FOREST TYPES
AND
THEIR SIGNIFICANCE

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Preface.

The theory of forest (site) types can be traced back to the grouping of wooded lands, used of old in the forest-economy in Finland, into a few natural, and popular collective units, and to the more exact analysis and definition of this grouping on the plant-topographic basis developed by Professor J. P. Norrlin.

The ideas developed in the present publication derive from the years 1904—1906, during which time the undersigned, as a student in the Evo Forestry Institute, tried to apply to forestry the plant-topographic knowledge he had gained in his previous botanical experience. The first, more detailed study on these lines was the »Ueber Waldtypen» (Acta forestalia fennica 1 and Fennia 28), published by the writer in 1909.

This publication contained the most important ideas of the Forest Type Theory, partly handled in more or less detail, and partly only outlined as a future programme. This provided the basis for rather intensive work in Finland during subsequent years, whereby the ideas developed in 1909 were confirmed in their essentials, while new, important tasks for study presented themselves. The results of these later investigations are set out in the publications »Metsätyyppiteoria», »The Theory of Forest Types» (Acta forestalia fennica 29) and »Wesen und Bedeutung der Waldtypen» (Tartu Ulikooli Metsäosakonna toimitused 1926 and Silva Fennica 15).

The writer was unaware that ideas on the same lines had also arisen in Russia, and for this reason the Finnish study of forest types, which has gone on quite independently of that of the forest types of the Russians, Morosow, etc., is essentially of other content than the latter. On the other hand, the Swedish forestry-geobotanical studies were known to the undersigned, insofar as they were included in articles by Lundström, Nilsson etc. The theory of forest types, in the form it has acquired in Finland, is, however, based to a very small extent on these Swedish predecessors.

Helsinki, January 1943.

A. K. Cajander.

Introduction.

In the cultural life of today, two mutually contradictory tendencies are discernible: specialisation and its opposite, generalisation and the synthesis of results.

The necessity for the former is directly due to the limits restricting human life and human skill. The more comprehensive the quantity of human knowledge grows, and the more human activities are developed and varied, the more impossible it is for anybody to master, in detail, the sum of human knowledge and the full extent of human activity. The learned of olden times had the command of the knowledge of their time in all its comprehensiveness, whereas the learned of the present day become absorbed in special questions which look negligibly small compared with the total of things known—not, however, because the clarification of these small details represents the goal of the scientist's thirst for knowledge, but because, on the whole, it is impossible to further human knowledge without exact studies in detail. A scientist of today, wishing to perform exhaustive scientific investigations in the different fields of science, will nearly always soon realise the impossibility of such an enterprise: his work easily becomes superficial, dilettante. Similarly, an individual worker in a modern manufacturing plant is capable of performing only a certain task; should he want to make himself acquainted with all the different details of work in a mill, he would be unable to master any one of them properly. In a modern office, each clerk knows in detail only his own special line. Division of labour and specialisation are what our time requires.

Specialisation alone does not, however, bring the goal nearer to us. It is not enough that a mill employs a number of specialists, each in command of his special, small section of work: on top of this, it is necessary to have a joint organising management that combines the work done by specialists into a harmonious, well-ordered whole. Neither is the human spirit satisfied with mere knowledge of detail, no matter how profound that detail is. The human spirit strives, now as hitherto, after wider fields. Its highest need is the combination of knowledge of detail into a uniform whole, and in particular it is desirous that the leading principles of this profusion of knowledge should be thoroughly investigated. And just as a new attainment, a new invention or discovery in the fields of practical activity, can have very widespread, revolutionary effects because different spheres of activity overlap so much — as for example the introduction of electricity and motors — so are the different spheres of knowledge so closely connected mutually that a result attained in some special line may, in a decisive way, alter prevailing ideas in the most varied branches of knowledge — a good example being the modern status of the science of heredity.

The question I have chosen for my special study here is not revolutionary in its character. It is one of the special problems of forestry and forest management. Yet it is one of those, the solution of which, in its applications, may affect even relatively distant spheres of knowledge and practical activity, and thus I venture to raise it here, in spite of its special character.

The Significance of the Natural Classification of Forest Sites and the Classification Methods Hitherto Utilised.

Forests, whether they are completely natural or subject to organised management, are of widely different kinds. Already at an early stage the necessity was felt of having them classified, according to their yield, in certain main classes for silvicultural purposes, and along with the developmens of forestry this necessity has increased. The yield classes are usually called site quality classes.

The classification is, principally, of two different kinds: either the forests themselves are classified according to quality, or the sites (forest lands) where they grow are classified. The former are »Stand quality classes» (»Bestandesbonitäten»), the latter »Site quality classes» (»Standortsbonitäten»).

When classifying forest growing sites, the purpose is to combine those having the same or approximately the same yield capacity, and to separate into different classes those whose yield capacity is widely different.

When classifying existing forests, special attention is paid to the actual yield of the forest growing on that particular site. The yield can vary a great deal depending on the density and on clearings, silvicultural condition etc., and it can be considerably smaller than a normal yield, i.e. that of a forest of normal density and otherwise normally developed, which can be regarded as a standard for the yield capacity of the site in question and thus also as a criterion of the »Site quality class» (»Standortsbonität»).

Site quality classification is of absolute necessity in organised forest management as it gives a basis for all forestry calculations concerned with yield and profit. Only an existing quality classification makes it possible to estimate which species of tree on a certain site, how long a rotation, which method of management, etc., is the most appropriate one — all of them questions not only of economic importance to private individuals, but also of great national economic value.

In addition, a scientifically justified classification of sites is equally important for purposes of forest management and forestry statistics.

The method of establishing site quality classes has mostly been rather schematic. H. Cotta, for instance, recommended in his classical work »Systematische Anleitung zur Taxation der Waldungen» (1804) the establishment of a hundred classes so that ground yielding no timber at all would be represented as 0 and the best possible ground as 100. A contemporary of his, G. L. Hartig again advocated in his work »Anweisung zur Taxation und Beschreibung der Forste» (1795), which has become equally classical, the restriction of the number of classes to three — good, medium and poor. As far as is known, the most general method in Central Europe is to use five quality classes (»Standortsbonität»).

A classification of this kind is, however, in the highest degree subjective. It is almost exclusively based on the personal considerations of the classifier. Through prolonged practice and continual observation of felling results actually obtained the classifier, it is true, learns to be relatively consistent in establishing site quality classes. But classifications, based on the experience of different classifiers, may differ widely from each other, and a method of this kind, totally dependent on subjective estimation, gives no reliable aid to a young inexperienced classifier.

Site classification has also been done on another basis. Attempts have been made to combine the sites into natural groups on the basis of some easily discernible qualities. As an example it may be mentioned that Dr. A. G. Blomqvist, for many years head of the former Forestry College at Evo, in his work called »Tabeller framställande utvecklingen af jemnåriga och slutna skogsbestånd av tall, gran och björk», divided Finland into three zones from South to North, and in each of these zones he distinguished three site quality classes so that the lowest class constituted sandy and stony soil, where pure pine woods are common and where pine, thanks to its modest demands is at all events the most important tree species; the middle class comprised fresh soil where, in addition to pine, spruce and birch thrive, and which in old Finnish land division maps was termed land suitable for burning-over for crops; the best class comprised the most fertile sites suitable for cultivation, the soil of which was mostly fine silt or clay.

For the purposes of practical forestry, the following site quality classification was widely used in Finland:

Dry solid forest land with a cover of raw humus
Moist solid forest land with a cover of raw humus
Low-lying forest land
Swampy forest land with the character of wet spruce-broadleaftree peat-moor.
Swampy forest land with the character of wet pine peat-moor.

This kind of site classification can, no doubt, in certain circumstances, lead to fairly satisfactory results. Particularly with regard to the Southern half of Finland, this classification was quite natural and, consequently, in frequent use. It is, however, far from accurate enough, since the »moist solid forest land, for instance, can include sites of widely varying yield, and in particular, the »low-lying forest land» is extremely indefinite. The weak points of a site classification like this, based on popular conceptions, show up more distinctly, if we try to apply them to larger territories. For instance the South-Finnish classification shows its weakness if applied to Lapland or Central Europe — but its fundamental principle, aiming at natural classification of sites, is no doubt correct.[1]

After Liebig had proved the extremely great significance which the chemical composition of soil has for the nourishment of plants and their existence generally, the hope arose that the question of quality classification of soil — actually of arable soil primarily — could be solved by means of chemical analysis of the soil. These hopes have, however, not been fulfilled. This is partly due to the fact that chemical analyses are defective; it is difficult to extract the plant nutrient materials from the soil in exactly the same proportions as they are available for the living plants in nature. The failure was also partly caused by the fact that the plant nutrient materials of the soil are not the only factors affecting the life of plants. The latter is naturally also affected by the physical qualities of the soil, its aeration, etc., which often play quite as important a part as the chemi-

[1] The methods of Th. and R. Hartig have a certain similarity in fundamental principle:

Th. Hartig: Vergleichende Untersuchungen über den Ertrag der Rotbuche im Hoch- und Pflanzwalde, im Mittel- und Niederwald-Betriebe, nebst Anleitung zu vergleichenden Ertragsforschungen. Berlin 1847.

R. Hartig: Vergleichende Untersuchungen über den Wachstumsgang und Ertrag der Rotbuche und Eiche im Spessart, der Rotbuche im ostlichen Wesergebirge, der Kiefer in Pommern und der Weisstanne im Schwarzwald. Stuttgart 1865.

R. Hartig: Die Rentabilität der Fichtennutzholz- und Buchenbrennholzwirtschaft im Harze und im Wesergebirge. Stuttgart 1868.

cal qualities of the soil. On top of that, the climate must also be considered as an important growth factor of very varied influence.

The attempts to define the yield capacity of the soil on the basis of chemical soil-analysis did not, however, pass without leaving any after-effects. As early as 1871 Schütze[1], who studied six North-German forest-soils of different quality classes, was able to ascertain that the estimated quality class was clearly reflected in the chemical composition of the soil. Soil analyses showed that soils estimated to belong to quality class I, contained phosphoric acid, lime, magnesia, potassium and sodium in bigger quantities than those belonging to quality class V, and that the phosphoric acid and lime content of the soil showed an almost regular increase from the worst to the best quality classes. — Later on, von Falkenstein[2] proved that also the humus, and especially the nitrogen content is of decisive importance.

In Finland, Y. Ilvessalo[3] on the basis of roughly 600 soil analyses made by Valmari, calculated the correlation coefficient obtaining between the normal growth of pine-woods and certain qualities of the soil, and ascertained that the correlation coefficient was:

with regard to nitrogen	0.736 ± 0.056
» » » lime	0.612 ± 0.069
» » » potassium	0.214 ± 0.091
» » » phosphoric acid	no correlation

For these analyses, the samples of soil were taken from normally developed, medium-aged stands of the kind mentioned, the growth of which was determined with exactitude, situated within the Southern half of Finland. — According to the figures, the yield capacity of the South-Finnish forest-lands are to be regarded as correlated, primarily, with the lime and nitrogen content of the soil.

Studies of this kind show clearly that the qualities of the soil, in this case the chemical qualites, have decisive influence on its yield capacity, some of them more so in certain conditions, some of them less. Liebig

[1] W. Schütze: Beziehungen zwischen chemischer Zusammensetzung und Ertragsfähigkeit des Waldbodens. Zeitschr. f. Forst- u. Jagdw. 1871.

[2] K. Vogel von Falkenstein: Untersuchungen von märkischen Dünensandböden mit Kiefernbestand. Intern. Mitt. f. Bodenkunde 1912.

[3] Y. Ilvessalo: Ein Beitrag zur Frage der Korrelation zwischen den Eigenschaften des Bodens und dem Zuwachs des Waldbestandes. Acta forest. Fenn. 25, 1923,

(1855) had already enunciated a so-called Minimum Law, according to which the yield capacity of a soil is dependent on that plant nutrient material the proportion of which in the soil is least. Wollny (1897)[1] extended the law to cover also the physical qualities of the soil. Having regard to the fact that one of the growth factors might be present in too great a strength, Vater[2] (1908) amended the law to state that the yield capacity depended on the relatively most unsatisfactory quality of the site or, in other words, those of Schimper, the famous geo-botanist, on the quality most distant from the harmonic optimum either in a plus- or minusdirection. It would thus be most appropriate to speak of the *Law of Harmonic Optimum.*

But although a certain correlation can be established between the yield capacity of a site and its physical and chemical qualities, there is a long way to go to achieve site classification on this basis. And again, although a distinct correlation can be established between the yield capacity and the growth factors of the soil, investigations — particularly those of the school of Mitscherlich — have shown that the growth factors interact in their influence, even to the extent that plentiful occurrence of one of them can make up for another less abundant. Thus, there can never be any question of a single »minimum factor» but what counts is the combined influence of all the growth factors, even if one or several of them may be of greater importance than the others. It is to be noted that the growth factors vary a great deal in nature, independently of each other, and thus almost an innumerable number of relationships between them is possible. When going over from one climatic region to another, these relationships assume new significance from the point of view of the existence of trees and of plants in general. And, above all, these mutually almost independent growth factors continually vary, in respect of the intensity of their influence between certain degrees of intensity. On the basis of growth factors only, no natural site classification, no natural quality classes of site can be determined.

If, however, the natural limits of quality classes could first be determined by some other means, even in a general way, it would hardly fail to

[1] B. E. Wollny: Untersuchungen über den Einfluss der Wachstumsfaktoren auf das Produktionsvermögen der Kulturpflanzen. Forschgn. auf dem Geb. der Agrikulturphysik. 1897.

[2] H. Vater: Bodenanalyse und ihre Anwendung in der Forstwirtschaft. Thar. forstl. Jahrb. 1908.

make possible the definiton of these classes more exactly on the basis of their growth factors. As an analagous case, it may be mentioned that Köppen[1] in his work called »Versuch einer Klassifikation der Klimate vorzugsweise nach ihren Beziehungen zur Pflanzenwelt» (1900) divided the globe, according to the general features of its vegetation into several Climatic Regions, the nature of which was defined on the basis of purely climatic factors in such a way that climatically similar regions in different parts of the globe were grouped into the same types of climate. It should not be impossible to devise some similar method of arriving at types of site and quality classes of site.

When discussing the classification of sites, the immediate aim is, naturally, their direct classification, i.e. classification on the basis of the site qualities or of the so-called site factors. Should the aim of the classification, however, be to bring about a classification according to the yield capacity of the sites, the yield itself can, on equally good grounds, be used as basis for the classification. This procedure has actually been adopted especially when compiling so-called growth and yield tables, i.e. tables showing the growth and yield of pure and regularly developed stands of different species of trees. This normal yield, as is well-known, varies in accordance with different sites, so that a quality classification of sites, done in the proper way, is of course of the greatest importance for the compilation of yield tables.

Of basic significance, in many respects, in the compilation of yield tables is the so-called Strip Method introduced by von Baur[2]. According to Baur's own words, the general lines of this method are as follows:

»In the forest region for which yield tables had to be prepared, a sufficient number of sample plots were taken in regularly developed stands of all ages and representative of all kinds of sites, distributed as evenly as possible over the whole area to be investigated. On the assumption that the number of quality classes was to be five, at least 150 sample plots had

[1] Georg. Zeitschr. 1900, 3. 593—611 and 657—679. Cf. also A. K. Cajander: Zur Frage der gegenseitigen Beziehungen zwischen Klima, Boden und Vegetation. Acta forest. fenn. 21, 1921.

[2] Fr. von Baur: Die Fichte in Bezug auf Ertrag, Zuwachs und Form. Stuttgart 1877.

Fr. von Baur: Die Rotbuche in Bezug auf Ertrag, Zuwachs und Form. Berlin 1881.

Fr. von Baur: Holzmesskunde. Berlin 1860. Vierte Auflage 1891.

According to G. Huffel (Les arbres et les peuplements forestiers 1893, page 89), De Perthuis had already published a similar method about 1788.

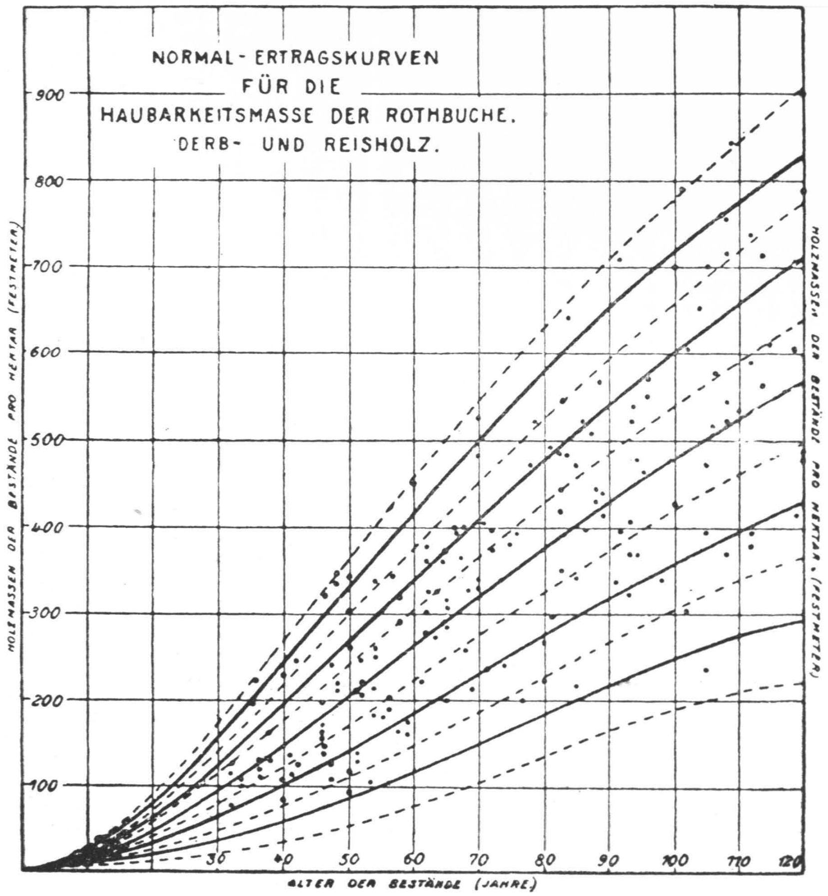
to be taken for each species of tree, with special attention paid to the best and poorest quality classes, so as to ensure that reliable yield tables were obtained.» »On completing the collection of data for all the sample plots in the forest... the timber volume curves were constructed for the site classes distinguished... For this purpose, a line drawn horizontally on paper (Abscissa on Fig. 1) was divided into as many equal parts as there were years in the age of the oldest stands considered (about 120). To each of the points of division on this line representing ages of the stands, vertical lines (ordinates) were drawn; on the ordinates, the mean timber volumes per hectare ascertained in each of the sample plots... were entered on a suitable scale and the terminals of the ordinates marked with small dots... The points on the ordinates (volumes) come naturally closer to each other when the stands are young, and with increasing age the points form an ever-broadening strip rising from left to right... In order to obtain the five yield curves for the five quality classes distinguished, free-hand curves are drawn, starting from the year 0, passing through or as near as possible to the highest and lowest points... The top line will thus express the *highest*, the bottom line the *lowest*, *average* limit of the volumes present at different ages of normal stands... Now we know the limits within which the yields of the stands vary from establishment up to maturity. As it is desirable that the graphic distances of the different quality classes should be equal, the space between the top and bottom line is now divided longitudinally into five sectional strips,... All the points, or stands, remaining within the top strip are considered as belonging to the first quality class, those within the next strip, to the second, and so on... The mean yield curves of each quality class are obtained by drawing the final horizontal lines through the middle of each strip.»

So as to have »the quality class of each stand defined quickly, accurately, and in a simple way», Baur used the average height of the stand to indicate the quality class. This height was defined for the different quality classes on the basis of a graphic method of a similar kind.

The strip method thus settles the question of quality classes in a surprisingly simple manner. But even a superficial examination will show that this method does not hold good when criticised scientifically and that, adapted to practical purposes, it cannot lead to satisfactory results. The objections to it are:[1]

[1] Cf. A. K. Cajander: Ueber Waldtypen. Acta forest.fenn. 1 and Fennia 28, 1909.

A. K. Cajander: Was wird mit den Waldtypen bezweckt? Acta forest. fenn. 25, 1923.



The strip-method of B a u r.

1. that the site quality classes obtained in this way are but graphic constructions arbitrarily limited — the number of quality classes distinguished may be 3, 5, 10, or even more — and that as such they have no equivalent in nature;
2. that the method provides no guarantee ensuring that the development of even a single regular stand is actually such as it ought to be according to the normal graphic curves;
3. that the method, in principle, is based almost exclusively on stands of the best and the worst yield; it is, however, most difficult to find normal stands in adequate numbers belonging to these extremes. B a u r himself managed to find for his yield tables of beech of the lowest quality class only 8 sample plots, and a closer investigation shows that even these 8

sample plots have been able to give only quite insignificant support in the drawing of the lower limiting curve[1];
4. that although this defect could be made good by not drawing the normal curves on the basis of the uncertain limiting curves, but by using the basis of a mean curve which takes into consideration *all* the points, yet this method of correction is not permissible as the assumption on which the whole theory is based, viz. that the direction of the normal curves in each quality class is similar, is not only doubtful but can even be proved wrong[2].

This method has moreover the following fundamental weaknesses:

1. The classification of sites is done separately for each region; the tables representing two regions, in all respects of similar quality classes, may produce widely different results from each other, if one of the regions by chance happens to have regularly developed stands (of which the number in existence is small) in somewhat different proportion to the other. The quality classes derived in different countries on the basis of this method do not, accordingly, correspond to each other[3].

2. As the sub-division of the different species of trees into quality classes is widely different and as quality classes are defined separately for each species in the manner described above, it is obvious that the quality classes of different species of trees cannot correspond to each other; thus, quality class III for pine does not by any means correspond to quality class III for spruce, beech or oak. In other words, a general site classification is not brought about in this way, and no calculations comparing the profitableness of prospective yields for different species of trees are possible on this basis. The defects of this method appear even more clearly if the number of species is large and if they, moreover, normally occur in mixed stands.

Objections can be raised also against the *use of height* as the sole *index of quality class.* Since the height curves are compiled in the manner described above independently of each other, there is nothing to guarantee

[1] Of the sample plot material on silver fir used by E i c h h o r n, 5 sample plots belonged to the first and a total of 5 to the fourth and fifth quality classes. F r. E i c h h o r n: Ertragstafeln für die Weisstanne. Berlin 1902.

[2] Cf. A. K. C a j a n d e r: Ueber Waldtypen 1909, p. 160—161.

[3] Even if two different persons were given the task of compiling, independently of each other, yield tables for one and the same species of tree in the same region, it is probable, taking into account the more or less subjective choice of sample plots in each case, that the quality classes established on exactly the same areas according to the strip method would not agree.

that the volume and height curves of the quality class of the same name would correspond to each other. It is true that this defect can be avoided by determining the height curves as averages for the heights of stands of which the quality class has been defined by means of volume curves. In this case the height, of course, is a reliable index provided the classification of sites done in the manner described on the basis of volumes can be considered correct. But even this is only possible provided that all the stands have been treated in the same way, that, above all, they are of the same age, with normal crown density, and all thinned in the same way. For stands thinned in a different way, average height is no reliable common index of quality class; the more open, the more they differ in age and the more irregular the stands are, the more uncertain as an index of quality class is even the dominant height. This is the position in most of the ordinary forests under supervision. Moreover, it has to be noted that an increase of height and an increase in volume, as is proved, do not develop along parallel lines; on the contrary, from a certain lower site quality class upwards the volume of wood may increase while the height remains unchanged[1].

The Baur method does not offer any guarantee that the development of any regular wood will be in reality such as it should be according to the curve. This basic defect, already mentioned above, can, however, be diminished by means of certain auxiliary methods.

One of the auxiliary methods is the so-called *directing-curve method*[2]. It is characteristic of this method that the sample plot stands, so-called permanent sample plots, are re-measured at fixed, say 5-yearly, intervals. When the resultant measurements are plotted as points in a system of coordinates, each sample plot is naturally not represented by one point only but by a row of points which can be connected with straight lines. The result is longer or shorter broken lines, which are used either as such, or by the aid of which special directing-curves are drawn which can be relied upon when drawing the final normal curves. The direction of these curves is thus not dependent on the uncertain limiting curves just mentioned, and

[1] Cf. Y. Ilvessalo: Tutkimuksia metsätyyppien taksatoorisesta merkityksestä nojautuen etupäässä kotimaiseen kasvutaulujen laatimistyöhön. (Investigations into the mensurational significance of forest types mainly on the basis of the compilation of growth tables in Finland.) Acta forest. fenn. 15, 1920. (Diagr. No. 45.)

[2] This method is presented by C. and E. Heyer:

C. Heyer: Aufruf zur Gründung eines forststatischen Vereines. Neue Jahrb. 1846.

E. Heyer: Ueber Ausstellung von Holzertragsstafeln. All. Forst- u. Jagdztg. 1877.

they can be made more accurate, the more often the sample plots are remeasured; in other words, the older the sample plot stands are. But it may easily take a lifetime before finished yield tables can be obtained in this way, and we cannot wait so long.

Another method which leads to quicker results but is considerably less reliable is the so-called *index method*[1]. This method is based on the same partially correct assumption that the dominant trees of an old stand have also been dominant while the stand was young, and that when a stand gets older, trees from dominant classes go over to dominated classes of trees, whereas an opposite tendency is observed only to a very small extent. On the basis of this assumption the trees of each sample plot are divided into groups of similar size from the thickest ones downwards, and from the mean tree or trees of the class comprising the thickest trees a so-called stem analysis is made; in other words, the growth conditions of these trees are investigated most thoroughly. All those sample plot stands, of which the analysed sample trees show a similar development, are considered to represent the same development series. This is also a way of obtaining series of points or broken lines.

Cajanus[2] has, on the basis of mathematico-statistical methods, developed a totally independent method for use in ascertaining which of the stands of a certain age can be considered as belonging to the same quality class. His starting-point was the so-called stem frequency distribution, obtained by dividing the trees into classes of equal size according to breastheight diameter. With stands of the same age, those are considered to belong to the same development series, whose stem frequency distributions are analogous; the analogy is determined on the basis of several different characteristics (such as number of stems, average diameter, standard deviation, asymmetry etc.). The analogy is significant whenever

[1] The method was presented by Huber (1824) but Th. and R. Hartig developed it further. This method has been, in different variations, used by:

G. Wagener: Anleitung zur Regelung des Forstbetriebs nach Massgabe der nachhaltig erreichbaren Rentabilität und auf die zeitgemässe Fortbildung der forstlichen Praxis. Berlin 1875.

T. Lorey: Über Stammanalysen. Stuttgart 1880.

T. Lorey: Ertragstafeln für die Weisstanne. Frankfurt am Main 1884, 1897.

Block: Ertragstafeln für schlagweise bewirtschaftete Hochwaldebestände. All. Forst- u. Jagdztg. 1889.

[2] W. Cajanus: Über die Entwicklung gleichaltriger Waldbestände. Acta forest. fenn. 3, 1914.

the deviation of the characteristics of the series is less than three times the standard error.

These auxiliary methods, each of them individually, and especially all of them together, naturally give a fairly good guidance when drawing the normal curves, and their direction can thus be drawn with considerable accuracy. But the main thing, the quality classification, remains unsettled. These methods will, it is true, help us to draw the growth curves with relative accuracy, but there will be an infinite number of them. All these auxiliary methods necessarily require that the quality classes are already determined in advance in some other way. In most cases, this has had to be done by means of the strip method, either directly or indirectly[1].

Those methods, in which the establishment of quality classes is based on the yield or the growth of stands, have thus not been adequate to solve the question of site classification[2].

The attempts at establishing natural quality classes which would not be based on graphic or mathematical constructions of any kind, have already been dealt with above. — While the graphic or mathematical methods of establishing quality classes are applicable only with difficulty even for the purposes of forest mensuration, they are totally unsuitable for use in the other main branch of forestry, the by

[1] This is the case for instance with regard to the decision taken by the German silvicultural experimental stations at Ulm 1888. In order to attain uniformity in the definition of quality classes, it was decided to accept for the different tree species the following scale, based on the stand volumes at 100 years' age:

	Cubic meters				
	I	II	III	IV	V
Pine	700	550	420	300	200
Spruce and fir	1100	900	720	550	440
Beech	720	580	460	350	250

As two points of each normal curve were thus settled in advance, viz. the O-point and the 100-years point, the drawing of the normal curve was a relatively simple, but wholly unscientific task.

[2] Regarding numerous less complete methods of site classification, we refer to the investigation by Lönnroth:

E. Lönnroth: Die Waldtypen und die innere Bestandesentwicklung. Finnland-Buch der Deutschen Dendrologischen Gesellschaft, Bd. XXXVI, 1926.

no means less important one, silviculture. Site classification is at least equally necessary for silviculture. Thus, the quality of the site is of decisive importance for the species of tree to be raised. All the trees that can be grown on the best sites cannot, quite naturally, thrive on the less good ones. Nor is that all. Even the same species require different tending methods on different sites. As is well-known, all pine-stands cannot be treated in the same way but the tending of trees growing on dry heath must be different from that of trees on moist forest soil, whereas a third kind of method is to be observed on wet peat-lands, to mention one example. The differences apply both to afforestation and the regeneration of stands and to improvement fellings as well as to the growth possibilities of reserve-trees and of undergrowth. Consequently site classification is also a matter of absolute necessity for silvicultural purposes. For this purpose, the quality classes established graphically or mathematically are of course totally unsuitable. It would be simply absurd to speak of the tending of Class V Pine forests, as this quality class comprises sites differing widely from each other biologically, for instance pine stands on dry heaths and on peatlands, the tending of which can have few features in common. Site classification carried out for silvicultural purposes must strive after the establishment of natural quality classes as far as possible, and at the same time after such quality classes as can be distinguished actually in the forest. The classification must be one which combines sites biologically near together but keeps apart those which differ biologically. One of the main requirements of the silviculture of the future will be that the silviculture applied on a certain site should achieve the best economic results on that site, due consideration being paid to the natural possibilities of the site. Forests have to be treated according to the site and not in a stereotyped way. To make this possible, however, a natural way of classifying the sites must first be realized. — With regard to the significance of natural site classification for both forest mensuration and especially for silviculture, it is obvious that a classification of that kind must also form the necessary basis for the organisation of forest management in general.

That the classification of sites according to their yield is also necessary, at least indirectly, for forest statistics and through them for forest policy, it is hardly necessary to stress in this connection. Naturally, it is not advisable to establish different quality classifications for different branches of forest management, such as forest organisation, forest mensuration, silviculture and forest statistics; on the contrary, the site classification must be the same both for all species of trees and for all the various branches of forestry. The more international forest statistics become, the more important is it that the site classification should be done in the different countries according to the same uniform principles.

It must be specially pointed out that an accurate definition of site quality classes is also necessary for forest research work, no matter whether mainly experimental or comparative research methods are used in this work; the latter involves critical comparison of the innumerable experiments already made in natural or cultivated forests. When the influence of a certain factor or of a group of factors on a stand or on trees is investigated, it is naturally necessary to keep all other influencing factors unchanged or identical because, otherwise, comparisons cannot be made. The first condition is that the sites of all sample or comparative stands should be of equal value. It is not enough to know that the stands grow on sand or clay soil, that the soil is moist, that it has a Northern aspect, that the stratification of the ground is such and such etc., but we must be perfectly certain that the sites in question are also, as a whole, of equal biological value, and we must be able to define the total character of the site exhaustively in a few words.

On the basis of what has been said above, it can be stated,

that a natural, uniform and international classification of sites adapted for forestry is highly desirable for the purposes of forest mensuration and forest survey and, generally, forest management, as well as for silviculture, forest statistics and all forest policy based thereon;

that an accurate, objective and natural site classification is necessary also for all such forest research the results of which, in one respect or another, are dependent on the site;

that this goal has not been reached and will hardly be reached even in the future by means of the methods described above.

The Nature of Vegetation-Units and Forest Types.

The vegetation covering the ground and to be seen all around us, varies to a great extent. We do not need, however, to examine it for very long before we find great regularity in it. Closer observations will show that the plants do not appear in nature, as a rule, as independent individuals but that they have, almost everywhere in our climate, joined together to form regular groups, vegetation-units. Each of these units is made up of an assemblage of vegetation, varying within certain limits and typical of the unit, and has a characteristic mode of occurrence and botanical range. The border lines of these vegetation-units are fairly distinct. Thus, our meadows with their abundance of flowers are widely different but one soon gets used to discerning in them certain vegetation-units, repeating themselves with fair regularity on similar sites. There are in Finland, for instance, Agrostis canina-meadows, Aira caespitosa-meadows, Trollius europaeus-meadows, and so on. Even wet peatlands are of widely differing nature, but different vegetation-units can be discerned on them also; for instance, Labrador tea-moors, ling-moors, bilberry-moors etc., which under given circumstances are repeated with essentially the same structure. On the most barren heathy forest lands are found lichen pine woods, and ling (Calluna) pine woods, on moister soils bilberry bushes (Vaccinium myrtillus) in spruce woods and, last of all, on the very best soils, luxuriant woods, rich in herbs and grasses. The vegetation covering the ground comprises, in other words, a great number, but by no means an unlimited number, of vegetation-units, linked together in a way rather like the squares on a chessboard or on an inlaid floor, differing from these, however, from the fact that they vary both with regard to quality and to size and have less distinct limits. Taken together, these squares, which are sometimes more, and sometimes less clearly visible, constitute the natural vegetation.

The question naturally arises whether the vegetation-units might not offer a possible solution to the problem presented in the previous chapter, whether it would not be possible to develop, on the basis of vegetation-units, the sort of site classification, even if it were only one on general lines, which forestry demands, — a site classification, moreover, which could, on a silvicultural-biological, agro-geological and forest mensuration-scientific basis, be further developed into a site classification method adequate for practical and scientific purposes — if it should happen that the classification effected on the basis of vegetation-units did not, in itself, fulfil that purpose. In the following, we shall go further into the nature of vegetation units from this point of view.

A primeval forest, spared the influences of man-made culture, is very regular. Thus for instance, in the East-Siberian primeval wildernesses on the River Lena, pine woods grow on dryish, warm Southern slopes, and spruce woods in fresh or moist valleys, whereas other forest-land is covered by larch woods.[1] The ground flora of the Siberian primeval forest, taiga, is also extremely regular. Thus, two main types are discernible among the larch woods growing about latitude 67: a Ledum-wood and a Myrtillus uliginosa- wood, each of them characterised by a vegetation of a fairly definite composition. The former type grows on fresh sites, whereas the latter is found on slightly moister soils. Of the dryish sites, larch woods characterised by Vaccinium-vegetation are typical. On the magnificent flood lands of the river, certain shrubs, two alder species, birch and spruce, form bushes or woods the limits of which are very exactly set by the height of the spring flood.[2]

So great a regularity is not found in inhabited areas. In Finland, for instance, the forest-forming species of tree[3], especially on burnt-over lands, on exactly similar sites is sometimes pine, sometimes spruce, birch, aspen, grey alder, and almost more common still are mixed woods of different kinds. The regularity of a primeval forest vegetation is hardly evident at all except that the pine woods dominate on dry heaths, whereas moister lands grow all other common species of trees, and so-called valuable broad-leaved trees appear on the very best sites only. Moreover, the ground flora varies to a very great extent.

This difference between primeval territories and inhabited areas can hardly be due to anything other than the struggle between different tree species and, in general, between different species of plants[4], which has

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[1] Cf. A. K. Cajander ja B. R. Poppius: Eine naturwissenschaftliche Reise im Lena-Tal. Fennia 19, 1903.

A. K. Cajander: Studien über die Vegetation des Urwaldes am Lena Fluss. Acta soc. scient. fenn. 32, 1904.

[2] A. K. Cajander: Beiträge zur Kenntnis der Vegetation der Alluvionen des nördlichen Eurasiens. 1. Die Alluvionen des unteren Lena-Tales. Acta soc. scient. fenn. 32, 1903.

[3] Cf. Olli Heikinheimo: Kaskiviljelyksen vaikutus Suomen metsiin. (The effect of burn-beating on the Finnish Forests.) Acta forest. fenn. 4, 1915.

[4] Cf. A. K. Cajander: Der gegenseitige Kampf in der Pflanzenwelt. Schröter-Festschrift. Veröffentl. des Geobot. Institutes Rübel in Zürich. 3, 1925.

been going on in the primeval forests for centuries, even thousands of years. In inhabited areas, however, this struggle is again and again disturbed by fellings, forest fires, burn-beating, etc. The powers engaged in this struggle can be estimated when we consider that, according to Y. Ilvessalo[1], an individual pine growing on a dry heath (CT), in the middle of a regularly developed pine stand, at an age of 25 years requires an average growing space of 0.62 sq. m., at 125 years 11.05 sq. m. and at 150 years as much as 15.08 sq. m. As, however, the site area at the disposal of the trees remains unchanged, all individual trees cannot have enough space, and thus most of them must go under long before they have time to develop into proper trees. From the 16,000 individual pines of a hectare of a regular pine stand of 25 years of age, only 663 are left at the age of 150 years, and by far the greatest number of them have gone under before the stand reached the age of 25. This struggle for space — in the first place for space required for providing nutrients in the broadest sense — is found everywhere in nature: in certain conditions, only a certain maximum number of individuals of a certain species — plant, animal, man[2] — can continually satisfy its requirements on an area of a certain size.

When an area, burnt over for cropping purposes or burnt by fire, begins to revert to forest, there is at first enough room for the young plants, and the composition of the seedling stand that grows up depends largely upon chance factors; it may depend on the quality of the seed year of the different species of trees, the weather conditions prevailing at the earliest stage in the life of the seedlings, etc.[3] In a few years, nothing definite may yet have happened in this original stand, possibly composed of many different species of trees, although the seedlings of Norway spruce, owing to their slower growth, may have been overtopped by the other species. Were we to visit the place again after 50 years, we would find that the

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[1] Y. Ilvessalo: Kasvu- ja tuottotaulut Suomen eteläpuoliskon mänty-, kuusi- ja koivumetsille. (Growth and yield tables for pine, spruce and birch woods in the Southern half of Finland.) Acta forest. fenn. 15, 1920.

[2] Ch. A. Penck: Das Hauptproblem der physischen Antropogeographie. Sitzungsber. der preuss. Akad. der Wissensch. XXII, 1924.

A. Penck: Die Bonitierung der Erdoberfläche. Verhandl. des XXI. Deutschen Geographentages zu Breslau vom 2. bis 4. Juni 1925.

[3] Cf. Olli Heikinheimo: Kaskiviljelyksen vaikutus Suomen metsiin. (The effect of burn-beating on the Finnish forests.) Acta forest. fenn. 4, 1914.

grey alder, to a great extent, has been forced aside, while the spruce has reached the level of the other species of trees. When the stand has reached an age of 150 years, the grey 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 birches and aspen have entirely disappeared, and only old Scots pines and spruces are found in the area, together with an abundant young growth of spruce, which gradually comes to dominate the site, whereas the pine has failed to regenerate itself owing to the shade. But before this final stage is reached, fellings etc. in inhabited areas have mostly disturbed this struggle or even interrupted it, and consequently, the forests in inhabited areas can never reach the characteristic regularity of the primeval forest. However, the struggle is also waged in the forests of the inhabited areas, although often in a milder form and with numerous interruptions, and, as a consequence, the development towards the final stage, the primeval forest, is discernible everywhere. In many places where burn-beating has been practised, for instance in some State forests in Eastern Finland, the spruce forest stage seems to have been reached, although some individuals of other species still try to survive among the spruce trees. — The better planned the silvicultural management of the forests, the more is their natural development disturbed. 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. Also when thinning special attention is paid to the selection of the species of tree.

But a forest consists not only of trees but also of a more or less rich variety of other plants: the ground flora of the forest. Among the ground flora too, the struggle between individuals is disturbed by cultivation. Ground burnt for cropping purposes or by forest fire again affords a good illustration. During the first years after the abandonment of such an area, the number of the plant species increases rapidly and, according to Linkola[1], it reaches its maximum, in normal burnt-over lands (MT), namely, 105 species of vascular plants, in 7—8 years. The site is now covered with plants; the struggle is at its fiercest, and along with the struggle going on and becoming more ruthless, the biologically weakest species perish to an ever greater extent. In about 20 to 40 years the number of species has decreased down to about 70, after 60 years to about 40, until, at about the

[1] K. Linkola: Studien über den Einfluss der Kultur auf die Flora in den Gegenden nördlich vom Ladogasee. I. Acta soc. pro fauna et flora fenn. 25, 1916.

70th year, the number becomes stationary at somewhere between 30 and 40 species. Long before the forest becomes exploitable the development has thus gone so far that only a small select body of all those species of plants remains, which would have thriven on the area if that struggle had not been going on. The entire vegetation has gone a long way towards regularity. But already in the vegetation which first makes its appearance on land burnt for cropping purposes (or on areas burnt by fire or on felled areas), differences arising from the quality of site are discernible. It consists, it is true, of a heterogeneous mixture of all those plant species the seeds or spores of which have found their way to the area, and which upon the whole have a chance to thrive there. But for the very reason that different kinds of site offer to different plant species varying opportunities of thriving, this kind of vegetation with an abundance of species acquires from the very beginning a very varied composition, depending entirely upon the nature of the site, so much so as to become more or less characteristic of the various sites. With the struggle going on, such species of plants as are biologically weaker on that site than their fellow plants grow less and less in number, and thus the vegetation becomes more and more regular and characteristic of the site. This struggle is not going on in the case of the ground flora only or among the trees only, but also between the different layers of vegetation[1] and, above all, in the ground as well[2]. A result of this is a very considerable regularity of vegetation and especially ground vegetation even in the forests of inhabited regions, often not much inferior to the regularity of the ground vegetation of a primeval forest. — Mutatis mutandis, the above is applicable also to the vegetation-units on meadows, moors, etc.

The final issue of this struggle going on everywhere in the plant cover-

[1] One of the forms which this struggle may take is that, on the best sites, the ground vegetation may be decreased to its minimum during the polewood age, on account of excessive shade, and increase again later on.

[2] Cf. for instance V. T. Aaltonen: Die Entwicklung des Waldbestandes und die Wachstumsfaktoren. Acta forest. fenn. 44, 1936.

Erkki Laitakari: Koivun juuristo. (The root system of Birch.) Acta forest. fenn. 41. 1935.

Erkki K. Kalela: Tutkimuksia Itä-Suomen kuusi-harmaaleppäsekametsiköiden kehityksestä. (Investigations into the development of mixed woods of spruce and grey alder in Eastern Finland. Acta forest. fenn. 44, 1936.

Erkki K. Kalela: Männyn taimien juurien suhtautumisesta emäpuun juuriin. (Concerning the relation between the roots of pine seedlings and of their parent trees.) Acta forest. fenn. 50, 1942.

ing depends both on the plant species engaged and on the nature of the site. Wherever the plant species engaged in the struggle are identical, the final outcome depends exclusively on the quality of the site, so that in this case the final result of the struggle must be the same vegetation-unit on all sites of equal biological value. The first condition is, however, hardly ever possible, for the species for which the site in general is appropriate, 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 species on the sites, however, are usually so common and numerous everywhere that, thanks to surviving roots and parts of rhizomes, seeds, fruits, spores etc. transported by the wind, the colony characteristic of the site in question, as a rule, is present everywhere in such an abundance of species that vegetation-unit arising as a result of 1. the specialised requirements of the plants with regard to site, 2. the struggle between the plants, and 3. the unconscious favouring of one species by another, from the very beginning assumes a character typical of the quality of the site. Thus it is possible, especially in exploitable forests, to distinguish certain typical vegetation-units. There are, for instance, pine forests abounding in lichen, in which the ground is covered with a white reindeer-moss carpet accompanied by certain typical isolated dwarfshrubs, herbs and grasses, there are Calluna pine woods, Vaccinium vitis idaea pine woods, etc. In all varieties of ground vegetation there exists a stock number of species always or nearly always present, and an uninterrupted succession leading from them down to those species that are only very seldom present in the vegetation-unit in question. Each of these species of different degrees of frequency may be present in varying abundance, although considerable similarity prevails among plant associations belonging to one and the same vegetation-unit[1] as regards the abundance of the species. One and the same vegetation-unit is considered to comprise, as a rule, all the plant associations whose vegetation, in respect of its composition by species, shows similar and characteristic features. Of decisive importance, when defining a vegetation-unit, are 1. first of

[1] Cf. A. K. Cajander: Zur Begriffsbestimmung im Gebiet der Pflanzentopographie. Acta forest. fenn. 20, 1922.

all, the plant species present in different plant associations always or nearly always and in considerable abundance; important are, however, also 2. the less abundant species which nevertheless are almost always present. On the other hand, 3. especially typical of a vegetation-unit are those plant species present exclusively or nearly exclusively in the vegetation-unit in question, and they are the more typical the more frequently and abundantly they appear in it. Finally, 4. the absence of certain plant species or groups may be just as characteristic of a vegetation-unit as the occurrence of others.

Further, characteristic of the vegetation of each vegetation-unit is, in general, a certain ecologico- biological structure and the external appearance acquired as a result of it. Thus the vegetation of dry heaths is extremely xerophilous. In its own way, also, the vegetation of pine moors is xerophilous. The structure of the most luxuriant deciduous forest vegetation is hygrophilous, etc. It may be useful to say a few words about this phenomenon.

In part, this structure must be due to the fact that every plant individual is capable of adapting itself; thus the ordinary bilberry, on a dry heath, is in respect of its structure much more xerophilous than on a moist site with rich nourishment. The exterior appearance of an ordinary pine varies greatly on different sites. Up to a certain degree this may also be caused, no doubt, by the formation of new varieties within the species on account of the sites.[1] It is known that each Linnaean species comprises a number,

[1] Cf. A. K. Cajander: Metsänhoidon perusteet I. Kasvibiologian ja kasvimaantieteen pääpiirteet. Luku »Lajien synty». (Fundamentals of forestry I. Main features of plant biology and geobotany. Chapter »Origin of Species», pp. 524, 572, 600.) Porvoo 1916.

A. K. Cajander ja Y. Ilvessalo: Über Waldtypen II. Acta forest. fenn. 20 ja Fennia 43, 1921, p. 4.

G. Thuresson: The genotypical Response of the Plant Species to the habitat. Lund 1922.

A. K. Cajander: Einige Reflexionen über die Entstehung der Arten. Acta forest. fenn. 21, 1921.

A. K. Cajander: Der gegenseitige Kampf in der Pflanzenwelt. Schröter-Festschrift. Veröffentl. Geobot. Inst. Rübel in Zürich. 3, 1925.

A. K. Cajander: Zur Frage der Allgemeinen Bedingungen der Kultur ausländischer Gewächse mit spezieller Rücksicht auf die Kultur der ausländischen Holzarten in Finnland. Finnland-Buch der Deutsch. Dendrol. Ges. 1926.

in many cases even a very great number, of inheritable minor forms, so-called biotypes, subject to (if cross pollination is necessary) the Mendel theory. Each of these biotypes, which have mainly arisen through the re-grouping of inheritance factors (genes), but also partly through the disappearance of certain inheritance factors or formation of new ones, has more or less specialised requirements as to site. Among these biotypes, the general struggle for existence naturally prevails and in consequence, certain biotypes perish on given sites, certain others again on other kinds of sites. Thus the population of a certain plant species may be, on different sites — especially where the sites are uniform over large areas — composed of a considerable variety of biotypes. It may even be differentiated into site races, which cannot but affect the ecologico-biological structure of the species in question. Without wishing in this connection to go into the problems connected with the origin of the ordinary Linnaean species, I would like to mention the fact referred to above, viz. that on certain sites certain individual plants, on other sites again widely different plant individuals are stronger than their neighbours. Thus, on each site, the ones which survive are those which prove biologically stronger in the struggle. These, however, can only be the ones which in their vital functions and, consequently, in their structure, are best adapted to grow on that particular site. The general structure of vegetation-units appearing on sites of a different nature and the external appearance connected therewith would thus be caused by the fact that, as a rule, those plants survive in the struggle for existence on a certain site which have the best prospects of winning on account of their external and internal structure and specialised biological qualities, as well as by the fact that among these species, at least within certain limits, a selection of biotypes (formation of race) goes on according to, in the main, the same principles, and finally by the fact that each individual has a considerable capacity for adaptation.

The dividing lines between the different plant associations are, as a rule, distinct[1] so that the charting of vegetation-units, as is wellknown,

[1] Cf. A. K. Cajander: Ueber Waldtypen. 1909, p. 9—10.
V. Kujala: Untersuchungen über die Waldvegetation in Süd- und Mittelfinnland. II. Über die Begrenzung der Siedlungen. Metsätiet. Tutkimusl. Julk. 10.

is quite common in geobotany nowadays. Also these distinct border lines between vegetation-units are essentially a result of the struggle among the plants. This is clearly seen, more especially, on sites where the plant covering comprises fairly pure plant associations adjoining each other, that is to say, plant associations with in the main just one dominating plant species. This is the case generally on flooded river banks the vegetation of which may comprise quite narrow zones, running in the same direction, of extremely pure plant associations.[1] Now it is obvious that the site is changed from the waterline upward only gradually with no sudden alterations, but the limits of the subsequent zones are, nevertheless, quite distinct and marked. This contradiction is easiest to explain by bearing in mind that the dominating species of each zone is stronger than that of the adjoining zone up to a certain limit, and that then the latter gains domination. Both of them can permanently appear as parallel dominating species only on sites where the conditions are so similar for each of them in this struggle that the one cannot extinguish the other; this kind of site is, however, only to be found along a very narrow demarcation line. — Where the plant associations are less pure, where there is a mixture of several equally dominating species, and especially where the vegetation is divided into layers according to height — as is usually the case for instance in a forest, where the moss and lichen form one layer, dwarfshrubs, herbs and grasses another, bushes perhaps a third and trees a fourth layer — the boundaries between different species by no means coincide. Thus the demarcation of these kinds of vegetation-units is not so distinct. The same struggle, however, exercises its influence there, too, and the transition zones, where the demarcation may be open to question, are as a rule of relative insignificance.

On the basis of the above it can be maintained, that the natural plant covering of the earth comprises a great number of more or less permanent vegetation-units[2] characterised by the fact

that the vegetation of the different plant associations in these vegetation-units, in respect

[1] Cf. A. K. Cajander: Beiträge zur Kenntnis der Alluvionen des nördlichen Eurasiens I—III. Acta soc. scient. fenn. 32, 33, 37. 1903, 1905 ja 1909.
[2] Vegetation-unit in the stricter sense of the word: cf. A. K. Cajander: Zur Begriffsbestimmung im Gebiet der Pflanzentopographie. Acta forest. fenn. 20, 1922.

of the frequency and abundance of the species, is essentially uniform and typical;

that their vegetation has also, generally speaking, a certain ecologico-biological structure and the exterior appearance dependent thereon;

It has further become clear:

that each of the vegetation-units is present on sites of a fairly similar character, which accounts for their geographical range, and

that the demarcation of plant associations one from another is, as a rule, fairly distinct.

Passing on now to stand-units, it must be said that one and the same stand, at different stages of growth may represent a completely different vegetation-unit.[1] Thus, for instance, a spruce stand on a rich forest soil, at the seedling stage, represents a kind of meadow with the soil covered by so abundant a vegetation of grass and herbs that the small spruce seedlings disappear completely among the luxuriant vegetation; they can hardly be discerned at a first glance. As soon as the spruce seedlings on a rich soil have developed on to the pole stage and are at their densest, they shade the ground so effectively that the shading — perhaps to some extent the root competition also — extinguishes almost all the ground vegetation; only a few species able to stand the excessive shade survive. When the spruce stand, at an older stage, becomes considerably more open and the shading consequently is less intensive, the ground flora gradually becomes more abundant, and thus in old, mature stands there is often a continuous, low plant covering. Different as these three vegetation-units are, they are undoubtedly closely related, representing merely different stages of development of one and the same spruce stand on one and the same site, which has all the time remained unchanged in all essential respects. — On slightly poorer soil we find for spruce stands another succession of developments, in which the vegetation shows corresponding changes but which at each stage differs from the corresponding stage of the succession mentioned above; in other words, these series are essentially different.

[1] Cf. A. K. Cajander: Über Waldtypen 1909, p. 22—49.
C. H. Bornebusch: Skovbundstudier IV. Det Forstl. Forsfgsv. Danmark, 8, 1925.

One of them cannot be changed into the other unless the site itself, either by manuring it or by strongly affecting the living conditions of the plant in some other way, undergoes a thorough change. — The composition and, in general the quality of the vegetation of such normal series may be considerably affected by all kinds of chance factors, such as intensive thinnings, devastations by storm and snow, grazing of cattle, etc. The changes arising from each of these influences take place in a similar way in each normal series, but the changes are quite different in the different series.

As a normal vegetation unit of a series of this kind may be regarded a vegetation-unit represented by a mature stand, of normal density and otherwise regularly developed, together with all its plants. As derivatives of this normal vegetation-unit may be regarded:

1. all those vegetation-units or variations of vegetation-units belonging to the same normal series as the normal vegetation-unit, as well as

2. all the vegetation-units that differ from the corresponding vegetation-unit of the normal series only with regard to qualities brought about by chance influences (thinning, grazing, etc.). As temporary factors are to be considered also

3. the alternations occasioned by the species of tree growing on the site at a given time.

Thus, we come to the definition of the forest type:

All those stands are to be classed in the same forest type, the vegetation of which, when the stand is exploitable or nearly exploitable, and of normal density, is characterised both by mainly identical floristic composition and a similar ecologico-biological nature, as well as all those stands the vegetation of which differs from that defined above only in those respects which — resulting from the difference in age of the stand, fellings, change in species of stand, etc. — have to be considered as merely accidental or ephemeral or at any rate not permanent. Permanent differences call forth a new forest type where they are sufficiently well-marked, or a sub-type where the differences are less essential but nevertheless noticeable.[1]

In a forest type, when understood in the way described above, only the primary site factors can be reflected, factors which would remain active even though the site were stripped of all plants. The secondary site factors, above all the changes in the local climate (including light conditions) and in the soil, brought about by the trees themselves (their age, density, etc.) do not as chance factors affect the nature of the forest types, although they put their additional characteristic stamp on the vegetation, and through their variation often bring about quite remarkable changes.

The fact that primary site factors thus mainly determine the forest type, seems to indicate that it might be possible to bring about, on the basis of forest types — that is to say indirectly — a natural and biological classification of sites, independent of which species of tree happens to be the dominating one, which could be used as a starting point for methods of classification based both on the qualities of the soil and on the tree stand. After having found a starting point of this kind they could be developed further independently, unless the indirect classification based on forest types proves satisfactory in itself.

The introduction of forest types understood in this sense into forest science and forest management does not, of course, imply any kind of simplification of forest site classification. Nor was it ever intended to. The purpose of the forest types is only to bring the classification of forest sites on to a more accurate, more objective, more definite, more natural and more general basis.

[1] A. K. Cajander and Y. Ilvessalo: Über Waldtypen II, p. 17.

A. K. Cajander: Zur Begriffstimmung im Gebiet der Pflanzentopographie. Acta forest. fenn. 20, 1922, p. 8—9.

A. K. Cajander: Über die Verteilung des fruchtbaren Bodens in Finnland und über den Einfluss dieser Verteilung auf die wirtschaftlichen Verhältnisse im Lande. Acta forest. fenn. 25, 1923, p. 5—6.

A. K. Cajander: Was wird mit den Waldtypen bezweckt? Acta forest. fenn. 25, 1923, p. 7—8.

The greatest difficulty — after the forest types of the area under examination are critically described — is to learn to recognise the forest types correctly. As long as the normal stage of each forest type series is in question, the task is relatively simple. The difficulties are encountered when, in connection with practical forest mensuration work, it has to be decided to which forest type the stands deviating most widely from the normal stage belong. In practice, the ascertaining and recognising of forest types does not, in general, present any difficulties worth mentioning. For that purpose one must get accustomed to recognising the forest types in their normal and especially, their most typical form, and after sufficient skill in this respect has been acquired one has to train oneself by comparative observations to discern which divergent vegetations are to be considered as belonging to which normal series. Special attention must in this connection be paid to the surrounding stands and to all those boundaries of the stand which appear to have been determined by factors other than differences of site. This task is greatly facilitated by the fact that the variations of vegetation in the forest types of lowest productivity, within one and the same type, have a comparatively small range, and even the influence of the species of tree is relatively small.[1]

On the lands of highest productive capacity, the difficulties are certainly greater, because the deviations shown by the vegetation at the different stages of growth of the tree stand, with its varying density, etc., are in this case quite considerable. Adequate training, however, will enable one to distinguish with accuracy the stands belonging to the different normal series of forest types, the more so as there generally is a sufficient amount of material at hand for comparison — parts denser or with more clearing than the rest of the wood, older or younger woods and, in general, woods differing from each other. The determination of a forest type, even in extreme cases — provided the forest types of the area have been described exhaustively and exactly enough — is not more difficult than the determination of the species of young **plants** or imperfectly developed

[1] Cf. A. K. Cajander: Ueber Waldtypen 1909, e.g. p. 40—42, numbers 1 and 2 (Beech and spruce stands at Ullersdorf).

Y. Ilvessalo: Vegetationsstatistische Untersuchungen über die Waldtypen. Acta forest. fenn. 20, 1922.

plant individuals or specimens with no flowers or whose flowering is over, etc. Even this requires training but is comparatively easy to perform with accuracy once the training is acquired.

As, particularly if fairly wide areas are considered, the number of forest types is rather large, it is necessary to create as natural a system of classification as possible so that forest types really related biologically come close to each other in the system. The principles followed in creating the existing system of forest types have been as follows: the forest types have been grouped according to their normal appearance (i. e., according to the vegetation-unit represented by an exploitable stand of normal density and development). These are grouped in such a way that those which most resemble one another as regards the composition by species of their vegetation are placed nearest to one another. Especially in establishing the more comprehensive classes, attention has been paid to the high or low demands of the vegetation (primarily species of trees) to the relative abundance of such physiognomico-ecological plant groups as lichens, mosses, grasses and herbs, dwarfshrubs and bushes, and finally to the ecologico-biological character of the vegetation. — This system, as every natural system must be, is of course tinged with a great deal of subjective theory.[1] No artificial — that is, logical but based on one or a few features only — classifications of forest types, as is true of vegetation-units in general, would, in my opinion, achieve results, however, and none would provide anything but artificial solutions.

In the nomenclature of forest types one can, naturally, follow various procedures. They could simply be designated by A, B, C,etc., or I, II, III, etc. These designations are, however, difficult to memorize. For this reason, the naming of forest types according to a plant species characteristic of them has been introduced; furthermore, abbreviations derived from the botanical name of this characteristic species have been introduced, as for

[1] The same is of course also true when demarcating individual forest types or vegetation-units.

instance, CT for the Calluna (ling) type, MT for the Myrtillus (Bilberry) type, etc. However, these are only names for certain forest types. The types themselves are by no means characterised exclusively by the species that have given the type its name but by its entire vegetation.

The system of forest types used in Finland is as follows:[1]

I. Dry and Dryish Land Forest Class.

The general character of the vegetation is xerophilous.

Lichen vegetation is nearly always present, forming a continuous cover on the driest heath. The moss vegetation stands almost in inverse ratio to the lichen vegetation. Herbs and grasses scanty. Dwarfshrubs for the most part rather plentiful, most of them decidedly xerophilous. Bushes very few (juniper, some species of willow). The forest-forming species mostly Scots pine, seldom any other tree.

The layer of humus is thin and on the driest lands very defective.

Cladina Type (ClT) (Lichen Type) together with intermediate stages leading to the Ling Type. Mainly in Nothern Finland.

Myrtillus-Cladina Type (MClT) (Bilberry-Lichen Type) in Northern Finland.

Empetrum-Myrtillus Type (EMT) (Crowberry-Bilberry Type) in Northern Finland.

Vaccinium Type (VT) (Cowberry Type). Most common within the Southern half of Finland.

Calluna Type (CT) (Ling Type). Most common within the Southern half of Finland.

Empetrum-Vaccinium Type (EVT) (Crowberry-Cowberry Type) in Northern Finland.

[1] Cf. A. K. Cajander: Metsätyyppiteoria. (The Theory of Forest Types.) (Acta forest. fenn. 29, 1926) p. 32—42. In addition to the types mentioned here there are individual, divergent forest types which have no general significance and which for practical working purposes are assimilated into the nearest forest type.

The Petsamo forest types have not been considered here. With regard to them cf. Viljo Kujala: Untersuchungen über Waldtypen von Petsamo und in angrenzenden Teilen von Inari-Lappland. Comm. Inst. Forest. Fenn., 13, 1929.

II. Moist Land Forest Class.

The general character of the vegetation is mesophilous.

The forest types belonging to this class are generally characterised by a fairly abundant or continuous moss vegetation (species of Hylocomium, Dicranum, etc.). Lichens are of little importance. Herbs and grasses are present in somewhat greater degree, and in the types approaching the next class to a much greater extent. Dwarfshrub vegetation is fairly plentiful or plentiful, consisting mainly of Vaccinium myrtillus.

As forest-forming trees, all the less exacting species of trees may occur (Norway spruce, birch, Scots pine, etc.); valuable broad-leaved species, as well as more exacting shrubs, are encountered only in the types approaching the next class.

The humus layer is well developed, of the character, as a rule, of dry peat.

Hylocomium-Myrtillus Type (HMT) (Thick-Moss Type) in Northern Finland.

Myrtillus Type (MT) (Bilberry Type). Most common within the Southern half of Finland.

Oxalis-Myrtillus Type (OMT). Mainly within the Southern half of Finland.

Pyrola Type (PyT) (Wintergreen Type) in South-Finland.

Geranium-Dryopteris-Myrtillus Type (GDMT) in Northern Finland.

III. Grass-herb Forest Class.

The general character of the vegetation is hygrophilous.

The lichens are of no significance at all, with the exception of epiphytes. Moss vegetation as a rule scanty, although rich in species. No or relatively little dwarfshrubs. Grasses and 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 broadleaved trees, among them valuable ones, and by Norway spruce.

The humus layer is fairly thick, porous.

Geranium Type (GT). Chiefly in North-Finland.

Geranium - Dryopteris Type (GDT). Mainly in North-Finland.

Oxalis-Majanthemum Type (OMaT). The most common grass-herb type in Southern Finland.

Fern Type (FT). Mainly within the Southern half of Finland.

Sanicula Type (ST). On the Aaland Isles.

Aconitum Type (AT). In Eastern Finland.

Vaccinium-Rubus Type (VRT) (Cowberry-Raspberry Type). In Eastern Finland.

Lychnis Diurna Type (LT) (Campion Type). In the seaside groves of South-Finland.

IV. Spruce and Broadleaf-tree Peat-moor Class.

The general character of the vegetation varies from mesophilous to hygrophilous.

The moss vegetation is variable, ranging from relatively scanty, though rich in species, to a continuous carpet, which then includes only a few species. Represented are the relatively exacting Sphagnum species (Sphagnum strictum, Sph. squarrosum, Sph. Wulfianum, etc.) and some hair-mosses (especially Polytrichum commune) in varying quantities. In certain rich types of this class, a large number of other true moss species (Mnium, Hypnum, Dicranum, etc.) may even be present.

The forest is formed by Norway spruce or broad-leaved trees; the significance of pine is very small.

These peat moors occur on boggy land which is comparatively rich in nutrients and where there is mostly moving water.

Two sub-classes are discernible among these forests: one of them more exacting, which corresponds to grass-herb forests and where the mosses are more abundant in species if scantier in number, grass and herb vegetation fairly abundant and broad-leaved trees (among others, often black alder and even ash) dominating or very copious in mixture; the other, less exacting — very common in Finland — corresponding to the moist land forests and characterised by an abundant moss vegetation, though scanty in species, scanty grass and herb vegetation, often fairly abundant bilberry, with Norway spruce as the most general forest-forming tree species.

This class comprises a considerable number of forest types (peat-moor types).[1]

V. Pine Peat-moor Class.

The general character of the vegetation is clearly xerophilous.

In typical pine peat-moor forests, the moss vegetation is continuous, although incomplete in the wettest ones. It comprises mainly less exacting Sphagnum species (Sphagnum fuscum, Sph. recurvum, Sph. acutifolium, etc.) and among them some other accommodating moss species (Aulacomnium palustre, Polytrichum strictum, etc.). Lichen, especially reindeer mosses (as well as Baeomyces ichmadophilus etc.) occur in certain types to some extent. Dwarfshrubs are, as a rule, fairly abundant (Ledum palustre, Cassandra calyculata, Myrtillus uliginosa, Calluna vulgaris, Betula nana, etc.); in certain types approaching spruce peat-moors, there is a relative abundance of bilberry. Grasses and herbs are scarce (Eriophorum vaginatum, Rubus chamaemorus, Drosera rotundifolia, etc.).

The principal species of tree is the Scots pine; in the more divergent pine peat-moor types, Norway spruce and birch are met as admixed tree species, exceptionally even as the dominating one.

The pine peat-moor forests come near to the dry and dryish land forests. They occur on poor or even very poor wet peat-land. The ground water present is, as a rule, fairly stagnant.

The Practical and Theoretical Significance of the Forest Types.

The above study has led to the conclusion that the methods of the science of forest mensuration as such are not sufficient to bring about a scientifically valid classification of forest sites and, further, that even on a purely climatic-pedological basis, it is impossible to establish a classification suitable for use. The study shows also

[1] Cf. A. K. Cajander: Studien über die Moore Finnlands. Acta forest. fenn. 2 and Fennia 35, 1913.

that it might perhaps be possible to establish detailed classification on the basis of both the science of forest mensuration and that of the soil, perhaps even to bring about a purely forest mensuration-soil science method, provided there were the means for a preliminary, if only a summary, classification of sites.

It has further been established that the forest types are a phytotopographic conception in which only the primary site factors are reflected and which therefore must be qualified for use as an auxiliary means for the purpose mentioned above.

Let us first find out to what extent the forest types can serve the purposes of forest mensuration. Of the numerous investigations, all of which have led to analogous results, I wish to mention here only two, viz. those of Y. Ilvessalo (1920) and E. Lönnroth (1925).

The former investigation[1] was carried out through the initiative of the Society of Forestry in Finland, and its aim was twofold. The main purpose of the investigation was to create yield tables for the three main species of trees, pine, spruce and birch, in the Southern half of Finland. For this purpose, a sufficient number of sample plots was to be chosen in regularly developed, young and old pine, spruce and birch stands. From these, all the data of a stand had to be determined which are indispensable in yield tables. Moreover, a full description of their vegetation was to be prepared. The whole sample plot material had thus to be divisible not only according to the species of trees, but also according to the forest (site) type; consequently, the material of each tree species was dealt with by forest types. Thus, and it was the second aim of this investigation, it was to be ascertained whether, for each forest type (dealt with, of course, by species of trees), the data of the stand — number of stems, diameter, basal area, volume, medium height, dominant height, etc. — formed regular

[1] Y. Ilvessalo: Tutkimuksia metsätyyppien taksatoorisesta merkityksestä nojautuen etupäässä kotimaiseen kasvutaulujen laatimistyöhön. (Investigations into the mensurational significance of the forest types based primarily on the compilation work of growth tables in Finland.) Acta forest. fenn. 15, 1920.

Y. Ilvessalo: Kasvu- ja tuottotaulut Suomen eteläpuoliskon mänty-, kuusi- ja koivumetsille. (Growth and Yield Tables for the pine, spruce and birch forests in the Southern half of Finland.) Acta forest. fenn. 15, 1920.

series and could thus serve as a basis for forest type classification in the compilation work of yield tables. This task was all the more important as regards site classification because the forest types, should they really prove serviceable for a classification basis, would guarantee for practical forest management a reliable means for site classification. — On top of this, samples of soil had to be taken in each sample plot stand in order to have soil analyses made.

The sample plots were selected during the successive summers 1916, 1917 and 1918, and their number amounted to a total of 467. They were scattered all over the Southern half of Finland. The analysis of the material of different forest types and tree species is as follows:

	AT	OMaT	OMT	MT	VT	CT	ClT
Pine	—	1	15	65	77	70	13
Spruce	4	3	50	27	—	—	—
Birch	3	29	44	38	5	—	—
Aspen	—	—	5	2	—	—	—
Grey Alder ..	2	7	1	—	—	—	—

For the sake of comparison, three sample plots of mixed stands and three of the thick-moss (Hylocomium-Myrtillus) type were taken. The material proved sufficient for the following forest types and tree species:

	OMaT	OMT	MT	VT	CT	ClT
Pine	—	+	+	+	+	+
Spruce	—	+	+	—	—	—
Birch	+	+	+	+	—	—

Other sample plots were only used as material for comparison.

The investigation showed that the features illustrating the development of the stands, viz. number of stems, average diameter, basal area, volume, height, etc. — independent of the tree species under consideration — display in every forest type exceptionally uniform trends when plotted against age of stand. The material was dealt with in detail by means of mathematico-statistical methods. To serve as a check, a stem analysis was made of the mean trees of the hundred thickest trees of the dominant crown layer of each sample plot stand. The investigations of Ilvessalo, done in the most objective manner, have completely proved the suitability of forest types for forest mensuration purposes in the Southern half of Finland.

Only the following figures, showing the cubic contents over bark of normally developed pine stands at different stages of growth (cu.m/hectare), are selected from the yield tables of Ilvessalo:

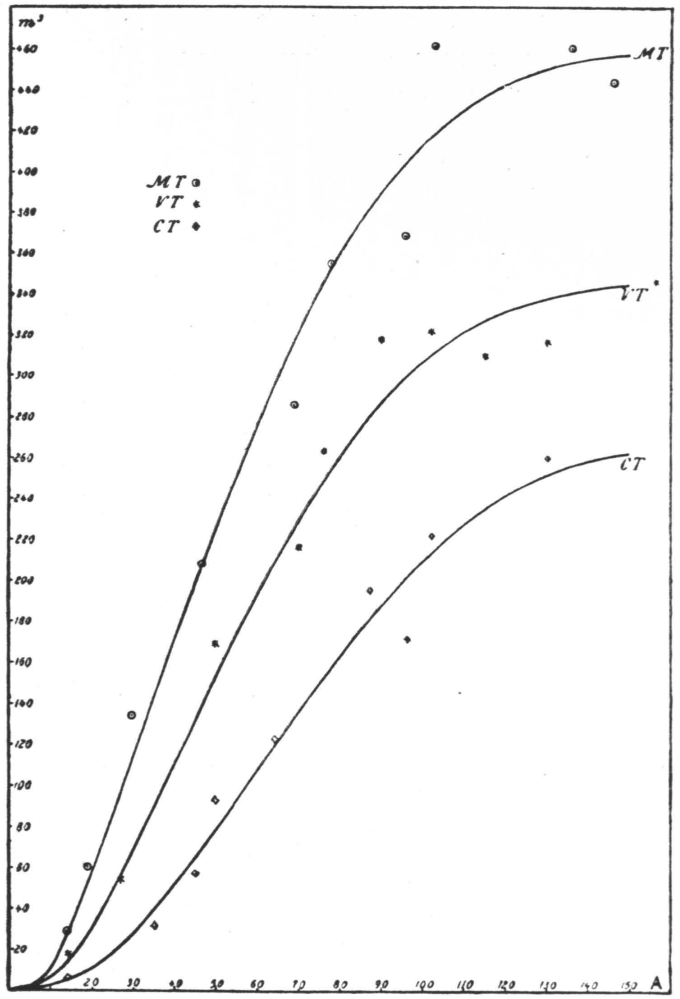
Age	OMT	MT	VT	CT	ClT
10 years	19	13	10	7	·
20 »	70	60	44	24	3
30 »	140	135	87	47	10
40 »	208	200	134	75	17
50 »	279	260	177	104	31
60 »	344	313	219	128	46
70 »	405	363	262	153	62
80 »	458	407	299	178	80
90 »	500	443	328	203	98
100 »	535	472	351	222	114
110 »	560	492	366	240	132
120 »	576	503	375	254	148
130 »	·	·	382	266	164
140 »	·	·	·	275	180
150 »	·	·	·	282	195

At breast-height (1.3 m) there are, according to the yield tables, the following numbers of trees having a minimum diameter of 28 cm in regularly developed pine stands of the relevant forest types:

Age	OMT	MT	VT	CT
50 years	15	—	—	·
60 »	63	21	—	—
70 »	145	63	12	—
80 »	229	132	43	—
90 »	287	200	86	—
100 »	319	248	130	6
110 »	348	273	158	17
120 »	375	292	178	37

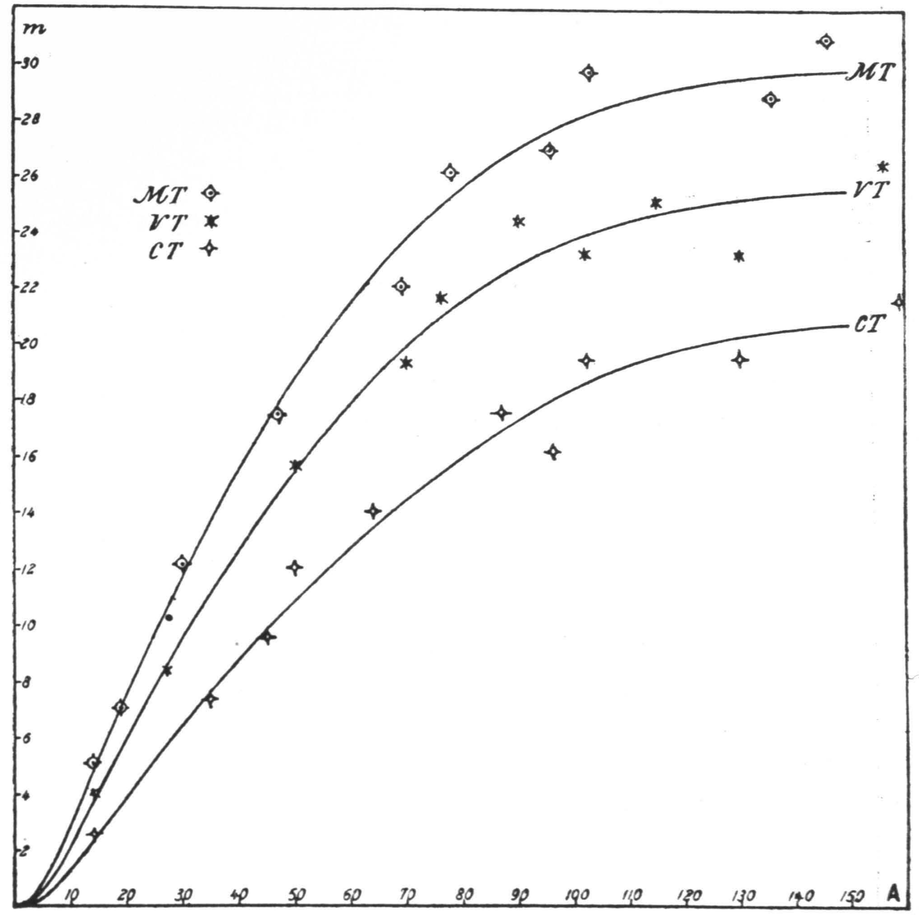
The investigations of Lönnroth[1] had another aim. Their purpose was to clear up with regard to pine stands of normal and natural type, the differentiation of tree individuals along with the advancing growth of the stands into various development classes and particularly the development of each of these tree classes. Such a study makes of course extremely

[1] E. Lönnroth: Untersuchungen über die innere Struktur und Entwicklung gleichaltriger naturnormaler Kiefernbestände. Acta forest. fenn. 30, 1925.



Development of the volume of the stand.

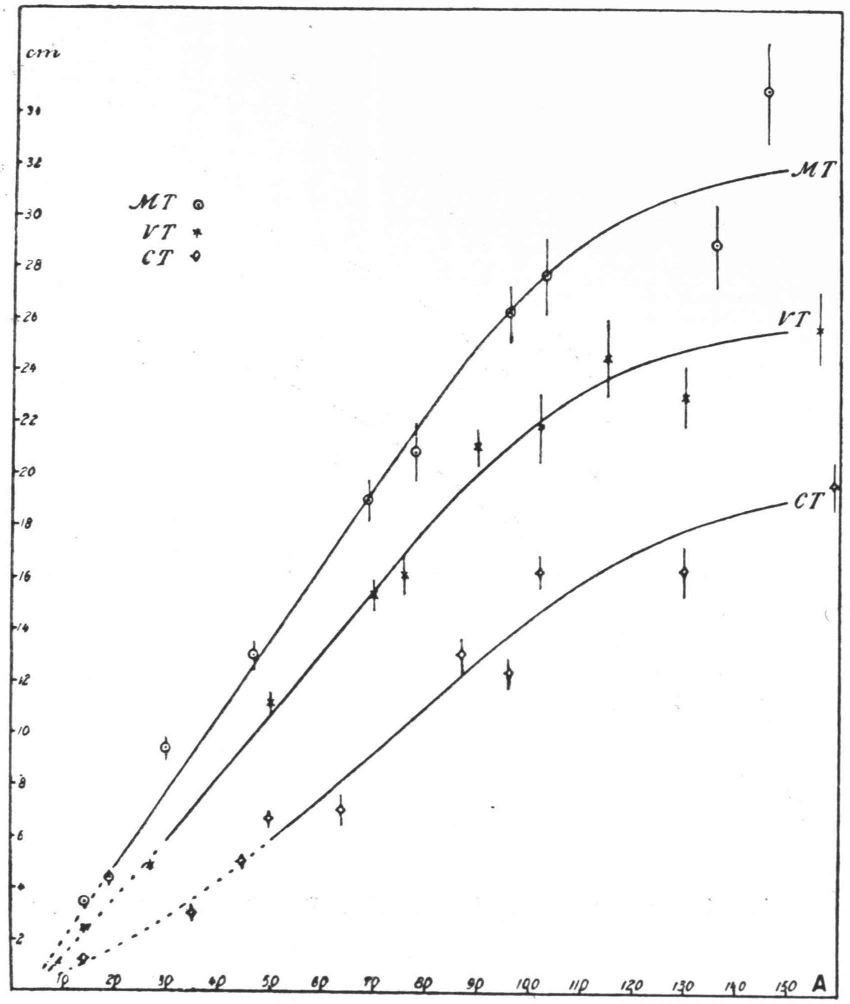
great demands on the regularity (normality) of the stands under investigation. The sample plot material of L ö n n r o t h is also much smaller than that of I l v e s s a l o; it comprises only 30 sample plots, 10 of each of the most important South-Finnish forest type of pine, taken at regular intervals of growth. As regards the possibilities of utilising the forest types, the investigations of L ö n n r o t h confirm the results achieved by I l v e s s a l o most convincingly. As it was necessary to select the sample plot stands with great care with a view to their regularity, so that the real purpose of the study — the elucidation of the inner structure and develop-



Height of dominant trees.

ment of the stands — would be fulfilled, the series of figures presented by L ö n n r o t h show, separately for each type of forest, surprisingly great regularity. In addition to this, in all those respects in which they are directly comparable with the figures of I l v e s s a l o, they are essentially in agreement with the latter figures. — Of the numerous diagrams of L ö n n r o t h illustrating what is mentioned above, those given in figures 2—4 may serve as samples, selected for this purpose.

In the foregoing have been presented t w o s t u d i e s c a r r i e d o u t i n d e p e n d e n t l y o f e a c h o t h e r a n d w i t h g r e a t a c c u r a c y, b o t h o f w h i c h a g r e e i n s h o w i n g t h a t t h e f o r e s t t y p e s, i n r e s p e c t o f t h e s c i e n c e o f f o r e s t



Average diameter of the dominant trees.

m e n s u r a t i o n, a n d a t l e a s t a s f a r a s t h e S o u t h e r n h a l f o f F i n l a n d i s c o n c e r n e d, f i l l t h e r e q u i r e m e n t s m a d e o f t h e m. I n o t h e r w o r d s, t h e y p r o v i d e a b a s i s f o r a c l a s s i f i c a t i o n o f f o r e s t a r e a s w i t h a v i e w t o t h e p u r p o s e s o f t h e s c i e n c e o f f o r e s t m e n s u r a t i o n, a n d t h e y e v e n p r o v i d e a m e a n s o f e s t a b l i s h i n g q u a l i t y c l a s s e s f o r a l l t h e s p e c i e s o f t r e e s j o i n t l y, t h a t i s t o s a y, i n d e p e n d e n t o f t h e t r e e s p e c i e s. Later on, I l v e s s a l o has studied the development

of stands also in respect of North-Finnish forest types and arrived at similar results.[1]

As the growth relations of a stand, especially when they are studied with such accuracy and from so many aspects as I l v e s s a l o and L ö n n r o t h have done, must be regarded as almost the most sensitive, if not the most sensitive i n d i c a t o r s o f t h e b i o l o g i c a l v a l u e o f t h e s i t e, t h e s e s t u d i e s h a v e a t t h e s a m e t i m e p r o v e d t h a t, w i t h t h e a i d o f f o r e s t t y p e s, i t i s p o s s i b l e t o g r o u p t h e f o r e s t s i t e s i n t o c l a s s e s o f e q u a l b i o l o g i c a l v a l u e.

With regard to studies showing the b i o l o g i c a l v a l u e of site defined by means of forest types, it may be mentioned that, according to I l v e s s a l o[2], the number of vascular plants in South Finnish woods of medium age and regular development is as follows: in ClT 9, in CT 28, in MT 86, OMT 105 and OMaT 107. These figures also reflect the biological value of the sites thus defined with the aid of the different forest types.

The site factors, that is to say, the total effect of the qualities of the climate and the soil, determine the biological value of the site. If the area in question is fairly uniform climatically, as for instance is the case, generally speaking, with regard to the Southern half of Finland, it is justifiable to assume that it is the p r o p e r t i e s o f t h e s o i l which essentially determine the biological value of the site. In order to ascertain which properties of the soil are relevant in this respect, the afore-mentioned soil samples were taken from the sample plots of I l v e s s a l o. V a l m a r i[3] analysed these samples, approximately 600 in number, ascertaining the loss of weight on ignition, the total of electrolytes and the content of nitrogen, phosphoric acid, potassium and lime. The results of the analyses are

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[1] Y. I l v e s s a l o: Perä-Pohjolan luonnon normaalien metsiköiden kasvu ja kehitys. (Growth of natural normal stands in Central North-Finland.) Comm. Inst. Forest. Fenn. 24, 1937.

More of the character of special studies are, among others:

L e e v i M i e t t i n e n: Tutkimuksia harmaalepiköiden kasvusta. (Studies on the growth of Grey Alder Stands.) Ibid. 18, 1932.

E r k k i K. K a l e l a: Tutkimuksia Etelä-Suomen viljelyskuusikoiden kehityksestä. (Studies on the development of cultivated spruce stands in Southern Finland.) Ibid. 19, 1933.

[2] Y. I l v e s s a l o: Vegetationsstatistische Untersuchungen über die Waldtypen. Acta forest. fenn. 20, 1922.

[3] J. V a l m a r i: Beiträge zur chemischen Bodenanalyse. Acta forest. fenn. 20, 1921.

expressed in the following average figures pertaining to the top layer of soil of about 20 cm in thickness.

Forest type	Per are (= 100 sq. m) Loss on ignition kgs	Total electrolytes kgs	Per hectare (= 10,000 sq. m) Nitrogen kgs	Phosphoric Acid kgs	Potassium kgs	Lime kgs
AT	1.894	578	4.500	284	840	4.012
OMaT	1.771	781	4.760	250	642	1.760
OMT	1.448	794	3.315	492	486	1.478
MT	1.237	497	2.428	910	446	1.257
VT	1.029	271	1.726	1.479	449	996
CT	1.085	418	1.547	1.080	429	680
ClT	601	220	860	1.471	531	464

These figures disclose a considerable degree of parallelism between the yield capacity of the forest type and the qualities of the soil, and they reveal, further, the difference in the importance of these qualities. A distinct correlation is ascertainable particularly in respect of nitrogen and lime. The following figures presented by Valmari are still more characteristic in this respect (Myrtillus type = 100):

Forest type	Current annual volume increment in Scots pine stand of 75 years	in birch stand of 60 years	The content of CaO in top layer of 20 cm thickness	and N
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 still the dependence of the yield on the properties of the soil, Y. Ilvessalo[1] has calculated the corresponding correlation-coefficients, which according to him are:

loss of weight on ignition	$r = 0.435 \pm 0.078$
total amount of electrolytes	$r = 0.407 \pm 0.081$
content of nitrogen	$r = 0.736 \pm 0.056$
content of phosphoric acid	no correlation
content of potassium	$r = 0.214 \pm 0.091$
content of lime	$r = 0.612 \pm 0.069$

[1] Y. Ilvessalo: Ein Beitrag zur Frage der Korrelation zwischen den Eigenschaften des Bodens und dem Zuwachs des Waldbestandes. Acta forest. fenn. 25, 1923.

In these figures the nitrogen is expressed as the total quantity present. From the biological point of view, however, it is of great importance to form an idea of the quantity of soluble nitrogen. Aaltonen[1] has determined the quantities of ammonia and nitrate nitrogen in the soils of different forest types and found that the forest types in this respect also are clearly different from each other. The greater the yield capacity of a forest type is, the greater is both the quantity of ammonia and nitrate nitrogen, and the total quantity of nitrogen present in the soil.

According to Aaltonen, the total quantity of nitrogen present in the humus of the various forest types is as follows (%):

CT	VT	MT	OMT	OMaT
1 495	1 666	1 796	2 234	1 795

The amount of ammonia and nitrate nitrogen was determined immediately after the sample was taken and after a storage of two months. Their combined share of the total quantity of nitrogen present was as follows (%):

	CT	VT	MT	OMT	OMaT
Immediately after the sample was taken	0.220	0.335	0.383	0.484	0.551
After storage of two months	1.074	1.207	1.819	2.868	4.425

Previous to that, Aaltonen[2] had examined the hydrogen-ion concentration of about 800 humus samples and arrived at the following pH-average for the forest types of the Southern half of Finland:

OMaT	(5.0) [3]
OMT	5.2
MT	4.8
VT	4.6
CT	4.2
ClT	3.6

Figures like those presented above leave no doubt that certain properties of soil, in climatically fairly uniform

[1] V. T. Aaltonen: Über die Umsetzung der Stickstoffverbindungen in den Waldböden. Comm. Inst. Forest. Fenn. 10, 1926.

[2] V. T. Aaltonen: Über den Aziditätsgrad (pH) des Waldbodens. Ibid. 9, 1925. Cf. also:

V. T. Aaltonen: Einige pH-Bestimmungen in Waldböden. Ibid. 25, 1937.

O. J. Lukkala: Über den Aziditätsgrad der Moore und die Wirkung der Entwässerung auf denselben. Ibid. 13, 1929.

[3] Material insufficient (only 5 samples).

areas, vary, on an average, directly with the quality of site, determined on the basis of forest types, which seems to justify the conclusion that, on climatically uniform areas, certain properties of soil determine the quality of the site. In individual cases the figures reflecting these different properties vary quite considerably, which, however, only confirms what is said above, viz. that the properties of the soil vary to a great extent independently of each other, and that in individual cases now the one, now the other property is so far away from the harmonic optimum that it can essentially affect the quality of the site, in spite of the fact that the properties can partly replace each other. Aaltonen[1] has very strongly stressed that the investigations have to be extended to comprise simultaneously as many properties of the soil as possible — including physical ones. On the other hand, the figures presented show that site conditions in nature are of decisive importance for the appearance of vegetation-units, which the geobotanists during the last few decades have tended to doubt, and on the other hand that a biological classification of sites has a very firm basis in the forest types. It should not be impossible to conceive that this way might eventually lead to such a classification of sites as would be based on purely climatic and pedological factors. But it is of equal importance that this method should lead to the solution of the question of the factors which in different conditions determine the magnitude of the yield capacity. In this way, a reliable basis is secured for measures aiming at an improvement of the yield capacity of forest-land. — To the knowledge of the soil-microbiological differences of the various forest types, the investigations of Svinhufvud[2] have made further important contributions.

[1] V. T. Aaltonen: Über die Möglichkeit einer Bonitierung der Waldstandorte mit Hilfe von Bodenuntersuchungen. Acta forest. fenn. 34, 1929.

V. T. Aaltonen: Über die Bodenkundliche Bonitierung der Standorte. Comm. Inst. Forest. Fenn. 25, 1937.

V. T. Aaltonen: Metsämaa. (Forest soil.) Porvoo 1940.

[2] V. E. Svinhufvud: Untersuchungen über die bodenmikrobiologischen Unterschiede der Cajander'schen Waldtypen. Acta forest. fenn. 44, 1937.

Silviculture has to be based on the biology [1] of the forests. Each normal stand with its whole living microcosmos constitutes a harmonic whole in a rather unstable state of equilibrium, the quality and character of which are essentially dependent on the site. This determines the growth and development of both the trees and the stands as well as its stem classes, and, in all probability, not only what pertains to the parts above the earth but also what is below the earth (roots). The site determines, not only the number of plant species present in a forest but, to an essential extent, also the floristic composition of this vegetation, and to a great part also the frequency and abundance of the species. In conjunction with the trees and other vegetation, the character of the site affects in a decisive way the well-being of the micro-organisms living in the soil, the formation and decomposition of the humus, and the leaching of the soil. The stand affects the climate of the forest very markedly, especially as regards light conditions, but also temperature, moisture, etc. It affects both in this way and with its root competition the conditions of life of the ground vegetation and the micro-biological happenings in the soil. In a forest, everything struggles against everything else, yet, on the other hand, there is a common though unconscious favouring of one species by another. All this results in the above-mentioned state of equilibrium, and thus the struggle in a forest is a most complicated series of events, arising from the quality and character of the site. However, this state of equilibrium is very unstable so that even small changes, such as, for instance, the thinning of the stand, bring about alterations in almost all the respects mentioned above — alterations which are analogous but not identical with each other in the different site classes and the different forest types.

Irrespective of whether the forest has come into being by sowing, planting or natural seeding, it grows and develops without human aid. The essential purpose of silviculture is to guide that development into an economically favourable direction. This can only be done successfully provided the life-history of the forests is known and understood in all its aspects.

[1] Cf. A. K. Cajander: Die Forstwissenschaftliche Forschungsarbeit in Finnland. »Vorträge über Waldwirtschaft und Forstwissenschaft in Finnland. Gehalten auf der Exkursionsreise der estnischen Forstmänner nach Finnland.» Helsinki. 1925.

A. K. Cajander: Some Aspects of Forest Research Work. World Forestry Congress 1926. Silva fennica 4, 1927.

A. K. Cajander: The scientific foundation of forestry as exemplified chiefly by forest research work in Finland. Silva fennica 4, 1927.

Systematic silviculture must thus be based on a full knowledge of the life-history of the forests and of their biology, and as the biology of forests is very different on different sites, it is obvious that silviculture must not become stereotyped, but must adapt itself to the conditions the different sites offer for the life of the forests, their renewal, growth and development.

In order to throw some light on the question of how classes of sites characterised by different types of forest require different kinds of silviculture, the following very general observations made on German forest conditions are offered.[1]

Regeneration of forests by means of clear cutting together with subsequent artificial reforestation encounters great difficulties in all grass-herb forest types and especially in the most luxuriant[2] ones. As soon as wood is clear-cut the felled area will be covered by a tall and dense weed vegetation, which practically covers the young planted seedlings during their first years of life. Even where the ground flora is annually mowed down or cleared away by some other means, a considerable part of the seedlings perish. Reforestation by means of clear cutting is much easier in forests on moist land; there no special precautions are required against the excessive growth of the ground flora, except, possibly, only in forest types verging on deciduous forest. Of still less importance are such precautions, generally speaking, in dry heath forests.

The success achieved by the group felling method is also different for different forest types. It leads to good results even in the most luxuriant forest types provided they consist of those species of trees whose seedlings can survive stronger shade than most of the ground flora, and for which the regeneration gaps can be kept so shaded that the ground flora does not become too dense. Tree species of this type are silver fir and beech, whereas the regeneration of spruce in this way proves exceedingly difficult. The regeneration of spruce can, however, be done successfully by means of group felling in the OMaT and OMT forests and, better still, in the MT forests.

The Schwarzwald group-selection method of cutting is all the more successful in grass-herb forests the more abundant the beech and especially the silver fir is, as the seedlings can then be kept heavily shaded all the time; in other words, a very slow regeneration can be applied. It is also well adapted for use in moist land forests (OMT, MT, etc.), all the more so the more the spruce predominates.

[1] A. K. Cajander: Ueber Waldtypen 1909.

[2] This applies to stands on fresh and not on more or less moist sites.

It would be easy to give examples of a similar kind from the Northern countries, not only with regard to reforestation but also concerning improvement fellings, the growing of undergrowth and of reserve trees, pruning, etc. — With regard to all this, it is quite natural that the application of forest type classification in Finnish forestry is becoming more and more common. For the purposes of organizing the management of the State forests, it was introduced in 1914, through the initiative of the Department of Forestry, and the Forest Taxation Act of 1922 is on all essential points based on the forest types.

It is a special feature of the Northern countries, that swamps are drained on a large scale for the purposes of forest management. Numerous types of swamps are recognizable, and the following question presents itself: what is the reaction of these different swamp types to drainage?

The forest type is a result of the biological total value of the site — a combined result of the total influence of all primary climatic and soil factors on the vegetation. When a swamp is drained and assumes the character of ordinary forest land in respect of its moisture conditions, therefore, it can be taken for granted that the forest type or forest types which correspond to the biological total value of the site, are likely to gain dominance. That this actually is the case is proved by the investigations of Tanttu.[2]

The investigations by Tanttu show that very waterlogged, treeless moor, depending on the effectiveness and duration of the drainage, gives either a slightly drier, treeless moor, a forested moor or, as a result of complete drainage, a certain forest type characteristic of normal forest-land. These series of changes are very regular, and hardly dependent on the thickness of the peat. Wet pine peat-moors change into dry and dryish and poorer wet spruce-broadleaftree peat-moors into moist forest-lands, better ones again into grass-herb forest-lands. The studies of Lukkala[1]

[1] Cf. especially Yrjö Ilvessalo: Metsätyyppien esiintyminen eri maalajeilla. (Occurrence of forest types onthe different soils.) Comm. Inst. Forest. Fenn. 18, 1933.

[2] A. Tanttu: Tutkimuksia ojitettujen soiden metsittymisestä. (Investigations into the natural forestation of drained swamps. Acta forest. fenn. 5, 1915.

show, too, that the growth of the stand in a forest type that has developed on wet peatland is, at least in general features, similar to the corresponding type on firm land, provided that the drainage goes deep enough and that the ditches are kept in good condition. The fact that a type of moor after draining changes into a forest type the character of which can be estimated, at least approximately, in advance, and which has the yield capacity peculiar to the forest type in question, is of course of the greatest practical importance as it makes possible advance calculation regarding the profitability of draining and different afforestation measures.

Also among meadows, different types can be recognized, and as the so-called natural meadows of our country are primarily either former moors or former forest-lands that have been cleared, the determination of the moor type or forest type corresponding to them (at least in the collective sense) might also be considered. And when moor types are changed into corresponding forest types, a uniform classification can be obtained for forests, moors, and meadows. As proved by Lukkala[2] and Linkola[3] fields also can be included in the same classification although only with great caution, and in the first place only where the field area is rather small compared with the forest area; in this connection, it is mainly groups of types which are applicable. The final clarification requires, however, further detailed studies. It is obvious, however, that a uniform and objective classification according to quality of all productive soil would be of importance both from a practical and a scientific point of view.

[1] O. J. Lukkala: Nälkävuosien suonkuivausten tuloksia. (Results of swamp drainings during famine years.) Comm Inst. Forest. Fenn. 24, 1938.

[2] O. J. Lukkala: Tutkimuksia viljavan maa-alan jakautumisesta pääasiallisesti Savossa ja Karjalassa. (Investigations into the division of fertile land primarily in the provinces of Savo and Karelia.) Acta forest. fenn. 10, 1919.

[3] K. Linkola: Zur Kenntnis der Verteilung der landwirtschaftlichen Siedlungen auf die Böden verschiedener Waldtypen in Finnland. Acta forest. fenn. 22, 1922.

After having described in the foregoing the significance of the forest types for forestry, both in the practical and scientific connections[1], I would now like to deal with some further general questions, in the sequel.

Sites are not permanently fixed. Their present state is permanent only in a relative sense. Numerous instances where forest soil, even under management, has changed in respect of yield capacity, are reported.

The most common phenomenon of this type is swamp-invasion on forest land that has taken place on a very large scale in the Northern countries. According to the first general survey of the forests in Finland, conducted by Y. Ilvessalo[2], 35.7 % of the total area of Finland consists of swamps, and all these swamps have come into existence during the post-glacial era, roughly within the last 10,000 years. According to the careful investigation of Backman[3], at least 95 % of the swamps of Central Ostrobothnia were formed through swamp-invasion of forest land, and his studies on the Carelian Isthmus have led to very similar results. It may be regarded as certain that the bulk of the peat-moor land of Finland is forest land invaded by swamp. This swamp-invasion goes on, even on a big scale.[4]

Many facts seem to indicate that, apart from swamp-invasion of vast forest lands, impoverishment of soil has also taken place in the Northern countries, partly due to the fact that rain water and water melting from snow percolating through the soil, carry with them materials in solution and very fine particles in the form of silt[5], and partly to the fact that water flowing along the surface carries these materials from higher soil levels to low-lying ones, to watercourses and to the sea. In our climate these processes are scarcely counterbalanced by the weathering pheno-

[1] Perhaps with certain exceptions cf., e. g. A. K. Cajander: Ueber Waldtypen 1909, pp. 173—175.

[2] Y. Ilvessalo: Suomen metsät. Metsävarat ja metsien tila. (The Forests of Finland. The Forest Resources and the condition of the Forests.) Comm. Inst. Forest. Fenn. 9, 1924.

Y. Ilvessalo: Die Waldvorräte Finnlands auf Grund der Taxierung aller Wälder des Reiches. Vortr. ü. d. Waldwirtschaft u. Forstwissenschaft in Finnland. Helsinki 1925.

[3] A. L. Backman: Moor-Untersuchungen im mittleren Österbotten. Acta forest. fenn. 12, 1919.

[4] O. J. Lukkala: Tapahtuuko nykyisin metsämaan soistumista? (Is there any swamp-invasion of forest land at present?) Comm. Inst. Forest. Fenn. 6, 1922.

[5] Cf. V. T. Aaltonen: Über die postglazialen natürlichen Veränderungen des Waldbodens in Finnland. Ibid. 18, 1933.

mena which give rise to new plant nutrients. Thus the investigations of Auer[1], carried out in the districts of Kuusamo and Salla, have shown that such swamps there as are swamp-invaded forest lands, in their bottom layers more generally contain remains of peat-moor types (fens, etc.) indicating a substratum richer in nutrients than those moors which in these days are formed by swamp-invasion of forest land. In agreement with this is the fact that, in mountainous districts, the tops of the hills and mountains are on an average more infertile than the bottom parts of the slopes and the valleys. The same phenomenon is also visible, on a large scale, in the difference in their main features which occur between large watershed regions consisting exclusively of poor lands and regions in the vicinity of watercourses.

Many factors may tend to accelerate these slow processes. Ordinary forest exploitation, when only the trunk is removed from the forest, seems to be of little consequence in this connection, because the wood of the trunk contains, as is well-known, only relatively little of the so-called mineral ash. Of greater importance are the forest-fires, and more remarkable still in respect of its consequences is burn-beating. In this cultivation, as is well-known, as many successive crops were taken as the soil could possibly grow, and after that the area was usually used for grazing without any kind of manuring. Thus the investigations Multamäki[2] has carried out in Eastern Finland seem to indicate that the intermediate grades between Myrtillus and Vaccinium types, often found on ancient burnt-over areas, to a great extent represent an original Myrtillus type soil, which on account of burn-beating and subsequent grazing, has degraded towards the Vaccinium type. The investigations of Palmgren[3] carried out on the Aaland Islands show that the grass-herb forests (ST) there tend to change into spruce forests on account of grazing, with simultaneous deterioration of the forest type.

[1] V. Auer: Suotutkimuksia Kuusamon ja Kuolajärven vaara-alueilla. (Swamp inveestigations in the hill districts of Kuusamo and Kuolajärvi.) Comm. Inst. Forest. Fenn. 6, 1922.

[2] S. E. Multamäki: Tutkimuksia metsien tilasta Savossa ja Karjalassa. (Invstigations into the condition of forests in the provinces of Savo and Karelia.) Acta forest. fenn. 9, 1919.

[3] A. Palmgren: Studier öfver löfängsområdena på Åland. Ett bidrag till kännedom om vegetationen och floran på torr och på frisk kalkhaltig grund. I. Vegetationen. Acta soc. pro fauna et flora fenn. 42, 1915.

A. Palmgren: Zur Kenntnis des Florencharakters des Nadelwaldes. Eine pflanzengeographische Studie aus dem Gebiete Ålands. Acta forest. fenn. 22, 1922.

In Central Europe, the use and removal of forest litter has in many places brought about a remarkable deterioration of forest-lands, which, however, has not yet been more closely investigated from the point of view of forest types.

It is generally assumed — and the Central-European investigations seem to confirm it — that the spruce, mainly because it promotes the formation of acidic raw humus, at least in certain circumstances may lead to deterioration of forest land. I would no doubt be of interest to ascertain, through detailed investigation of typical cases, on the basis of forest types, whether and to what extent for instance such Central-European spruce forests, rich in bilberry bushes, where there is a raw humus layer, grow on former grass-herb forest lands. It seems quite probable that the North-Finnish thick-moss type actually is a result of the deterioration of forest land caused by spruce forest in certain climatic conditions; many facts actually point in that direction.

On the other hand it is worth mentioning that, thanks to the development referred to earlier, low-lying lands, water-course valleys, etc., have become more fertile at the expense of the higher lands. A very important factor in this connection is also the rise in land taking place on the shores of the Gulf of Bothnia and of the Gulf of Finland, through which land is continually being exposed that is not only unleached but even enriched; the geobotanical significance of this phenomenon was especially stressed by Palmgren.[1] — Very common is the belief that broad-leaved trees, expecially the so-called valuable ones, will improve the soil. It would be of great importance to make quite clear by means of detailed investigations on the basis of a comparison of forest types, to what extent improvement of this kind of soil has actually taken place. It may easily be the case that the significance of beech and other so-called soil-improving tree species has been partly exaggerated, in the same way as Aaltonen[2] and Wie-

[1] A. Palmgren: Hippophaës rhamnoides auf Åland. Acta soc. pro fauna et flora fenn. 36, 1912.

A. Palmgren: Hafstornet (Hippophaës rhamnoides), dess utbredning, biologi och uppträdande på Åland. Acta forest. fenn. 7, 1917. A lecture delivered Feb. 22. 1913.

A. Palmgren: Die Artenzahl als pflanzengeographischer Charakter, sowie der Zufall und die säkuläre Landhebung als pflanzengeographische Faktoren. Acta bot. fenn. 1 and Fennia 46.

[2] V. T. Aaltonen: Über neuere Betriebsarten in Deutschland. Acta forest. fenn. 25, 1923.

demann[1] by their special studies have proved to have been done in respect of the so-called »Dauerwald»-system.

The object of these remarks is by no means to belittle the significance silvicultural operations may have in maintaining and improving the yield capacity of the soil. On the contrary, it is of particular importance to find out by what measures, whether agrogeological or purely silvicultural, forest lands could be temporarily or, better still, permanently improved; it is equally important, however, to ascertain by site classes, whether and to what extent the general ideas concerning the deteriorating or improving influence on the soil of silvicultural operations are correct, and to give them their correct value. It is of equal importance, further, to clarify the extent to which the above-mentioned natural impoverishment and local improvement of soil has taken place and actually takes place and whether these processes can be affected by economic operations. These are questions of the greatest importance, and their solution is hardly possible without accurate, critical, detailed, and in the first place probably comparative investigations, whose object is to study the quality conditions of the sites. It seems to me as if these questions could be brought considerably nearer to their solution if due attention is paid to the proportional presence of the forest types, and naturally also to the leaching phenomena[2] characteristic of the different forest types.

Forest types are, of course, applicable as a basis for forest mensuration and mapping as well as for the collection of various statistical information. They were utilised to their greatest extent in the survey of the Finnish forests carried out in 1922-1924 by the line-survey method with a distance of 26 km. between the lines all over Finland. In this connection the type of each stand-unit (totalling about 100,000 in number) on the map coinciding with the line was determined. In this way, very useful statistics were obtained on the quality of sites in this country. The usefulness of these

[1] E. Wiedemann: Die praktischen Erfolge des Kieferndauerwaldes. Braunschweig 1925.

[2] Cf. e. g. O. Tamm: Markstudier i nordsvenska barrskogsområdet. Medd. Stat. skogsförs. anst. 17. Stockholm 1920.

statistics is enhanced by the fact that in the yield tables of the Finnish main tree species the quality classes of forest lands are the same as the forest types applied in this survey. At the same time, statistics were also obtained with regard to peat-moors, meadows, etc. This fact is of significance not only in connection with forest science and forest policy, but it provides also a good general survey of the fertility conditions of our country. By calculating the percentage of the total forest area of various natural districts covered by grass-herb forest types, or covered by this type and types resembling grass-herb forest types (OMT, PyT), or by these two and Myrtillus type, we obtain a fairly clear picture of fertility conditions in different part of the country. — In 1936-1938, a new survey of the forests in Finland was carried out with a distance of 13 km. between the lines.

The results can be checked by means of another, purely floristic method. On the basis of investigations and observations made, and from the herbaria of botanists and those interested in botany, the botanical range and appearance of plant species in Finland is, generally speaking, fairly well known.[1] When particularly exacting species of plants are picked out and their sites marked with dots on a map, these dots naturally are grouped together in districts where the sites favourable for these plants are most numerous; in other words in districts where the soils are rich, and mainly in districts where exacting and rich forest, swamp and other types are most frequent.

Certain areas are recognizable in Finland, which, on account of their richness in grass-herb forests and forests resembling grass-herb forests as well as the unusual frequency of valuable broad-leaved trees and, generally, of more exacting species of plants, are called grass-herb forest centres.[2] Their fertility exceeds the average considerably, and all kinds of transitional degrees connect them with districts which in this respect are the antithesis of grass-herb forest centres. Of such grass-herb forest cent-

[1] Cf. especially the merited work of Hj. Hjelt: Conspectus florae fennicae. Acta soc. pro fauna et flora fenn. V 1888—1895, XXI 1902, XXX 1906, XXXV 1911, XLI 1919 and LI 1923.

[2] A. K. Cajander: Viljavan maa-alan jakaantuminen Suomessa. (Division of fertile land in Finland.) Published in the periodicals entitled Metsätaloudellinen Aikakauskirja 1916 and Metsänhoidon perusteet I, 1916.

O. J. Lukkkala: Tutkimuksia viljavan maa-alan jakaantumisesta Savossa ja Karjalassa. (Investigations into the division of fertile land in the provinces of Savo and Karelia.) Acta forest. fenn. 9, 1919.

res, the following may be particularly mentioned (in pre-war Finland). The Centre of the Aaland Isles and South-Western Finland, the Lohja water system centre, the Pirkkala centre (Tyrvää—Ikaalinen—Längelmäki—Vanaja), the Hollola centre (the surroundings of the Vesijärvi Lake, Southern part of Lake Päijänne and the upper course of the River Kymi), the Vuoksi centre (Viipuri with surrounding district), the Sortavala centre (South of Ruskeala approximately) and the slightly less well-marked Kuopio centre. Outside these special grass-herb forest centres, forests resembling grass-herb forests are found fairly frequently on the Southern coast, partly also on the Gulf of Bothnia, in the district of Lemi-Mikkeli, etc. and finally in Kuusamo and Salla as well as in farthest Lapland, Petsamo. In contrast with the grass-herb forest centres are the extremely barren districts, not only in Northern Finland, but also in wide areas on the aforementioned watersheds of Suomenselkä, Maanselkä, Karjalanselkä, et c — This unequal distribution of fertile land has. had an extremely marked influence on the colonisation of Finland and its agricultural conditions. This influence was felt as early as the times when fishing and hunting were the most important means of subsistence of the population, for both game[1] and fish[2] — provided they have not been destroyed by excessive exercise of these pursuits — are most abundant in the most fertile districts; and the influence increased when cattle breeding and agriculture had become the main occupations. As a matter of fact, the earliest centres of settlement of the Karelians were situated in the fertile grass-herb forest centres of Sortavala

[1] Cf. P. Palmgren: Quantitative Untersuchungen über die Vogelfauna in den Wäldern Südfinnlands mit besonderer Berücksichtigung der Wälder Ålands. Acta zool. fenn. 7, 1930.

Olavi Kalela: Über die regionale Verteilung der Brutvogelfauna im Flussgebiet des Kokemäenjoki. Ann. zool. soc. bot.-zool. fenn. Vanamo. 5, 1938.

[2] Valle in particular has convincingly proved that »die südfinnischen Seen im grossen und ganzen auf Grund der sie umgebenden Vegetation und Flora bonitieren können and that »auch in vielen unklaren Einzelfällen die pflanzentopographische und floristische Bonitierung der Umgebung Hinweise auf die Produktivität des Sees geben kann, wenn dies auch nicht in allen Fällen möglich ist.»

K. J. Valle: Über die Bonitierung der Südfinnischen Seen. Acta forest. fenn. 34, 1929.

and Vuoksi, those of the Tavastians in the grass-herb forest centres of Hollola and Pirkkala, while the Swedish settlement was found particularly in the grass-herb forest districts of South-West Finland. From the most fertile regions, culture spread step by step to those next in fertility. Thus, for instance, Kuopio was colonised earlier than the barren districts of Pieksämäki, though situated further South, etc. Northern Finland and the extensive watershed regions in the Southern half of Finland, which for this reason have been taken possession of by the State, are still the most thinly populated. Very similar to these are the districts where wood-working companies are great landowners (Ilomantsi, Rautavaara, etc.), whereas the state farms and old manors, etc., are situated in more fertile districts.

The influence of the different fertility conditions has not only made itself felt in the development of land ownership relations but is still being felt everywhere today.[1] The grass-herb forest centres where the first settlements were made are, other things being equal,[2] still the best agricultural districts of Finland whereas agriculture in areas found infertile has remained at a considerably less advanced stage. As Linkola in particular has proved this influence is not confined exclusively to agriculture, but is felt also in general economic conditions: in otherwise identical circumstances, the population of more fertile areas is in all respects better off and the general level of education is at its highest. This does not, however, apply to Finland only, and Linkola[3] records observations of a similar nature also in the Swiss Alps.

[1] Cf. K. Linkola: Zur Kenntnis der Verteilung der Landwirtschaftlichen Siedlungen auf die Böden verschiedener Waldtypen in Finnland. Acta forest. fenn. 22, 1922.

K. Linkola: Maan viljavuussuhteista Suomen eri osissa kasvimaantieteellisten havaintojen valossa. (On the fertility of lands in the different parts of Finland in the light of geobotanical observations.) Publ. in the Year-book of Finnish University at Turku in 1923.

[2] As regards the centres of Vuoksi and Sortavala, it should be borne in mind that these districts from 1721 till 1812 were part of Russia, and the Russian land grants constituting a considerable part of these districts were not redeemed by the Finnish State before the latter half of the 19th century.

[3] K. Linkola: Waldtypenstudien in den Schweizer Alpen. Veröffentl. Geobot. Inst. Rübel in Zürich, 1, 1924.

Here an extremely productive field is revealed for investigation, which will enable us to understand and account for an important but hitherto comparatively neglected point of view as to how colonisation, cultivation and intellectual culture have developed up to the present stage in the Northern countries and those comparable to them, and which will furnish guidance of great practical value for future activities on these lines. The division of fertile lands, which is found to be unequal, has, on the other hand, occasioned investigation into which factors in general natural conditions have brought about this differentiation — a subject which in itself is one of the basic research tasks of geology, and to which hardly any attention has hitherto been paid.

Along with the promotion of forest research work and the allround development of forestry, specialisation and differentiation are also taking place in forestry. As regards silviculture in particular, the fact that the attention paid to the natural site classes in the near future no doubt will become more and more important, denotes an ever more widespread specialisation. In silviculture as everywhere else, specialisation is essential for all progress.

But mere specialisation cannot satisfy a professional forester either. He must find his way out of the labyrinth of detailed knowledge to the free air where he can gain a general view of forest knowledge in its entirety and, in particular, where he can form an idea of what is essential and what is less essential. He also strives after forming general rules from the sum of his knowledge. And for purely practical reasons, it is of the greatest importance for him to know to what extent the results attained in the field of forestry in other countries are applicable in the forests for the management of which he is responsible. This idea leads to the question of the internationalism of silviculture. Is international silviculture possible and to what extent?

The several parts of our globe are, as is well-known, very different from each other. Geobotanists divide the earth into extensive regions depending on the climate: forest, grassland, moss and lichen formation (tundra, etc.),

and desert. The forest area again is divided into, for instance, the area of tropical rain forests, that of savanna forests, of broad-leaved sclerophyllous forests, of deciduous broad-leaved forests and of coniferous forests of the cool climates. In all these, the plant covering, like mosaic work, is composed of numerous vegetation units, the distribution of which is essentially determined by climate and soil together. Each of these main formations of forests comprises a number of subformations with their characteristic forest types, the boundaries of botanical ranges of which do not even approximately coincide with those of the formations mentioned above.

On the basis of what I have said above, the forest types or, in general, the natural site classes have to form the foundation for determining whether silviculture can be made[1] international; and also to what extent those silvicultural methods can be generalised as international attainments which have been locally developed, are exclusively in local use and have locally led to good results. In all probability, it is justifiable to assume that, when forest types are identical, identical treatment of the forests will lead to the same results. On the other hand, if mutually interchangeable or otherwise closely related forest types are in question, the possibility of a successful application of the same methods must be greater the more the forest types in question resemble each other. Already for this reason the application of common silvicultural methods becomes geographically restricted. At the same time it has to be taken into consideration that the market conditions of the forest products in each case give local features to silviculture, as they, in a decisive manner, determine the economically most favourable methods of management from among those that are biologically possible.

The above does not apply exclusively to forestry but the specialisation of economic activities for geographical reasons applies to plant cultivation in general, and indirectly also to those branches of economic life that are based on plant cultivation or dependent on it. Whereas agriculture in the Southern half of Finland — to mention just one example — gives prominence to field cultivation, agriculture in Northern Finland, where the forest types differ considerably from those in South-Finland,

[1] This applies to some extent also to the organisation of forestry.

as do those growing in similar conditions in more Southern mountain regions, abounds in meadows and gives preference to pasture farming. In the Central-European deciduous forest district where the area of arable land is in proportion incomparably bigger than in South-Finland, wheat is grown more than any other cereal. In still milder climates, where the forest types characteristic of them predominate, a combined cultivation of trees (mulberry trees, fruit trees, etc.) or vine and of field-crops is encountered.

General natural conditions and the economic life dependent of them, as shown above, put their stamp on the intellectual culture. It is not to be considered a mere chance that the oriental culture was established and developed in the area of the tragacanthic climate, scarce in forests and abounding in grass-lands; the Greco-Roman culture again in the district of the olive climate in the Mediterranean countries, characterised by evergreen broad-leaved sclerophyllous forests and bushes; and the Western civilisation in the area of the oak climate, characterised by deciduous broad-leaved forests. In the same way, in spite of adverse currents, the economic and, along with it, the intellectual culture, resulting from natural differences in the various areas, will no doubt retain special features, which may even become more and more distinctive as economic competition intensifies which, when we approach the maximal density of population, will compel the nations to develop their means of livelihood to the extreme. The natural conditions of each region provide a certain framework for its economic activities, and the economic and intellectual level of each nation depends decisively on how well the nation knows the natural possibilities of its own country and how effectively it understands and is capable of utilising them.

Instructions for the Establishment of Forest Types.

For the establishment and description of the forest types of a certain area, either a geobotanically trained forestry expert or a geobotanist sufficiently acquainted with forestry and equipped with practical field experience must be referred to.

When classifying forest types, virgin forests or, in their absence, regularly developed mature or nearly mature stands verging on natural forests, have to be taken as a starting-point.

Before the description of forest types is begun, it has to be ascertained by excursions into natural forests or forests verging on the natural, which forest vegetation-units are the most dominant or frequent ones in the area in question. The description of these typical vegetation-units cannot be started unless this kind of thorough investigation is made in advance.

The botanical description of sample stands must be as many-sided as possible and comprise both tree and ground vegetation, and — particularly in tropical and subtropical districts — at least the most important epiphytes and lianes. Information of a general nature, at least, on the growth of plants and particularly of trees (for instance, on their height and age) is of great importance. Of course, the more comprehensive and detailed the vegetation analyses of the sample stands are, the better. But the more one considers details in this respect the more time it takes to make a description, and for that reason it is often essential to be content with descriptions of a more general, guiding character. In any case it is absolutely necessary to make all notes concerning the vegetation in strict conformity with one and the same formula, and the sample plots selected for them must not be too small.[1] These notes are most appropriately made on printed forms. To measure the degree of abundance of ground vegetation species, I should like to recommend the Norrlin[2] scale.

Even though the descriptions of sample stands or vegetation test plots should so far as possible be made according to the same formula, the procedure of classifying and demarcating the vegetation units must not by any means be too schematic. On the contrary, it has to be carefully considered which qualities are characteristic of any one vegetation-unit, and every individual forest vegetation-unit has to be defined according to its typical qualities. In addition to this, the growth of tree stands especially and their different tree species, has to be taken into account.

After the vegetation-units of the natural forests or the mature forests in the district in question are described, we have to go on to describe the vegetation of all kinds of stands treated by fellings, of felled areas, of burnt-over and seedling areas, of pole-stage forests, etc. — Not even the densest pole-stage stands in which the other vegetation is often

[1] Y. Ilvessalo: Vegetationsstatistische Untersuchungen über die Waldtypen. Acta forest. fenn. 20,

[2] Cf. A. K. Cajander: Gedächtnisrede für J. P. Norrlin. Acta forest. fenn. 23. p. 46.

very scanty — though, nevertheless, characteristic of the forest type in question — can be omitted. And it must always be carefully decided[1] to which vegetation-unit of natural forests or regularly developed, economically mature forests each of these differing botanical formations belongs. In this way, a comprehensive idea can be formed of the range of variations within each forest type (cf. above, pp. 00—00).

It is of course desirable that all the forest types in an area should gradually be described, including the rare and less important ones, which actually are only of theoretical interest. But in the first place it is essential to describe all predominant forest types important from the economic aspect because rare and more or less accidental forest types have for the purposes of forest mensuration and organised forest management to be grouped under the more important types to which they are related.

As soon as the forest types of the area in question have been provisionally distinguished, more detailed investigations, as comprehensive as possible must follow, comprising 1. the still more detailed vegetation analyses of the variation range of each forest type, 2. as complete as possible plant biological (or plant ecological) studies on each forest type of importance[2], in which connection attention must also be paid to 3. soil biological studies, and 4. all kinds of studies within the science of forest mensuration (such as those by Ilvessalo, Lönnroth, etc.).

With the aid of the last-mentioned studies (14), the provisionally distinguished forest types are of course more accurately defined and their system in its entirety to some extent revised, so as eventually to achieve such a forest type system as fulfils the highest requirements of both natural science and practical purposes. In this connection, it may easily happen that, for practical reasons, floristically different but ecologically closely related forest types have to be grouped together, and vice versa. For, as seen from a forester's point of view, the final result must be the creation of a forestry and not only plant-sociological forest type system.

In approximate accordance with these methods, Y. Ilvessalo[3] and Kujala[4] have studied the forest site types of Canada and of

[1] Cf. A. K. Cajander: Metsätyyppiteoria. (The Theory of Forest Types.) Acta forest. fenn. 29. pp. 28—29.

[2] Cf. Congress Reports. Silva fennica 4, 1927, pp. 31—32 and 84—88.

[3] Yrjö Ilvessalo: Notes on some Forest (site) Types in North America. Acta forest. fenn. 34, 1929.

[4] Viljo Kujala: Waldvegetationsuntersuchungen in Kanada. Ann. Acad. scient. fenn. A. IV. 7.

the Northern parts of the United States. Linkola[1] has studied important parts of the Swiss and Esthonian forest types, with particular regard to botanical conditions. Aarno and Erkki K. Kalela[2] together have made investigations into East-Patagonian forest types. Of American studies on the same questions are to be mentioned especially those of: Heimburger, Ray, Sisam and Petawawa Forest Experimental Station.[3]

[1] K. Linkola: Waldtypenstudien in den Schweizer Alpen. Veröffentl. geobot. Inst. Rübel in Zürich, 1, 1929.

K. Linkola: Zur Kenntnis der Waldtypen Eestis. Acta forest. fenn. 34, 1929.

[2] Erkki K. Kalela: Über die Entwicklung der herrschenden Bäume in den Beständen verschiedener Waldtypen Ostpatagoniens. Ann. Acad. scient. fenn. A. IV. 3. 1941, containing as a prefatory note a survey of the East-Patagonian forest types by Aarno Kalela.

[3] Carl G. Heimburger: Forest-Type studies in the Adirondack region. Cornell Univ. Agricult. Exp. Stat. Memoirs 165. Ithaca, New York 1933.

Carl G. Heimburger: Forest site classification and soil investigation in the Lake Edward Forest Experimental Area. Canada, Dept. Mines and Res., Dominion Forest Service Silvicult. Res. Note 66. Ottawa 1941.

R. G. Ray: Site-types and rate of Growth. Canada Dept. of Mines and Res., Dominion Forest Service. Silvicult. Res. Note 65. Ottawa 1941.

J. W. B. Sisam: The correlation of tree species and growth with site-types. Canada Dept. of Mines and Res., Dominion Forest Service Silvicult. Res. Note 53. Ottawa 1938.

Petawawa Forest Experimental Station. Report by Canada Dept. of Mines and Res., Dominion Forest Service. Ottawa 1938.

Appendix.

On German Forest Types.

In 1906—1907, the author had an opportunity of investigating several German forest areas. The purpose of these investigations was twofold: firstly, to make himself thoroughly acquainted with silviculture in Germany, and secondly, to carry out preliminary studies of the scientific value and economic significance of forest types.

The investigations were made in the following German supervisory districts: in Ullersdorf in the Silesian mountains near the town of Liebau, in Tharandt on the Northern slopes of the Erzgebirge mountains, in Bischofsgrün on the Fichtelgebirge mountains, in Wolfstein, Bayrischer Wald, near the town of Freyung, in Kelheim on the Danube near Regensburg, in Sachsenried on the plateau of Bavaria-Schwabia between the rivers Lech and Wertach, and in Wolfach on the Western slopes of the Black Forest. In addition, forestry studies were carried on in the Tyrol in the neighbourhood of Brixen, etc.

The results of these investigations are published in the study »Ueber Waldtypen» by the author.

The purpose of these studies thus has not been to establish a systematic general picture of the German forest types, but the aim was in the first place the consideration of principles. At all events, they may provide a certain, though very imperfect starting point for a more thorough recognition and description of German forest types. The intention is to give in the following a brief account of the forest types distinguished by the author on the basis of his investigations revised, however, to some extent, in accordance with more modern conceptions in conformity with the forest type theory.

1. The Grass-herb Forest Class.

The general character of vegetation similar to that of the corresponding Finnish forests (p. 36).

I m p a t i e n s-A s p e r u l a T y p e (IAspT). Comprises spruce, fir, and beech woods in fertile, moist to fresh hollows and creek bottoms, particularly on fresh to moist Northern slopes or relatively flat, fertile and humid soils.

In more or less mature forests, there is a fairly continuous and abundant ground flora consisting mostly of hygrophilous grasses and particularly of herbs: *Impatiens noli tangere, Asperula odorata, Oxalis acetosella, Senecio nemorensis, Polystichum spinulosum, Majanthemum bifolium, Stellaria nemorum, Geranium robertianum, Mercurialis perennis, Circaea alpina* and *C. lutetiana, Galeobdolon luteum, Prenanthes purpurea etc., Festuca gigantea, Milium effusum, Carex silvatica*, etc.

The mosses are scanty though fairly abundant in species.

In regeneration areas, the vegetation is high and extremely luxuriant comprising mainly herbs: *Senecio nemorensis, Impatiens noli tangere, Chaerophyllum hirsutum, Mercurialis perennis, Prenanthes purpurea, Lactuca muralis*, numerous ferns, etc.

A s p e r u l a T y p e (AspT). Comprises spruce, fir, beech, and oak woods on fertile fresh soils in valleys or lower parts of mountains on nearly level lands or insignificantly sloping terrain mostly with a Southern aspect.

In more or less mature forests, the ground is covered with a fairly continuous herb vegetation with isolated grasses: *Asperula odorata, Oxalis acetosella, Athyrium filix femina, Majanthemum bifolium, Fragaria vesca, Ajuga reptans, Prenanthes purpurea*, etc., such as *Milium effusum, Poa nemoralis, Carex silvatica, Luzula pilosa*, etc. The moss-vegetation (*Hypnum striatum, Thuidium tamariscifolium, Mnia, Hylocomia*, etc.) is less conspicuous.

In the densest pole-stage forests, the absence of ground vegetation is almost complete. When the forests are thinned, low-growing mosses (*Thuidium tamariscifolium, Hypnum striatum, Hylocomium triquetrum, Mnium undulatum*, etc.), a few herb species (*Asperula odorata, Athyrium filix femina*, etc.), and grasses (*Luzula pilosa, L. nemorosa, Milium effusum*, etc.) make their appearance.

Characteristic of seedling areas is an abundant, luxurious herb (*Eupatorium cannabinum, Epilobium angustifolium, E. montanum, Asperula odorata, Fragaria vesca, Myosotis arvensis, Galeopsis tetrahit, Prunella vulgaris, Ajuga reptans, Veronica officinalis, Galium silvaticum, Carduus crispus, Cirsium palustre, C. lanceolatum*, etc.) and grass vegetation (*Dactylis glomerata, Agrostis vulgaris, Poa pratensis, Anthoxanthum odoratum*, etc.). Bushes are also frequent (*Sambucus racemosa*, species of *Rubus*, etc.).

O x a l i s T y p e (OT). Comprises primarily spruce, fir, and beech woods. This is a very common forest type on level and sloping grounds fairly rich in nutrients.

In woods of 80 to 120 years of age, which have experienced fairly intensive thinnings, the ground is covered with relatively continuous, mainly low-grown herb carpet (*Oxalis acetosella, Polystichum filix mas, P. spinulosum, Majanthemum bifolium, Galeobdolon luteum, Asperula odorata, Galium rotundifolium, Senecio nemorensis, Prenanthes purpurea, Lactuca muralis*, etc.), with infrequent grasses (*Milium effusum, Agrostis vulgaris, Aira flexuosa, A. caespitosa, Melica nutans, Festuca gigantea, Carex silvatica, Prachypodium silvaticum, Triticum caninum*, etc.). *Myrtillus nigra* is frequent but not abundant. Mosses are not particularly conspicuous (*Polytrichum attenuatum*, etc., *Dicrana, Mnia, Thuidium tamariscifolium, Hypna, Hylocomia*, etc.).

In pole-stage forests, the ground is incompletely covered by low moss (*Mnium undulatum*, etc., *Hypnum striatum, Hylocomia, Polytricha*, etc.), herb (*Oxalis acetosella, Galeopsis tetrahit, Veronica officinalis, Galium rotundifolium, Lactuca muralis*, etc.) and grass vegetation dependent on the degree of thinning.

Seedling areas are covered with abundant, luxuriant »weed growth», often over a metre high, the botanical composition of which is rather heterogeneous. The following herb species may be mentioned: *Polystichum filix mas, P. montanum, P. spinulosum, Urtica dioica, Fragaria vesca, Mercurialis perennis, Impatiens noli tangere, Epilobium angustifolium, E. montanum, Galeopsis tetrahit, Scrophularia nodosa, Gnaphalium silvaticum, Senecio nemorensis, Prenanthes purpurea, Lactuca muralis*, and grass species: *Milium effusum, Agrostis vulgaris, Calamagrostis arundinacea, Aira flexuosa, Aira caespitosa*, etc. Of bushes, *Rubus idaeus* and *Sambucus racemosa* are the most frequent ones.

2. Moist Land Forest Class.

The general character of forest types similar to that of corresponding Finnish forest types.

R u b u s i d a e u s T y p e (RT). Is very close to the previous forest type. Comprises mainly spruce and fir forests mostly on mountain slopes.

Characteristic of more or less mature forest is the fairly abundant appearance of *Aira flexuosa* and *Rubus idaeus*. *Myrtillus nigra* is common.

Typical of regeneration areas is the frequent and often very abundant *Rubus idaeus* as well as *R. fruticosus*, and the frequent and abundant *Aira flexuosa* and frequent *Myrtillus nigra*. Of other species may be mentioned: *Agrostis vulgaris, Carex leporina, C. pallescens*, etc., *Majanthemum bifolium, Rumex acetosella, Epilobium angustifolium, Galeopsis tetrahit, Veronica serpyllifolia, Senecio nemorensis*, etc.

Oxalis-Myrtillus Type (OMT). A mountain forest type, very close to ours of the same denomination. Comprises primarily spruce and fir woods.

In more or less mature forests, there is a low, fairly abundant ground vegetation, consisting of mosses (*Hylocomia, Dicrana, Polytricha*, etc.), of *Oxalis acetosella, Myrtillus nigra* and *Aira flexuosa, Polystichum spinulosum, P. filix mas, Majanthemum*, etc.

Aira flexuosa Type (AiT). Comprises mainly spruce and fir woods on fairly good soils on slopes and in valleys.

Characteristic of oldish woods is the fairly abundant presence of *Aira flexuosa;* it sometimes forms a short continuous green lawn, though mostly sterile. *Myrtillus nigra* is always present, even if not specially abundant. Moss cover (*Hylocomia, Dicrana, Polytricha*, etc.) may be fairly well developed. Of other herbs are worth mentioning: *Rumex acetosella, Epilobium angustifolium, Veronica officinalis, Galium uliginosum*, (and *G. hercynicum*), etc., and of grasses: *Anthoxanthum odoratum, Carex leporina, C. pilulifera, Luzula multiflora*, etc.

In the densest pole-stage forests, the absence of ground flora is fairly complete. The ground is covered by coniferous and leaf litter. Only isolated *Hylocomium* and *Dicranum species* and sterile individuals of *Aira flexuosa* and *Myrtillus* are present. When thinnings are introduced and shade reduced, the ground assumes again a dense carpet of plants, where *Myrtillus nigra* at first is often more abundant than *Aira flexuosa* although the latter eventually gains dominance.

Also in this case, characteristic of the regeneration areas is very heterogeneous and accidental vegetation, with *Aira flexuosa* and *Myrtillus nigra* always present, mingled with the following species: *Agrostis vulgaris, Cerastium vulgare, Galeopsis tetrahit, Veronicae, Senecio silvaticus, Cirsium palustre*, etc.

Myrtillus Type (MT). This type is very closely related to the previous one but is present on somewhat less fertile lands, often in higher parts of mountains, and characteristic of it is a vegetation somewhat less rich in species, and therefore more monotonous, in which *Myrtillus nigra*

and mosses (*Hylocomia, Dicrana, Polytricha*, etc.) play the main part; *Aira flexuosa* is less frequent than in the previous type. The humus is fairly typical raw humus, and the soil sometimes tending to become swampy. This type comprises mainly spruce forests and approaches particularly in the upper parts of mountains to a great extent our *Myrtillus Type.*

In more or less mature forests, the moss cover (*Hylocomium proliferum, H. parietinum, Dicranum majus, D. scoparium, D. undulatum, Polytricha*, etc.) is fairly continuous. *Aira flexuosa* is everywhere present, though fairly infrequent. *Myrtillus nigra* is quite dominating. Herbs are infrequent and scattered (*Polystichum spinulosum, Pteris aquilina, Melampyrum pratense*, etc.).

Regeneration areas are characterised by abundant or continuous presence of *Myrtillus nigra. Aira flexuosa* is always present though generally not abundant.

3. Dry Land Forest Class.

The general character of the vegetation is that of the corresponding Finnish forest types.

This class comprises, in the first place, pine forests characterised by *Calluna vulgaris;* in the forestry districts included in the author's investigations, these forests were, however, very infrequent. They are, for the most part, very close to our *Calluna Type.*

This class of forest types comprises also the stunted pine woods of *Erica carnea* type found on the dry, sunny slopes of the Tyrol, at a height of a few hundred meters from the valleys. Higher up in the mountains, different pine forest types are found in which mosses, lichens, and *Calluna vulgaris* as well as *Erica carnea* are present in different degrees of abundance. Some of these forest types are quite close to the Northern dry heath forest types. This is still more the case with the pine forests higher up, often mingled with larch, spruce, and *Cembran pine*, in which there is an abundant moss cover (mainly *Hylocomia* and *Dicrana*), and great abundance of *Vaccinium vitis idaea, Myrtillus nigra, Calluna vulgaris* and *Erica carnea*, and a scanty mixture of grasses, mostly *Aira flexuosa*, and herbs (*Pteris aquilina*, etc.). The last mentioned forest type is very closely related to our Vaccinium Type.