and grazing, however, that type has deteriorated towards the *Vaccinium* type. To what extent this impoverishment of the soil here and there has gone on with the *Vaccinium* type as its result, in other words, how large an area of the forests of the *Vaccinium* type occurring in crop-burn regions, could possibly have been of the *Myrtillus* type originally, is a question which requires further and closer investigation. According to the investigations of Palmgren (1915), the grass-herb forests of Ahvenanmaa have been changed in a natural way as a result of grazing, into spruce forest, and so in course of time also into a forest type inferior to the original 'wood-meadows' (ST). The fact that in the conifer regions of Ahvenanmaa numerous areas occur representing the 'wood-meadow' vegetation is, in the opinion of Palmgren (1925), most naturally explained by assuming that the 'wood-meadow' type was formerly more widely distributed even on the higher lands, which first rose from the water. — The utilization of forest litter, formerly a very common practice in Central Europe, which obviously has impoverished a great many forest soils permanently, has been out of the question in Finland.

By furthering the formation of raw humus and raising the acidity of the soil in general, the spruce is the species amongst our forest trees which tends to hasten to some extent the process of impoverishment and deterioration going on in our forest soils, although it is fortunately true, that the process appears to be a very slow one. The *Hylocomium-Myrtillus* type prevailing over extensive areas in North Finland — according to the General Survey conducted by Y. Ilvessalo, on 9.9 per cent of the economically productive forest land of the Province of Oulu — which is almost exclusively occupied by spruce forest of very slow growth, although birch and some Scots pine are met with, seems to represent rather a degenerate type of forest soil, which has, in the presence of certain special conditions, deteriorated under the influence of the spruce. At least it may sometimes be observed that the presence of the spruce on rather dry heaths has resulted in the appearance of *Hylocomium* growth in patches and even continuously in those places, where the growth of the spruce is more dense. — In Central Europe, as is well-known, the common opinion is, that spruce forest generally impoverishes the soil. To what degree the raw humus forests, rich in *Myrtillus nigra*, especially of the hardwood regions of Central Europe, might represent to some extent the outcome of a process of degeneration, is a problem worthy of thorough study on the basis of the forest types. The problem, into which degeneration type every original forest type passes, ought also to be specially investigated.

As some compensation for the impoverishment of the soil described above, one fact may be mentioned, to which reference has already been made, namely that the low-lying lands and the valley-bottoms have benefited at the expense of the higher lands. In this connection another very important fact may also be mentioned, namely the rise in the land taking place round our coasts, a phenomenon the phytogeographical importance of which has been emphasized by Palmgren (1913, 1925). Because of this phenomenon, new land has continually been exposed on the Finnish coasts, which has not been leached out and to it in course of time fine earth material has been transported from higher ground. — The view is commonly held, that broad-leaved trees, especially the so-called hardwood trees — in contradistinction to the spruce — improve the soil. It would be important to elucidate to what extent — up to what limit — this improvement of the soil can possibly proceed.

Afforestation of bare ling areas is also held to be one method of improving the forest soil. In some parts of South Sweden, for instance, it has been possible to turn ling areas into forests of as good a type as the OMaT, solely by afforesting them. This is a matter which obviously calls for further investigation. With regard to quality and biological value, ling heaths show great differences. The ling areas of South Sweden were originally clothed with forests which obviously represented widely different forest types. At different periods, for the most part centuries ago, the forests were devastated, and owing to burning, grazing, etc. the land has remained bare. On such burned, isolated, areas the ling very easily gains the upperhand, even on good ground. Examples which illustrate this fact to some extent, are the ling vegetation and grass plots rich in ling that are met with on bare hillsides, scorched by the sun in inhabited countries. These, to be sure, have not been burned, but have been grazed continuously, and actually represent the OMaT and OMT. When ling areas are afforested, the original forest types, wherever no impoverishment of the soil has taken place during the time the ground has been exposed, re-establish themselves after having been in a more or less latent state during the whole time that the land lay bare. It may be pointed out that it is a hopeless undertaking to attempt to change by ordinary sylvicultural operations the ling heaths proper, i. e. bare ground of the CT, of Finland as well as those of Norrland, into MT, OMT or even OMaT. This fact quite clearly shows that not every ling area can be turned into a forest of the OMaT, but that there are wide differences between one ling area and another.

In recent years much attention has been attracted by the Bärenthoren Forest in Anhalt, Germany, the yield capacity of which is claimed to have been greatly improved by the so-called »sustained management» (Dauerwaldwirtschaft). Aaltonen, however, has shown (1924) that no reliable record exists of the forest type condition that prevailed in this forest region at the time, when the rational management was started in it. Accordingly, there is no reliable basis for the assessment of the presumed improvement of the soil, and the more probable assumption is that the improvement in the yield capacity is due to improvement in the quality of the stand, and not in the quality of the locality. [1]

The object of these remarks is not to belittle the significance which sylvicultural operations may actually have in improving and conserving the growth capacity of the soil. Any measure by which, in our climate, the acidity of the soil is lessened may, no doubt, be considered an advantage in this connection either directly or indirectly, and worthy of commendation, above all, those measures which promote the formation of well-decomposed forest humus. The results thus attained need not be very great, but changes of this nature probably range only within the limits of one and the same forest type at least in the climate of North Europe. In practice, however, even these results are not to be despised, for even a small rise in the yield of a forest may mean a good deal, even if it persists only as long as the measure adopted is in force, since the areas are often large. Similarly, the avoidance of all those measures which further the impoverishment of the soil, such as too intensive burning, the employment of forest as pasture, without corresponding fertilization, etc., may be of the greatest importance. Such procedure is the more to be commended, as it agrees to a large extent with the measures adopted for raising the quality of the stand, which must always be the aim and object of rational forestry, especially in North Europe, because it is

[1] Since the above was written E. Wiedemann's remarkable investigation »Die praktischen Erfolge des Kieferndauerwaldes» has been published. It must be considered, that it has demonstrated, that the idea of the excellence of the »sustained management» was exaggerated.

from this policy, as well as from the drainage of moor lands or of lands under the action of swamp-invasion, that the most tangible results are to be expected. These measures will be of still greater significance, should the post-glacial impoverishment of the soil, pointed out above, prove to be true.

The problems discussed in this chapter are of such importance that their most careful objective investigation is indispensable. Just as the system of moor and forest types provides a more exact basis for investigations into water-logging and drying-up of moor soils as well as into the phenomena of invasion of forest lands by swamp conditions, so there is no doubt, as is evident from the foregoing, that it furnishes a criterion and index for assessing the amelioration and deterioration of forest soils, with regard to which widely different views are held in the meantime.

The International Aspect of Sylviculture in the Light of Forest Types.

At the commencement of this treatise (p. 19) it was mentioned that Prof. HEINRICH MAYR, of Munich, had been striving to evolve an international system of sylviculture. What follows is a discussion of the question: — How far is an internationally uniform system of sylviculture possible of realization?

It has been mentioned above (p. 12) that KÖPPEN, setting out from the phytogeographical point of view, has recognised a number of climate types, each of which is represented in a certain part, and most of them in several parts, of the world. Thus it is possible to distinguish regions which, broadly speaking, are climatic and phytogeographical regions at the same time, and regarding which it may be further asserted with a high degree of probability that they can also be differentiated from the point of view of soil science.

From the point of view of forestry the line of demarcation between the oak climate and the birch or conifer climate in Europe is an important boundary line. In the territory of the oak climate, the mean temperature is +10° C. or more for at least 4 summer months and in the region of conifer climate for at least 3 summer months.

In the region of oak climate the hardwood forest types are predominant or at least so prevalent as to affect appreciably the general character of the forests. The *Impatiens-Asperula*, *Asperula*, and *Oxalis* types, as well as others closely allied to them and certain other less closely allied types, are met with in this climate in Europe. Wherever moist moss-forests are encountered, they are specially represented by a number of forms belonging to the collective *Myrtillus* type; whereas the region of conifer climate is characterised by the moist moss-forest types and the moss-forest types closely related to them, viz. by the *Myrtillus* type and its northern substitute, *Hylocomium-Myrtillus* type, also by the *Oxalis-Myrtillus* type and the *Pyrola* type as well as by the *Fern* type and the *Oxalis-Majanthemum* type on lands bordering on grass-herb forests; finally the moderately dry moss-forests are characterised by the *Vaccinium* and *Empetrum-Myrtillus* types. Dry moss-forests proper are met with in both regions, but much more frequently in the moss- or conifer forest region, where also spruce and pine peat-moors are far and away more frequent than in the hardwood forest region, where their proportion is rather limited. — LINKOLA has shown (see p. 58) that the percentage of Chamaephytes for these regions is so far characteristic that in the hardwood forest region it is below 10 per cent, but above that in the conifer forest region, and that it rises more and more towards a colder climate.

Regarding the soil it can be stated that the hardwood forests are characterised by mild, non-acid or slightly acid and loose forest humus, and relatively slight leaching of the soil, the heath forests by rather acid or strongly acid raw humus as well as by a more or less strong leaching of the soil, which results in special leached and enriched soil horizons. They probably differ considerably in regard to the quantity of the plant nutrients. At any rate the soil tests made in our country indicate that this is so.

With regard to tree species, these regions differ considerably from each other in Europe in that in the hardwood forest region the so-called hardwood tree species, the oak, beech and hornbeam etc. have been particularly prevalent in the natural state, whereas in the region of moss-forests, conifers, especially the spruce and pine (larch, *Pinus cembra*, etc.) as well as the broad-leaved trees with light seeds (birch, aspen, etc.) are the forest-forming species of tree.

The line of demarcation between these two regions is not sharply marked. On the contrary, its position is to some extent arbitrary, but it may be taken that it runs approximately through the southernmost part of Finland, the hardwood character being most pronounced in Ahvenanmaa. This character is also present along the whole of the south coast, where the oak occurs as a natural tree species, the hardwood forests, and forests resembling them, being so numerous as to furnish those districts with a distinctive feature of their own. A corresponding line of demarcation is, of course, met with also in the mountains of Central (and Southern) Europe. According to Linkola it is situated on the Swiss Alps at an altitude of 4,750—5,080 feet. On the Central Mountains of Germany it lies somewhat lower, at an altitude roughly of 2,600—3,000 feet.

These two climatico-phytogeographical regions fall further into several sub-regions. It has been explained above that, with respect to climate, North and South Finland differ quite considerably from each other and particularly with regard to the length of summer, with regard to the mean temperature of the warmest month, and also so far as the forest types are concerned. North Finland is characterised especially by the *Empetrum-Myrtillus* and *Hylocomium-Myrtillus* types, in addition to which the *Geranium-Dryopteris* and *Cladina* types occur in the main in North Finland. Finally, the *Vaccinium* and *Calluna* types are represented there by their respective sub-types, whereas South Finland is characterised by the *Myrtillus* type, which is only to a small extent met with in North Finland, by the *Oxalis-Myrtillus*, *Pyrola* and *Fern* types as well as by some other grass-herb forest types (*Aconitum* and other types). The line of demarcation between these two regions has not been

very closely investigated, but probably it should be drawn in the vicinity of 66° N. Lat. The corresponding line on the Swiss Alps, according to Linkola, is generally at an altitude of about 5,900—6,600 feet, corresponding approximately to the 20 per cent 'biochore' of the Chamaephytes.

This is not all, however. These regions also fall, in respect of climate and at the same time in respect of their forest types and their vegetation in general, into sub-types from west to east, owing to the climate becoming more and more continental from the Atlantic away towards the east. As the author has previously shown (1909, 1916, 1921) the following successive climatic types can be distinguished in the climatic region of conifers or the region of moss forests, proceeding from the most maritime to the more continental climate: — Oceanic, Norwegian, Fenno-Scandian, North Russian, Central Siberian and, as the most continental one, East Siberian, and the Kamchatkan climate type, each of them obtaining within its own well-defined region. They have their counterparts in North America as well as on mountains further south. [1]

[1] What is known for the present of the problem of the relations obtaining between climate, soil and vegetation may be laid down as follows: —

Climate acts as the most universal locality factor. Parts of the continents characterized by the same climate type are populated by a vegetation the general biologico-ecological character of which is on the whole the same. Owing to the climate, and the vegetation determined thereby, in the regions belonging to each climate type, the soil-forming processes — weathering, leaching by water and formation of humus, in the first place — are identical in their main features, though varying locally.

Those differences which are independent of the soil and climate, at least of the present climate, such as differences in the topographic conditions, bedrock, kinds of soil, etc., bring about in regions of the same climate type, especially where the climate and the soil are so favourable to plant-growth as to make the vegetation covering complete and to call forth a struggle for room between individual plants, a differentiation of the local vegetable covering, characteristic of those regions, i. e. the component plant species marshal themselves into regular plant associations, which recur with a considerable degree of resemblance (analagous associations, if the migration of species has been prevented or has not yet reached completion) in diverse places. The vegetation types characteristic of a climatic region do not cease abruptly at the boundaries of the climatic region, but encroach a greater or less distance on to the

These regions and their respective sub-regions, which are also definitely demarcated by their forest types and forest type groups, determine very precisely the general character of the sylviculture in the different regions, above all as regards the species of tree grown. In all the regions, for instance, where the same kind of climate prevails, the same species

contiguous regions, with the result that the boundaries of the climatic regions are not phytogeographically well-defined.

Vegetation — forests, open plains of grass land, etc. — influences to a certain extent the local climate and still more decidedly the processes going on in the formation of the soil, which in turn may have a repercussive action on the vegetation. Under certain conditions — take swamp-invasion of forest lands for instanse — the influence of the vegetation on the formation of the soil and even on the local climate may be quite marked, calling forth in the long run, especially in the case of the former, changes which, although originally of a secondary nature, act as primary locality factors when considered from the point of view of the present. (see p. 28.)

Chance (see PALMGREN) exerts a very great influence on the details of the floristic composition of plant associations, giving rise to fluctuating variations, but on the principal features of the vegetation its influence appears to be rather restricted. Its influence immediately increases, wherever the struggle between the individual plants is disturbed, or, in extreme cases, it is wholly absent, so that the occurrence of the plant species is limited only by their respective capacity to thrive on the different localities. Complete absence of any struggle, however, occurs very seldom in forest regions proper under natural conditions — only on places laid bare by fires kindled by lightning, on new land due to an elevation of the coast, on river alluvium, on soil newly exposed by the abrading and eroding action of water along shores of the sea and banks of rivers, and so forth. It occurs much more frequently in cultivated districts. On the whole, however, even in cultivated areas a struggle is going on, in spite of interruptions, nearly everywhere, although the final stage of the struggle is more seldom reached. The result of this struggle is that the constitution, even of the plant associations produced by cultivation, may be nearly or even quite as regular and characteristic as that of original natural plant associations. Disturbances in the state of equilibrium which results from the struggle between plant individuals, bring about greater or less deviations from normal also in the active processes of soil-formation.

The more or less unstable plant associations resulting from interruptions and disturbances in the struggle between plants, due to cultural operations by man, tend to develop towards the plant associations, which would prevail under natural conditions. All the forest vegetation associations and modifications of these which belong to the same forest type, develop towards their respective natural forest associations.

of tree can be grown — independently of what part of the world is being considered. So far as the species of trees are concerned, forestry may be internationalized to the extent that it may be said, that, broadly speaking, the same species of trees may be grown in regions of the same climatic type (or sub-type), however widely separated they may be over the globe, whilst in regions of different climatic types, the composition of the forests will always differ widely. Further, wherever the same species of tree thrives in several of these regions or sub-regions, its treatment will differ more or less in the different regions, according to the forest types. To put it more concisely, sylviculture varies from place to place, as is apparent from the foregoing, according to the quality of the locality. The latter, which is expressed by the resident forest type, determines the tree species (even the exotic tree species, where they are cultivated), sylvicultural treatment and yield.

Within the range of similar climate types characterized by various forest types and within the range of the same degree of quality of locality, as indicated by the forest types, it therefore appears to be possible to place forestry everywhere on a common foundation and to treat it from an international point of view. On such a basis it further seems to be possible to generalize as common international methods of procedure, all those sylvicultural methods which have been developed or are being developed in the various local districts, and which have led or are leading to satisfactory results. At the same time it should, however, be noted that the market conditions of the different regions will always furnish forestry with local features, since these conditions are vitally important in deciding which of the methods of treatment possible from the biological point of view, are economically advantageous, and how near it is possible to approach to the sylviculturally and biologically most productive method of treatment after first taking the economic point of view into account.

The above statements hold good not only in forestry, but clearly also in plant cultivation in general, as well as, more or less indirectly, in those industries which are founded on plant cultivation or depend upon it. Whilst agriculture in the southern half of Finland — to give one example — consists mainly in growing crops, in North Finland, where the areas under the plough are relatively small, as well as in corresponding districts elsewhere, for instance at corresponding altitudes in the Central European mountains, agriculture consists for the most part in the cultivation of meadows. In the Central European hardwood forest regions, where the proportion of land suitable for cultivation is incomparably greater than in the southern half of Finland, wheatgrowing takes precedence over the growing of other crops.

The general conditions of nature and the economic life dependent thereon, as has been shown above, also set their mark in turn on intellectual culture. Just as it cannot be regarded as mere chance that Oriental culture originated and developed in the region of Tragantha climate, poor in forest and more or less rich in grass; that Graeco-Roman culture originated and developed in the olive climate region of the Mediterranean, characterized by evergreen forests or bushes with broad, coriaceous leaves; and that Occidental culture originated in the Central European oak climate region with robust deciduous hardwoods; so it also seems probable that in the future, in spite of conflicting currents, economic culture and in its wake intellectual culture, will retain certain peculiar features, owing to natural differences between the different regions. These features may even be somewhat accentuated, so as to become more real than ever before, in so far as economic competition compells the nations to develop their resources to the utmost. The natural conditions of each country set definite limits to economic activity therein, and the state of economic and intellectual culture of every nation depends decidedly on how well a nation is acquainted with the natural resources of its own country and how effectively it knows, how to utilize them.

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