FINNISH RESEARCH IN THE FIELDS OF FOREST MENSURATION AND MANAGEMENT IN 1909—1959

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HELSINKI 1959

Contents

Abbreviations

AFF Acta Forestalia Fennica
FFM Finska Forstföreningens Meddelanden
MA Metsätaloudellinen Aikakauslehti
MTJ Communicationes Instituti Forestalis Fenniae (Publications of the Forest Research Institute in Finland)
SF Silva Fennica
SMY Suomen Metsänhoitoyhdistyksen Julkaisuja

Introduction

Several quite independent fields of study are included in the science of forest mensuration and management in Finland. Of these, the study of the methods in forest mensuration, of forest growth and yield, and of forest management ought especially be noted. In the following survey these three fields will each be considered separately. Besides them it seems appropriate to view the mapping methods in a different section as well as the national forest inventories, which have gained considerable significance.

Mapping of Forests

Regardless of the fact that the actual mapping belongs in the field of surveying, the preparation of different kinds of forest maps has for a long time been regarded as forest management work. Maps are necessary in the demarcation of the different sites, whose classification is considered elsewhere in this publication in the writing concerned with research on forest site types, and furthermore in describing the often changing borders of stands, the ever-recurrent silvicultural measures, the location of roads, etc.

Mapping has until recently taken place by the long-known base line method, which during the present half-century has been developed and made more exact, for example, in the instructions drawn up for the University's program for practical experience (Lönnroth 1919), in the circulation letters of the State Board of Forestry, and in published textbooks (e.g., Linnamies 1948 Metsämiehen karttaoppi).

During the past couple of decades there has come alongside of the old method a new one, aerial photo mapping, now replacing for the most part the old. This method was begun in the 1920's and 1930's to be developed to suit the conditions of Finland. An interest on the part of foresters was also felt in the matter at this time (Aro 1934 YMV VII; Kytönen and Tuura 1937 MA; Sarvas 1938 SF 48), but aerial photographs did not attain noticeable practical significance before the wars. The breakthrough took place only at the end of the wars, particularly in connection with two extensive projects. On one hand, the classification of forest lands required by the taxation system had to be carried out; and on the other hand,

mapping surveys relating to management plans, especially from northern Finland, were made by the State Board of Forestry. Both of the projects have been based on the use of aerial photographs, but field work has also played an important part in them. Especially the mapping methods used by the State Board of Forestry, which are said to have lowered the cost to less than half of the costs required by the base line method, have been explained in many papers (e.g., 1951 SF 69; 1956 SF 90; 1951, 1955 MA; 1954 Suomen Fotogramm. Seuran julk. n:o 2) by the foresters taking part in the project (Kuusela, Linnamies, Olenius, and Setälä).

It is natural that in the future the need for primary mapping will be reduced. However, this will not mean a reduction in the total amount of aerial photography and other mapping projects. Repeated aerial photographing is already needed in more efficient planning to show the changing borderlines of stands, for example. Research of this and of a related nature will require attention.

Methods of Forest Mensuration

The methods of forest mensuration are usually considered separately when an individual tree, a stand, and a forest area are in question. The same division is followed in this review but such special questions as growth and cut, equipment, and calculation methods will be dealt with as separate parts.

I n d i v i d u a l t r e e. For individual trees forest mensuration in Finland has dealt primarily with the problems of determining the volume of the tree. Many studies have also been made concerning the stem form, but these are related to the before mentioned because their practical aim generally is to discuss stem form for the purpose of volume determination.

The research field in question had not received noticeable attention until the beginning of the century, which can be seen, for instance, from the textbooks of forest mensuration by Ericsson (1903) and Arimo (1909). The stem form of our main tree species had not been studied, nor had our own volume tables been prepared for use. Instead, volume formulae of Central European origin were known and are often mentioned even in our days. Additional light was supplied for the formulae by Sivén (1909, 1913 SMY) who had even during the last century discussed the question (1887 FFM), Poukka (1912 SMY), and, in addition, Heikkilä (1915 MA) who viewed principally the usefulness of Huber's formula. The conclusions drawn by Heikkilä and especially the thorough study of volume formulae by Lönnroth (1927 AFF 31) for their part gave support for the selection of form factors to be used in the general volume tables, which will be discussed later. The interest in the volume formulae themselves noticeably diminished later.

To form a correct foundation for the method of studying the stem form, which method is closely related to the volume formulae, Cajanus (1911 SMY) suggested that a series of ratios of diameter and height should be used. In agreement with his principles, Lakari (1920 AFF 16) studied the stem form of Scotch pine on the basis of empirical data and extended the research into the factors which influence the stem form and which should be taken into account in the preparation of volume tables. The problem was further studied by Lindholm (1934 MA) and Lappi-Seppälä (1936 AFF 44), both of whom stressed the use of two diameters in the preparation of volume tables if, for example, the primary diameter is taken at breast height. In addition, both emphasized the influence of the crown length on the form of the upper stem. It may be mentioned that this objectively measured indicator has been taken as a factor in volume tables published later in Sweden. Still after that, Lappi-Seppälä (1952 MT J 40) pointed out the significance of the crown length. In a study by Ylinen (SF 76) published the same year, he discussed in a noteworthy manner the so-called theory of mechanical stem formation. In addition, many still unmentioned studies based on empirical data discuss the effect of various factors on the stem form, especially that of stand density and of different silvicultural treatments (e.g., Lappi-Seppälä 1929 AFF 34; Sarvas 1944 MT J 33; Nyyssönen 1954 AFF 60).

It should be mentioned here that the error in the computed cross-sectional area related to the cross-sectional form has been discussed by Heikkilä (1927 AFF 32).

As far as is known, the first Finnish volume tables published were compiled by Cajanus on the basis of data measured in 1912 (Ilvessalo 1923 AFF 26); in 1909 he had already explained some tables prepared for birch. These local tables were based on a few thousand standing sample trees whose diameters, for the determination of the volume, were taken at certain intervals with a dendrometer designed by Cajanus himself. In addition to the tree species and forest site type, the tables had only the diameter at breast height as a factor. The other commonly used factor, height, was not included. Thus the tables resemble the local volume tables, »tariffs», commonly used in Central Europe. The possibilities offered by these kinds of tables have not been taken advantage of later in Finland. They especially would have value in the continuous inventory of certain forest areas if prepared, for example, on the basis of general volume tables.

The tables for birch published by Hildén (Osara) based on data collected in northern Carelia were also local in nature (1926 AFF 32). For this work he had to study the stem form of birch. After noting that the point of inflection of the taper curve is primarily at the height of 3 to 5 meters, he did not take the d.b.h. as the principal diameter because it was still at the region of root swelling, but used instead the diameter at the height of 3 meters. The other factor he used was the height of the tree.

Because of the lack of general domestic volume tables, the Swedish tables by

Jonson were widely used in Finland. Their suitability for our conditions had been studied around 1915 by comparative measurements. In 1947, however, the tables by Ilvessalo (MTJ 34) appeared, based on 12 000 sample trees, and have been commonly used since then. These tables, prepared with graphic fitting, give the unit volume including bark for each tree species when the diameter at breast height, the height, and the taper are known. By taper is meant the difference between d.b.h. and the diameter at 6 meters for trees at least 8 meters high. The volume excluding bark can be obtained from that incl. bark by using percentage figures based on the previously mentioned factors and, when needed, by measuring the thickness of the bark at breast height. Assuming that the required measurements were made accurately, information about the dependability of the tables appeared with the tables and was also given later (Ollinmaa 1953 MA).

These tables have great value in practical forest mensuration. However, they have not entirely eliminated the need for further research in the field, as is natural. Some aspects will be mentioned here. It seems important to study the various causes of systematic errors so that these could be avoided. For the calculation of growth, tables should be prepared to give directly the unit volume excl. bark. In practical mensuration work more such tables are needed which give results with fewer measurements than the ones now in use; some have already been published. And finally, presentations in the form of mathematical functions could be of help for the mechanical process of computation.

Besides the total volume of the stem, the amount of timber products obtained from the stem has great practical importance. The saw-timber portion of the stem has received special attention in Finland. The laborious method of measuring the top diameter and length of the butt log and ocularly estimating the upper logs has been employed since the beginning of the century in the determining of the saw-timber portion and has remained in use to the present. The reliability of this method has been discussed in many papers (Vuoristo 1936 MA; Pöntynen 1944 MA; Heiskanen 1950 MTJ 38). Another method to be mentioned is that suggested by Lönnroth in 1917 (AFF 7). It requires a measurement of diameter at the height of 6 meters and determination of the length of that part of the stem from 6 meters to the point where the stem diameter is 6 inches.

Instead of the previously mentioned methods requiring the somewhat inconvenient use of a measurement rod, attempts have been made to develop methods in which the only necessary diameter is that at breast height. Although the results thus obtained would not satisfy very strict requirements, the method can very often be applied in practice. Of the volume tables for conifers based on d.b.h., the ones prepared by Heiskanen and Tiihonen (1958 MTJ 49) ought to be mentioned. The other factor in these tables is the length of the saw-timber portion or, alternatively, the number of saw logs that can be obtained from the stem.

Practical forestry still needs research on the amounts of different timber products obtainable from the stems, not only saw logs but others as well. The

question is closely related to the problems of the taper of the stem. Also, more complete bases are needed for the various conversions from technical measurements to actual solid measures and *vice versa*. These conversions are necessary in dealing with the problems in the fields of forest management, forest technology, and forest economics.

F o r e s t s t a n d. At the beginning of the century, methods af Central European origin were recommended for the calculation of the volume of a stand. In these methods the trees are grouped into diameter classes in a certain manner and a mean tree or possibly many sample trees of each group are selected to represent the group. Later, the use of the mean trees in this sense has been left aside even though the theory has received notice (Lönnroth 1926 AFF 30). On the basis of felled sample trees for the determination of the volume of the stand, more attention has been given instead to the methods based on the volume line. Thus, Lönnroth suggested in 1917 the use of Kopezky's method of fitting the volumes represented by the sample trees in such a way that, instead of squaring the d.b.h., it would be raised to varying powers (cf. 1934 AFF 40). In the data for Finnish yield tables the appropriate power fell generally between 1.5 and 2.8, and in the majority of the cases between 2.0 and 2.5 (Ilvessalo 1920 AFF 15).

The ocular estimation of a stand has been important in Finland for a long time. It has been employed even in the estimation of such factors that could be determined by measurements and calculations based on them. The most important of these characteristics is generally the volume of the stand. It has been attempted to facilitate the estimation by the use of certain simple formulae and auxiliary tables which give the volume when, for example, the density figure and either mean height or dominant height are known (e.g., Ilvessalo 1951 MTJ 39). However, the results as such are not always usable because of their subjectiveness. This is apparent when the characteristics include such an ocularly estimated, indefinite factor as stand density.

A method which sets inexpensive and rapid ocular estimation onto objective grounds was presented by Cajanus (1913 Tapio, 1917 AFF 7; Ilvessalo 1923 AFF 26). It is based on the fact that, regardless of the deviations of individual stands in one direction or another, each person with a certain amount of experience in mensuration has an individual manner in which the estimations are carried out. By finding out this manner on the basis of such stands whose volume is either already known or can later be computed, the estimation can be corrected. For the purpose of correction Cajanus suggested that a regression line be computed on the basis of the observations from ocular estimations and volumes based on measurements. Besides this analytical fitting, the fitting is naturally possible graphically.

The ocular estimation with related corrections has been applied on a large scale. For example, in the national forest inventories the relation between the

estimated and calculated volumes has appeared to be steady, the coefficient of correlation being generally about 0.9. The same short-cut method has also been extended to the determination of volume increment by auxiliary tables and has received considerable additional light from forest surveys (Ilvessalo 1927 MTJ 11, 1942 MTJ 30, 1956 MTJ 47; Linnamies 1944 MA). The use of ocular estimation in determining the various timber products by means of the structure of solid volume deserves special mention (Lihtonen 1942 AFF 50).

The approximate estimation of stands has come to a new stage after the Austrian scientist, Bitterlich, presented at the end of the 1940's a new method for determining the basal area of a stand with a relascope. Simultaneously with the study of the dependability of the method under Finnish conditions the possibilities for using the relascope in determining the volume of a stand have been investigated. Bearing this in mind, Nyyssönen prepared volume tables based on the basal area and mean height for stands of our three major tree species (1954 MTJ 44). One advantage of this method over ocular estimation is that one can obtain satisfactory results with relatively little experience. Even though the relascope is now in fairly general use, the possibilities which it has to offer are not yet fully known. Therefore it is appropriate to continue the research on the uses of the method.

The estimation of stands based on aerial photographs received attention as early as the latter part of the 1930's (1937 MA; 1938 SF 48). The State Board of Forestry carried out several experiments after the wars. Furthermore, Ilvessalo (1950 MTJ 38) shed light on the basis for aerial estimation by viewing the correlation between the maximum crown width and the stem. To gain an idea of the dependability of the results when using aerial photographs in estimating stands, Nyyssönen carried out an investigation which suggested volume tables for pine stands using crown closure and mean height as indices (1955 MTJ 46). At the same time it was investigated how the dependability of the indicators in question can be determined from ordinary aerial photographs. It appeared that the standard error of estimate for the volume is noticeable, in all approximately $\pm$ 30 %. In the investigation attention was also given to the estimation of mean diameters.

The estimation of stands from aerial photographs seems to suit Finnish conditions primarily in the rough classification of stands. Thus, since in practical mensuration work usually observations made on the ground are also required, the combining of aerial and ground surveys in the most efficient way would require further research.

Forest area. At the beginning of the century, already, the most important of those methods still most commonly used in the surveys of forest areas were known; namely, the ocular estimation by stands either by the use of selected sample plots or without them, and the strip survey, which now is mainly changed

into the line-plot survey. At first glance it does not seem that the research in this field has caused a fundamental change in the methods of forest survey. In the preceding, however, the making of ocular estimation more objective has been discussed. Also for the development of strip and line-plot methods and for the determination of their accuracy, much work has been done, especially up to the 1930's.

As far as is known, the strip survey was originated in Sweden where af Ström presented its main principles already in 1830. In Finland, the State Board of Forestry is known to have used it as early as the 1880's in different parts of the country, and the students of Evo Forestry School made comparative surveys in 1897. However, the results of the research on the method 50 years ago did not give the right to draw any conclusions about the method. The first important study was the survey of the forests of Sahalahti and Kuhmalahti communes. It was planned and the field work conducted by Cajanus under the commission of Tapio, Central Forestry Association in 1912. The accumulated data was processed and results published by Ilvessalo (AFF 26, 1923). An attempt was made to determine the accuracy of the strip survey and to draw conclusions about the minimum survey percentages in surveys of fairly large areas. In calculating the dependability of some of the major results, attention was given to the systematic deviation among strips. It was not possible to obtain a thorough explanation for the effect of the distance between strips, but valuable information was given about the increase in error as the distance between the strips increases.

In 1919, in connection with the University's program for practical training in forest mensuration, complete and strip survey were carried out in certain forest areas. The results were analyzed both by Ilvessalo (1920 AFF 14) and by Lappi-Seppälä (1924 MTJ 7), who discussed the effect of different factors (the direction of the strips, survey percentage, area, and indicators used) on the reliability of the results and drew practical conclusions, for instance, from the distance between strips. Later, additional information was obtained from strip and line-plot surveys and from the expenses caused by them, mainly from the standpoint of the number of saw-timber trees in some forest areas (Ilvessalo 1937 SF 39).

Broad experience in making strip surveys has been gained from the national forest inventories which will be discussed later in more detail. The calculation of the accuracy of the results of all the inventories has been made according to the practice suggested by Lindeberg (1924 AFF 25, 1926 AFF 31). He starts from the already mentioned fact that the ordinary formulae used to calculate the standard error are not suitable, because there can be noted very commonly the continuous systematic error among the strips in addition to the accidental errors in the survey. To eliminate the error, the results from two adjacent strips or parts of strips are continuously compared with each other. The differences thus obtained appear as factors in the formula for standard error.

May it be said that also in the Scandinavian countries the question has, at the same time and later on, been fairly much under consideration.

In examining the actual strip survey and line-plot survey as a whole it appears that certain rules for them are available, but there is still much room for research. Thus, additional information is needed for determining the most favorable line spacing and size of sample plot under different conditions, the way in which the standing sample trees should be selected, etc. At the moment it cannot be said what will be the effect of the relascope on these surveys. There is a need for research also in the field of recurrent inventories of forest area, which will become timely when renewing management plans. Until now the new inventories have been generally carried out independent of the previous so that, for example, the estimation by stands in the state forests has been entirely repeated. As the methods based on sampling have become common, the question of establishing a permanent network of sample plots has arisen. There already exist some in Finland, established from the 1920's on, but still the experience and research concerning them are negligable.

I n c r e m e n t. The measurement and estimation of the increment of trees is, on the whole, one of the broadest and most complicated problems of forest mensuration. Thus there is already a danger of becoming confused about the terms appearing in dealing with the problem. Although at the beginning of the century many characteristic features related to increment were known, uniform definitions with a theoretical basis and concepts of the happenings related to growth and drain were needed. To accomplish such a thing, Lönnroth (1929 AFF 34) published a review giving light to the question, based on the directions written by him in 1919.

The analytical interpretation of the increment curve was discussed by Lindholm and Sivén around 1910 (1909, 1910 SMY). At that time different methods based on felled sample trees were used in the actual computation of the increment. In addition, the use of increment percents obtained from borings into standing sample trees, for instance, by the application of Schneider's formula, was recommended. But at least in the extensive survey of 1912, increment percents and also the volume increment were computed on the basis of bored standing sample trees by the use of the so-called Jonson's method (Ilvessalo 1923 AFF 26). It can be said that thereafter this system and the methods based on it — particularly as applied and developed by Ilvessalo for Finnish conditions — have gradually begun to govern the determination and estimation of growth in our country (e.g., 1927 MTJ 11, 1939 SF 52, 1942 MTJ 30, 1948 tables published by Tapio, 1956 IUFRO Oxford Congress).

The method mentioned above gives the percentage of the volume increment when to the increment percent of basal area, obtained by the use of the radial increment of the last 5 or 10 years and d.b.h. under bark, is added the increment percent of the form height, which is obtained by using the height of the tree and either the height increment or age and position in the stand as factors. Increment percent determined from individual sample trees, whose number has been discussed also by Nyyssönen (1951 MA), when weighted and multiplied by the volume of the stand will lead to a result which has been used as the annual volume increment at the time of measurement. Actually, the value received for the increment of the stand by this method is the mean of the period just past, but the changes in direction of growth — not counting the ones caused by climatic variations — have been considered slow and not systematic, making the method usable.

On the basis of the great amount of sample trees studied in national forest inventories, auxiliary tables based on various factors (tree species, age, density, etc.) have been prepared to facilitate the estimation of increment. They have been accepted for common use, while the growth and yield tables, which will be discussed later, as well as other methods are used less. Noteworthy, however, is the general practice of determining the growth on permanent sample plots as the difference between the volumes measured at two different times. Furthermore, attention has been directed to the use of stand table method also for temporary sample plots (Keltikangas and Kuusela 1952 MA; Vuokila 1956 MTJ 48; Kallio 1957 AFF 66).

Kuusela discussed the theory of increment determination in the study published in 1953 (AFF 60). It examines the way in which it is possible to calculate the mean increment and increment percent for the past period, on one hand, and the probable increment and increment percent for the measurement year, on the other, for an individual tree, a stand, and a forest. The practically important result of mainly theoretical argumentation was to show that the increment of the surviving growing stock of forests to be treated cuttings is generally increasing. This being the case, the method generally applied in Finland for determining the increment of the measurement year would yield on the average too small a result when the increment is taken only from the standing stock as explained previously, thus disregarding the drain.

With the information now available it is not possible with sufficient grounds to evaluate the preceding statements because of the lack of enough assurance about such things as the reliability of increment percent of form height in different kinds of forests. Thus, at least in stands under intensive cutting, the previously mentioned auxiliary tables may yield results slightly greater than the true periodic annual increment of still existing stands, as Nyyssönen has noted (1952 MTJ 40, 1958 MTJ 49). In any case, it is apparent that research based on empirical data is still needed to clarify these questions. Because different kinds of methods can be considered for use under various conditions, this has to be taken into account in planning future investigations. Furthermore, additional light should be obtained for the important problem of growth prediction, which

has been considered by Kuusela to some extent (1955 MA, 1958 AFF 67). Both in connection with this task and in the interpretation of growth figures in general will come also the climatic variations of growth, which will be discussed later.

Cut. In forestry, information about trees cut is often needed. Almost always when it cannot be obtained from records of studies concerning wood use, it is necessary to resort to the study of stumps, a method which in principle has long been known. The idea of an extensive drain estimation from stumps appeared in Finland as early as 1911. In a committee report the plan was set forth to measure the stumps of trees felled during three previous years in connection with the strip survey of two communes, but the work was never carried out.

After that, the stump measurements were used only occasionally until Sarvas gave more attention to them in conjunction with his investigations concerned with forests under selective cutting both in southern and northern Finland (1944 MTJ 33, 1950 MTJ 38). Among other things, the change in appearance of stumps and methods for determining the cutting year in general were studied. Furthermore, the interrelationship between stump diameter and d.b.h. was examined and some comparisons of the reliability of the results in determining the volume were made. Later Nyyssönen made a special investigation of this problem (1955 MTJ 45). Now the previously mentioned questions were treated more extensively and thoroughly. In addition, the question of the height of the removed trees was given consideration and the investigation was extended to include also the viewpoints to be taken into account in surveys on a forest area. Besides the cubic content, the comparisons were concerned with the diameter relationships. The results obtained from stumps were shown to meet quite high requirements.

When, in addition, the experience gained, for example, in Sweden by extensive survey of cut from stumps is taken into account, the method in question has to be considered within certain limits as a positive solution. The possibilities provided by stumps for determining the amounts of cut will possibly be taken advantage of more in the future than before.

Instruments and processing of data. In the measurements in the field of forest mensuration various types of instruments are needed. Their construction is the work of investigators and inventors. Many of the instruments in everyday use in mensuration problems and research have been developed in our own country. Thus there have been some dendrometers prepared, of which the one suggested by Hackstedt and Cajanus deserves first mention. With Cajanus' instrument (1912 SMY) many measurements were made, for example, in 1912 (cf. page 5). The same types of instruments were presented later, for example, by Lönnroth (1926 AFF 30), whose instrument meets the numerous theoretical requirements of a dendrometer, and by Heikkilä (1932 AFF 38).

Lönnroth has also presented the commonly used hypsometer which is based on an arithmetical scale and the use of a comparison rod.

Of the other apparatuses, Cajanus' cylinder for determining the crown widths and crown closure (cf. Sarvas 1953 MTJ 41) and the different kinds of calipers developed, for example, in the Forest Research Institute for both practical and scientific use deserve mention (Ilvessalo 1932 MTJ 17, 1947 MTJ 34). Similarly, other devices such as those used for aerial photo interpretation and relascope measurements have been developed.

Means are needed also for handling the collected material. Work can be spared with the kind of short cuts Cajanus suggested for the determination of basal area and mean diameter (1912 SMY). Previously, the auxiliary tables have been mentioned for determining the volume and increment. Condensations of these tables have later been collected and presented in practical handbooks (e.g., Tapion taskukirja and Metsäkäsikirja 2). In processing the material the actual computations were still done manually in the beginning of the century. It was not before the 1920's that the calculation machines were used commonly, and since the 1930's the larger amounts of data have been processed by the punch card method. Several articles have been written about this method since that time (e.g., 1942 MTJ 30; 1950, 1954, 1956 MA; Metsäkäsikirja 2). In its farthest reaching forms the use of the electronic computer has thus far been in the surveys of the forests of some forest industry companies.

Growth and Yield Studies

Numerous factors affect the development of the growing stock in the forest: site, tree species, age of trees, the character of previous cuttings, etc. There are many reasons for wanting to study the growth and structure of the growing stock under different conditions. Some of the goals to be reached are the understanding of the type of desirable growing stock, the establishing of bases for site classification and silvicultural measures, and the forming of grounds for making different kinds of financial estimates.

Investigations in the field carried out in Finland during the last century include, for example, several numerical series presented by Gyldén (1853) and, furthermore, yield tables published by Blomqvist in 1872 in which the quality of the soil and its suitability for different tree species were used as the basis for site classification. However, the tables were not used much in either the original or revised form (Heikkilä 1914 SMY Erikoistutk. 2). Blomqvist (1897) studied also the diameter growth, as did Lindholm later (1912 Tapio).

As explained elsewhere in this publication, Cajander set forth in 1909 (AFF 1)

an original theory of forest site types. About the same time and shortly thereafter, he himself and certain other foresters (e.g., Thomé and Minni 1909 SMY; Karlsson and Silfverberg 1910 SMY) carried out fairly brief investigations which gave an understanding of the significance of forest types in forest mensuration and survey. Soon it was felt essential to prepare yield tables based on forest site types. The need for such tables was especially argued by Cajander in 1912 and simultaneously Cajanus dealt with the questions concerning the method of preparing the tables (AFF 7). At that time and more specifically in a study published in 1914 (AFF 3) based on Swiss data, Cajanus stressed the importance of the stem distribution series in preparing the yield tables. He felt that this series can be characterized accurately enough with only a few easily-determined, typical figures. On the basis of these figures it is possible to solve the important question in the preparation of yield tables, of stands belonging to the same developmental series better than, for example, on the basis of volume as had been much done abroad.

When the Society of Forestry in Finland received funds for the preparation of yield tables, the task was given to Ilvessalo in 1916 whose study of the growth of dominant trees in pine stands of *Myrtillus* type and *Calluna* type was completed at about the same time (AFF 6). In this manner began the studies of naturally normal stands (fully stocked, unthinned). They are based on Cajander's forest types with regard to site classification and the most important of them with regard to statistical processing on variation methods, which in Finland were first applied by Cajanus.

Ilvessalo's yield tables (1920 AFF 15) are prepared for pure stands of our major tree species, viz., Scotch pine, Norway spruce, and birches (*Betula verrucosa* and *B. pubescens*), in the southern part of the country. The structure and development of the growing stock are indicated by different characteristics such as stem distribution series. In addition, the growth and self thinning at different ages are viewed. Before the actual preparing of the tables, investigation into the significance of forest site types in mensuration was completed forming the grounds for the preparation of these tables. Conclusions were drawn that forest site types were suitable for classification of the site quality. The research done and the tables prepared have had a great practical importance because of their usable form and because of the lack of completed studies on the development of managed forests until the 1950's.

Lönnroth (1925 AFF 30) has formed the development series of pine stands on *Myrtillus*, *Vaccinium*, and *Calluna* types based on a fairly limited but carefully selected data. The investigation is characterized by the thorough consideration of the methods used. In it the significance of forest types in the classification of sites is further stressed and the internal structure and development of virgin pine stands are thoroughly analyzed by means of biological tree classification and by using different types of indicators.

The study by Lappi-Seppälä (1930 MTJ 15) on mixed stands of pine and

birch is the first concerning mixed stands, which offer certain methodical difficulties. The practical outcome of this rather extensive investigation has been considered to be the result that the mixing of birch in a certain proportion into a pine stand increases the total yield.

The investigations by Miettinen (1932 MTJ 18) in grey alder (*Alnus incana*) stands and by Erkki K. Cajander (Kalela 1933 MTJ 19) in cultivated spruce stands on comparatively good sites have indicated the relatively rapid development of these types of stands. Similarly, the development of Siberian larch (*Larix sibirica*) (Lappi-Seppälä 1927 MTJ 12) has been an object of brief investigation; the same is true with Siberian fir (*Abies sibirica*) and lodgepole pine (*Pinus murrayana*) (Miettinen 1941 MA, 1952 MTJ 40). Development studies have also been made of the dominant trees of *Pyrola* type (Kalela 1939 MTJ 27), spruce stands of *Vaccinium* type (Sarvas 1951 MTJ 39), and young cultivated pine stands (Blomgren 1952 MTJ 40).

The first growth studies in northern Finland based on forest site types were made by Lakari as early as 1920. After discussing the forest types of that area (AFF 14), he carried out an investigation on the growth relations of Norway spruce and Scotch pine on *Hylocomium-Myrtillus* type (MTJ 2). Later Ilvessalo prepared yield tables, corresponding to those made for southern Finland, on the basis of naturally normal stands in Central North-Finland (1937 MTJ 24). As far as the method of investigation is concerned, more graphic fittings were used than in the corresponding work in the southern part of the country. From the investigation, in which the development of pine, birch, and old spruce stands in Central North-Finland is studied broadly, the comparatively favorable development of pine appears especially in this area. In some respects the results from an extensive study by Sirén in 1955 (AFF 62) complete the picture of Ilvessalo's investigation significantly.

Although experimental thinning for solving the problems connected to growing forests had obviously been done before in different parts of the country, systematic work was started as late as 1924 by the Forest Research Institute when the establishment of permanent sample plots was begun, mainly in experimental forests of the Institute. Thereafter, measurements have been made and certain cutting methods applied for these plots at set intervals. The methods applied in the work have been described by Ilvessalo (1932 MTJ 17) who has lead the operations. Until now it has been attempted to base the determination of the grade of thinning on biological tree classification (L. Ilvessalo 1929 AFF 34), conclusions about the suitability of which for this purpose were made on the basis of the first thinnings (Miettinen 1930 MTJ 16). Relascope, too, is used in recent years. Actual results based on these sample plots have been published so far only in two brief publications by Nyyssönen (1950 SF 68) and Ilvessalo (1952 MTJ 40).

More information about forests where cutting has been done has been published on the basis of temporary sample plots than of permanent ones. In this

respect, the most notable sources of information are the national forest inventories which will be discussed later and, in addition, the investigations by Lihtonen (1943 AFF 51) and Sarvas (1944 MTJ 33). However, the primary objective of these investigations was not the analysis of growth and structure. In the report of the former about cutting regulation, one of the things discussed was the growth relations of the portion of stock to be grown and that to be removed. Sarvas, on the other hand, deals with the effect of selective cutting of saw-timber trees on the development of the stands. The picture from that investigation became more complete and changed in some respects when Nyyssönen (1954 AFF 60) in his study of pine stands had an opportunity to compare selectively cut stands with very heavily thinned stands of about the same volume. This investigation was the first attempt in Finland to determine the growth reactions of repeatedly thinned stands as a continuous series according to age.

Parallel to the last mentioned study Vuokila (1956 MTJ 48) discussed the development of managed spruce stands, dealing also with the output of timber products. The same subject has also been touched upon by Kallio (1957 AFF 66). Kuusela (1956 SF 90) and Koivisto (1958 MA) have examined birch stands under cutting. Furthermore, Nyyssönen has discussed the output of timber products in thinned pine stands (1957 MA) and in pine and spruce stands where the regeneration has occurred gradually (1958 MTJ 49).

The investigations carried out to determine the variations in tree growth are also interesting. After Laitakari (1920 AFF 17) had given attention to the question, Boman (Puumanen 1927 AFF 32) studied the long-term variation periods occuring in pine by analyzing individual trees. The results showed that it is necessary to take long-term variations into account in growth studies. Because the matter was also treated in some other investigations both in Finland and abroad, it was felt urgent to combine the study of the problem with the Second National Forest Inventory in 1936—38. The results, which were analyzed by Ilvessalo (1942 MTJ 30, 1945 MA) and by the Swedish scientist, Eklund, supplied significant addition for the interpretation of growth results obtained in different surveys and for different species of trees. By using the accumulated data and by collecting additional material, Mikola (1950 MTJ 38) made a more thorough investigation in which he clarified, for instance, the regionality of variations and their dependence on climatic factors and internal conditions of the stand, and examined the effect of the variations on growth studies. Additional information about the growth of conifers has been obtained in the 1950's (Ilvessalo 1956 MTJ 47; Nyyssönen 1954 AFF 60, 1958 MTJ 49), and the growth of birch has been examined in some manuscripts.

The effects of climatic variations on growth appear so clearly that they should be attempted to be taken into account always when possible in dealing with the growth results. Therefore, these variations should constantly be followed. Similarly, the character of their effects on forests under cutting requires further investigation.

As the preceding review has shown, the number of investigations on the development, structure, and growth of trees has become great. Many of these publications indicate notable work for the whole field of forest mensuration. Illustrative is the fact that over ten of the publications mentioned previously are doctoral theses. One would suppose that, therefore, the work done in the field would fulfill even great requirements. However, the field is so central and broad that the work done until now is not sufficient and further investigations are urgently needed.

The main emphasis in the work done so far is clearly on the side of virgin forests. Regardless of the many investigations of stands under cutting, the work in this field has only the character of preliminary studies. However, practical forestry awaits results from especially the effects of cuttings. Often has been heard the justified demand for the preparation of yield tables for managed forests and for concrete directions which could be obtained from them for carrying out such practices as thinnings. At the present, there are not enough grounds for giving this kind of advice, because the necessary research has not been done on the probable results of alternative procedures.

The continuation of studies of growth and structure should be emphasized more than before. By its nature this research work belongs principally to the realm of the Forest Research Institute; but in solving such questions as methods outside forces too may be needed. The investigational methods especially require much thought; thus the suitability of the use of permanent and temporary sample plots in different investigations is not clear. Correct techniques of research are surely able to clarify simultaneously the different kinds of questions, such as those mentioned in the beginning of this section.

National Forest Inventories

The knowledge of the country's forest resources, condition of forests, possibilities for cut, and procedures for increasing the cut is important for many reasons. With this in mind many reports of this nature were made in Finland already in the 19th century and in the beginning of the 20th, as appears from committee reports and other papers (cf. Ilvessalo 1927 MTJ 11). The numerical data from these commendable attempts was, however, comparatively small — concerned with such things as forest area and the volume and growth of stock — and the estimates were uncertain.

The obtaining of information by forest survey was discussed in the meetings of the Finnish Forest Union a few times, starting as early as 1880. The question was presented first by Blomqvist and later, in 1907, by Cajander. In regard to the methods applied in later inventories, the survey carried out under the leadership of Cajanus in 1912 is significant (cf. page 9). It was followed by many pa-

pers on the condition of forests according to locality and ownership (e.g., Lukkala, Multamäki 1919 AFF 9; Heikinheimo 1920 MTJ 3; Renvall, Boman 1919 AFF 13, 1921 AFF 19). An important step toward the general inventory of national forest resources was taken in 1921 when investigations commissioned by the committee for the revision of taxation were carried out under the leadership of Lakari; among those was a survey line in the southern half of the country. On the basis of the plan drawn up by him, the decision was made to include the whole country in the work. The detailed proposal for the actual working plan was now prepared by Ilvessalo, under whose leadership the work was carried out at the Forest Research Institute. In addition to this First (1921—24) Inventory, Ilvessalo has also conducted the Second (1936—38) and Third (1951—53) Inventories and has presented the results.

The methods used in the inventories have changed somewhat as time has passed. Particularly the estimation of silvicultural condition and necessary measures have been developed continuously. However, the essential features of the methods followed have remained unchanged. Thus the survey has every time been carried out in the field by using survey lines with southwest—northeast direction. Aerial photography has been used only experimentally in the Third Inventory in areas in which field work has been difficult and which have little economical importance. The distance between lines, which in the First Inventory was 26 kilometers throughout the country, was narrowed down to 13 kilometers in the Second Inventory elsewhere than in the more northerly parts of the country. In northern Finland and also in some areas in the southern half of Finland the distance was made still shorter during the Third Inventory. In surveying along the line, ocular estimation of every stand is made to record the site, growing stock and its condition, etc. The purpose of the sample plots measured in regular, usually one-kilometer, intervals is, on one hand, to form bases for the correcting of ocular estimations (cf. pp. 7—8) and, on the other, to form possibilities for the calculation of additional information (e.g., the division of the growing stock and its increment into diameter classes, the quality and quantity of saw-timber trees, etc.). The processing of the data has been done partly by calculation machines and partly by the use of electronic computers. The determination of the accuracy of the results has been mentioned earlier (p. 9).

The results of the inventories have appeared for the most part in the publications of the Forest Research Institute, the major results in numbers 11, 30, and 47, in the years 1927, 1942, and 1956, respectively. Besides for the whole country and for the southern and northern halves separately, the results have also been described within the framework of various area divisions, both in the mentioned publications and elsewhere (e.g., 1929 MTJ 13, 1930 MTJ 15, 1943 publ. by Tapio, 1949 MTJ 35). The abundant material accumulated in the inventories has offered an opportunity for the director of the work to discuss certain

special questions in research publication series (1933 MTJ 18, 1934 AFF 40, 1951 MTJ 39), in numerous periodicals and newspaper articles, and in lectures. To these presentations are joined also papers of others about such matters as studies concerning forest ownership relations and the inventory of state forests carried out by Linnamies (1958 AFF 68) in the 1950's, which is partly based on the data of the Third National Forest Inventory.

It is not possible to explain in connection with this, even in the form of a brief summary, the picture given by the inventories about the forests and their development. It must be noted, however, that the results of these logically executed inventories are among the most frequently used results of forest research in Finland. But in this field also the need for development appears. Thus, even when the Third Inventory was still in the planning stage, the idea of carrying out a supplementary inventory around 1960, i.e., at the middle of the current 15-year period, was suggested. It appears, however, that in the long run the need for a constant following of the development must be kept in mind, which means that the inventory should be carried out continuously. In this way the taking care of matters such as personnel concerned with the practical side of the work would be made easier. Then it would seem appropriate to combine in the inventory under the same leadership the following of cutting and wood utilization which until now have been studied separately. In fact, the research methods for forest resources and their development and those for wood utilization are not strangers to each other, as is indicated by some countries where the stump measurements are used in connection with forest inventories for determining the cut. Apparently this development would be suited to facilitate such things as the preparation of the most usable recommendations as to the allowable cut.

Forest Management

The concept of the title as used in Finland might require closer examination. In a textbook of forest management (Ericsson 1903, 1906) published at the beginning of the century, forest mensuration was discussed on one hand and »subdivision of forests» on the other. For the questions in the latter part, Finnish word translated »forest management» soon became common. Forest management primarily included the preparation of maps and certain management records which was considered to require, in addition to the knowledge of preparing a cutting budget, the knowledge and use of methods, only of those belonging to the field of forest mensuration and perhaps somewhat silviculture. However, the demands have increased with time and the field of forest management grown. In order that the plan, either in the mind or on paper, formed as a result of

management planning characteristic for this method could be considered successful, basic information has to be collected also from sources other than forests. One must go deeply into the problems of harvesting and transporting of wood, use of labor, business economics, etc., as is clearly indicated, for example, in a textbook by Lihtonen published in 1959.

Against the background presented it can be noted that the inclusion of forest management as a part of the »science of forest mensuration», as is the case in Finnish forestry terminology, is based on an old custom. It would be more logical, however, to discuss forest management as its own field of science whose links to forest mensuration indeed are the strongest, but which can completely fail in its functions if it does not follow and use for its benefit the development of many other fields.

In forest management the results of various kinds of investigations, which are explained in other writings of this publication, are thus used advantageously. But forest management also includes forms of investigation that will not be discussed elsewhere. The most central of these is the calculation of the allowable cut, or cutting regulation.

After the State Board of Forestry was established in 1859, one of its first tasks was to get the cutting regulation onto a solid basis. The so-called periodic method by area was approved, which in actuality, however, has had practical meaning only in certain state forests. Particularly because of the lack of demand for small-sized wood the method of selective cutting was applied, beginning in the 1880's. The number, size, and diameter growth of saw-timber trees were the bases of calculation. Some growth studies (p. 13) and earlier papers concerning cutting regulation (Moring 1907 SMY; Lindholm 1909 SMY) must be seen against this background. Forest management by stands, which has been used in state forests since 1907, was not able to prevent the continuing practice of selective cutting until about 1920, which in many places was done even in the form of exploitation cutting to a diameter limit. In private forests, the strong grip of this last method held even longer.

Since approximately 1920 cutting regulations have begun to have forms more clear than before corresponding to the improved silvicultural techniques. The calculation of the allowable cut in this site-type forestry, as Lönnroth (1927 AFF 32) characterized it in his review outlining the principles of forest management, has been made by using the method of comparative calculations based on different standards. On these grounds Lihtonen developed the method of cutting regulation for progressive yield (1943 AFF 51, 1946 AFF 53, 1952 MTJ 40), the most outstanding result of Finnish research in this field. It is an attempt to give a fixed form to the calculation of cutting regulation by collecting together the bases considered most important under simultaneous examination, which makes it easier to give each factor its proper emphasis. These kinds of factors are the area of the forest, composition by tree species, age-class composition, volume and

volume increment by age classes, rotation period, and the mensurational and silvicultural condition of the forest. A prerequisite for the calculation is either a survey by stands or one based on some representative method which in the mentioned respects gives the necessary information.

The method of cutting regulation for progressive yield has received wide use. With its help the allowable cut has been calculated both for the whole country and by areas on the basis of the National Forest Inventories (Lihtonen 1946 AFF 53; Ilvessalo 1956, 1957 MTJ 47), for state forests under the control of the State Board of Forestry (e.g., Linnamies 1959 AFF 68), for fairly large private forests, etc. In this way it has been possible to gain much experience in determining the cut. On the other hand, in the short time that the method has been used, not enough experience has been received regarding the usability of the results. It is best not to set very high standards in this respect so long as many of the basic factors are on uncertain grounds. May, for example, the incompleteness of growth and yield studies, which have been discussed elsewhere, and also the still unstable ideas about the optimum rotation under different conditions be pointed out. The latter question had received only little mention earlier until Kallio (1957 AFF 66) made calculations on the basis of spruce stands and Nyyssönen (1958 MTJ 49) examined a rotation based on marginal rate of return. In this investigation the effect of various factors, such as tree species, site, price relations of wood products, etc., were considered. However, there still remains much to be studied in this field. Especially such things as the relative maturity of different types of stands need clarifying.

The determination of the allowable cut, which has been touched upon above, generally forms a part of the preparation of management plan, an operation characteristic of forest management. Comparatively much work has already been done in this field during the past hundred years, especially in large-scale forestry. The organization of the work is most uniform in forests under the State Board of Forestry for which it is a custom to prepare, primarily for the coming ten-year period, a management plan with related records by districts (cf., for example, Lakari 1937 SF 39; Lihtonen 1944 AFF 52, 1959 textbook). Plans have repeatedly been prepared also for the forests of forest industry companies, cities, communes, and parishes and for joint forests. Aside from these, the number of plans is relatively limited in the comparatively small private forests which still, however, are important from the standpoint of the nation's forest economy since the major part of the wood utilized annually comes from them.

As the need for long-range planning is apparent also in small-scale forestry, it should be attempted to find methods for their advancement (cf., for example, Appelroth 1942 AFF 50). Attention should then be given to such things as the appropriate form for the plans. An important work in this respect is a book of instructions published by Osara (1948). Obviously the preparation of very simple plans has to be continued as well, in which the costs remain low. For lowering

the expenses and rationalizing the collection of basic information, attention should be paid to simplifying the field survey, for example, by the use of the relascope.

In general, it is still necessary to study the question of how the management plan should be prepared so that it would best suit the purpose and that the profit gained by using it would be in the proper proportion to the costs. Also, the possibilities offered by methods in which information is collected continuously are perhaps worth consideration so that the inconveniences caused by the information's rapidly becoming out-dated, one of the disadvantages of the plans, could be avoided. The modern methods of processing data should offer possibilities for the development of a flexible, ever-renewing method.

* * *

The survey of the research work belonging in the fields of forest mensuration and management can be concluded here. According to the assigned task, attention has been directed somewhat in the foregoing also to the present state of this field of science and its future work. The goal has not been to attempt a comprehensive inventory of these because it would have required as a base such things as a discussion of many foreign research works, too. But even those suggestions for the existing problems which have been presented in the preceding paragraphs have indicated that the need for research in one field is greater than in another. Of the preceding ought especially to be mentioned the development, structure, and growth of growing stock and to a certain extent also methods of forest survey. In some other fields, on the other hand, the main emphasis would appear to be on the practical application of the already existing knowledge.

The development during the last half century has led to the differentiation of forest mensuration into a few independent fields of knowledge. It is no longer possible for one person to master all the fields and to carry out the research effectively in all of them. In connection with this one must also remember such fields closely connected with forest mensuration as photogrammetry and statistical methods. While the former is a comparatively newcomer, the latter have been for a long time forming the necessary bases on which it has been built relatively early in Finland. But the field has developed considerably during the last decades and Finnish forest research does not have permanently a man to master and develop these modern methods. On the basis of what has been said, it is justified and proper to present the wish that the research in the forest mensuration and management would not be left without the addition of man power, which it now needs.