ANALYSIS OF TWO ALTERNATIVE METHODS FOR NATIONAL FOREST INVENTORIES IN NORTHERN EUROPE

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Introduction

National forest inventories have long been applied in north European countries with a view to providing bases for the determination of forest policy, and for the making of plans for the development and use of the forests. Finland, Norway and Sweden have more than 40 years of experience in carrying out such inventories. The fourth survey will soon be completed in Finland; in Sweden, the field work has recently been finished for the third inventory; and in Norway, the third is in progress. The survey years are as follows:

	First	Second	Third	Fourth
Finland	1921—24	1936—38	1951—53	1960—63
Norway	1919—30	1937—56	1957—	
Sweden	1923—29	1938—52	1953—62	

Earlier Finnish surveys were carried out as concentrated efforts periodically over periods of three to four years, but from 1960 onwards, making the inventory has been a continuous task. In Norway and Sweden, the same system was adopted as early as in the late 1930's. As regards the reasons for making a continuous inventory, it should be mentioned that it is necessary to make use of approximately equal budget appropriations every year, as well as to maintain a trained technical staff. Naturally, the increasing intensity of forestry also demands that the trends are kept under constant observation.

In all the Norwegian inventories, and during the first two inventories in Sweden, the annual work was completed province by province. The survey results for the whole country have been calculated by combining the results from different years for the individual provinces. However, the third Swedish inventory, started in 1953, covers the whole of the country each year. The results for individual provinces can be presented by combining the data collected over a 10-year period if it is desired to achieve an accuracy comparable with that obtained by the Norwegian system.

The purpose of the present paper is that of discussing various possibilities for continuous forest inventory, and in particular one of the Swedish type, and one of the Norwegian type. In Method 1, annually-measured samples are distributed throughout the whole country, in Method 2 samples are confined to one section of the country for each year or period. Since this particular problem concerning the advantages and disadvantages of these alternatives for continuous forest

inventory is also of interest in some of the areas in which inventory methods differ from those in northern Europe, it is necessary first of all to give a brief description of the methods applied in the area concerned. This, together with a subsequent cost analysis, will give a better basis for a comparison of the two procedures.

Inventory methods

The methods applied in making different inventories in northern Europe have been explained in detail in papers which relate to the plans or results of inventories. The best account which summarizes the methods of all three countries has been given in English by ARMAN and HAGBERG (1962), who published for instance models of various blank forms used in the field. In the following, an attempt is made to describe only those features which are of interest for the purposes of the present paper. To begin with, mention can be made of the kind of information published, and the intensity of the inventory.

First of all, there is given the area of forest land and some other land use classes, together with the distribution of forest land into site classes, age classes, and so on. The growing stock volumes and their distribution among different tree species, tree size classes, kind and quality of timber, etc., are very essential; this is also true with respect to the growth and its composition. Stand conditions and treatment needs have also been estimated. Determination of the allowable cut is based upon these results, a further step being a general programme for the development of forest production. On a number of occasions calculations of the forest balance, i.e., the relationship between the allowable cut and the actual timber removals, have been made. The removal (annual or periodic cut) may be estimated as part of a national forest inventory, or separately. All of these findings are often given by province, by water system area, by ownership class, and so on.

In addition, facts have been compiled in these inventories for many other purposes. The work in each country has had some special aims. In Finnish surveys, a great deal of attention has been paid to the biological description of the site and to the stand conditions. In Norway, more detailed registration of some soil features and conditions of logging has been made than in the neighbouring countries. In Sweden the statistics of timber removed have been compiled by means of stump enumeration, and a detailed inventory of seedlings has been conducted in order to elucidate the conditions of regeneration.

Some standard errors of mean volume of growing stock per area unit (hectare) may illustrate the intensity of sampling in different inventories. In the province of Ostfold, Norway, in 1957, with a total growing stock of 16.6 million cubic metres, the standard error was $\pm$ 1.7 per cent. In the different provinces of Finland in 1951—53, the errors were $\pm$ 1.2 to $\pm$ 2.6 per cent (growing stock 64

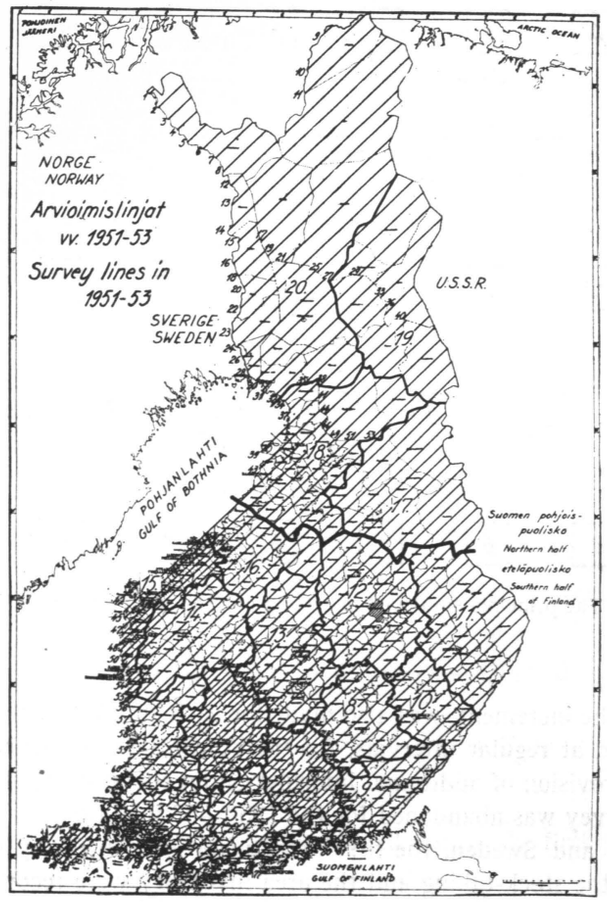

Fig. 1. The survey lines in the third Finnish national forest inventory in 1951—53.

to 38 million cu. m.). In Sweden, the standard error of the individual provinces after 10 years of surveying is expected to range between the same limits. For the whole of Finland, the standard error was computed at $\pm$ 0.4 per cent (total volume 1 500 million cu.m.). The result after one year of surveying in the latest Swedish inventory has a corresponding error of about $\pm$ 1.5 per cent (total volume 2 100 million cu.m.). The result based on 10 years of surveying is expected to be about $\pm$ 0.5 per cent.

All of the Finnish national forest inventories have been combined line and line-plot surveys. Survey lines run from SW to NE cross the main configuration of land as shown by Fig. 1 (ILVESSALO 1956). Each particular characteristic of the land and forest stands crossed by a survey line is recorded on a separate line survey form. In the three first surveys, ocular estimation of the growing stock

Fig. 2. The principle employed in setting out the survey tracts in Sweden.

volume, and the increment, was also made for each stand. Circular sample plots were measured at regular intervals, for the rectification of ocular estimations, and for the provision of additional information on the growing stock. However, the ocular survey was abandoned for the 1960—63 inventory.

In Norway and Sweden, the first inventories were made by means of strip survey: both the stock-taking and the area inventory were recorded within the limits of a strip 10 metres in width. During the second inventories in these countries, a combination of line survey and circular plot survey was applied. In the third Swedish survey, started in 1953, the continuous lines were replaced by the squares (= survey tracts), as explained below.

The survey lines employed in the second survey were used in planning the new inventory. It was decided that the whole country would be covered by survey work each year. Since the length of the inventory cycle was 10 years, an annual survey would comprise one-tenth of the total sample. To this end, the full length of each line was divided into sections of 4.8 to 8.8 kilometres, dependent upon which of the 5 regions of the country was in question. Every second one of these line sections on every fifth line was surveyed during the course of a year. Instead of surveying these sections along a straight line, the survey was carried out along the four sides of a square; the total length of the sides was equal to the length of the corresponding line section of 4.8 to 8.8 kilometres. The principle employed in setting out the survey tracts can be seen in Fig. 2 (cf. HAGBERG

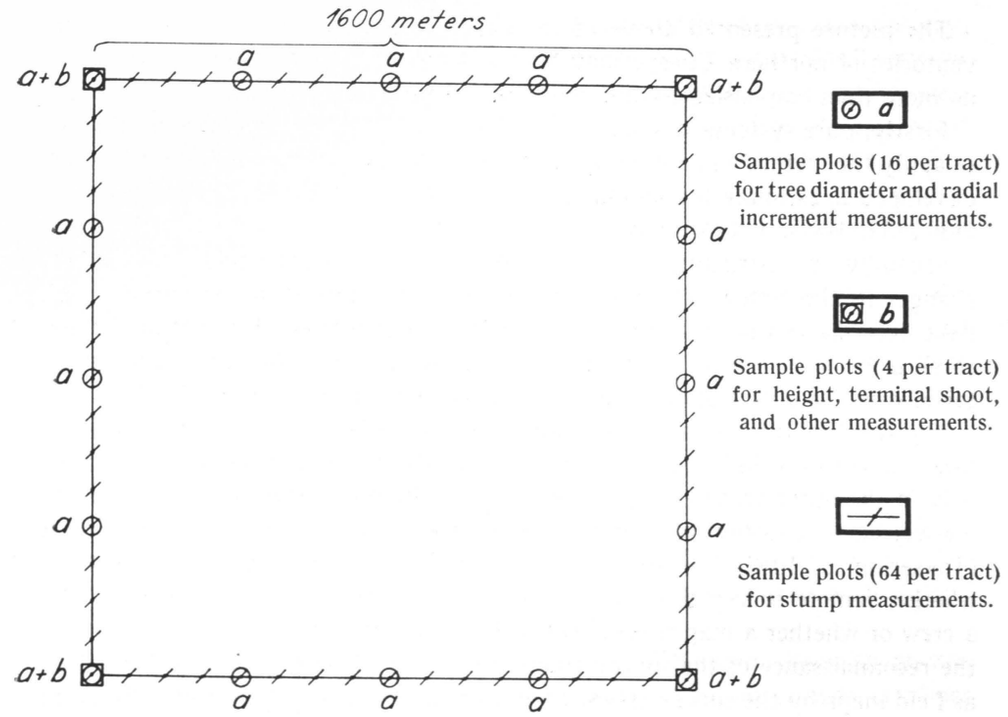

Fig. 3. A survey tract with sample plots in Region III in Sweden.

1957). No. 1 refers to the tracts to be surveyed during the first year, No. 2 the tracts in the second year, and so on.

The tract system helps to obviate unnecessary walking, as the transport of survey crews from one location to another is effected by motor vehicles. The survey work can be started at any point on one of the sides, where road access is easiest, and finished at the same point.

The location of small-sized (138 sq.m.) circular sample plots can be seen from Fig. 3 (HAGBERG 1957), which also gives an idea of the tasks carried out at different locations. An area register was made continuosly along the tract sides. The field crews were quite large, consisting of 6 to 7 men, and on an average one tract was finished in a day.

It should be pointed out that survey tracts, square in shape, have also been used in the Norwegian inventory since 1954. Each tract side there is 1 kilometre in length, and the distance between neighbouring tracts in both directions is 3 kilometres. If all the plots happen to be in forest land, 20 plots of 100 sq.m. are measured in each tract. Survey crews are relatively small in comparison with Swedish crews, consisting of no more than 3 men.

The picture presented above of the basic features of the national forest inventories of northern Europe may be supplemented by some aspects which do no more than emphasize certain points in the earlier description.

Firstly, pure systematic sampling has been used. Endeavours have been made to apply the method in such a way that bias is avoided, and procedures have been developed to estimate the sampling error (ref. LINDEBERG 1924, 1926; LANGSAETER 1932; MATÉRN 1947, 1960).

Secondly, no permanent, remeasured plots have been employed to follow changes in the timber situation. In general, such plots in forest survey work have been used rather seldom in north European countries, although in Finland these plots have in recent years been established in some other large-scale inventories with the object of providing experience of the procedure involved.

The third feature is the rather limited use of aerial photography in national forest inventories. In Finland, the inventory has been based on aerial photographs only in the outer archipelago, and on some of the northernmost survey lines. In Norwegian inventories, photographs were used in a northern province, Troms (Taksering . . . 1962). »In Sweden, aerial photographs are employed to explore whether remote survey tracts are forested to an extent that justifies a visit by a crew or whether a map survey will suffice. Otherwise being of great value for the reconnaissance of the survey tracts, the aerial photographs have been used as field maps by the survey crews» (ARMAN and HAGBERG 1962). But estimation of the growing stock has been made almost exclusively on the ground.

Of course, there exist definite reasons for the limited use of aerial photographs. Apart from traditions, there must be borne in mind the achieved intensity of forestry. Furthermore, the fact that these countries are forested rather homogeneously may reduce the necessity of aerial photographs in this type of work. Again, forest ownership is rather intermingled; the efficient use of photos would demand a great deal of cooperation between different owners.

As a fourth point, it might finally be stated that the use of motor vehicles for survey crews should be considered as an established fact, and one which certainly has an effect on inventory methods.

Costs of the alternatives

It was mentioned in the introduction that the main purpose of this paper was that of comparing alternatives for a national forest inventory, one of them of »the Swedish type», in which annually measured samples are distributed all over the area, and the other of »the Norwegian type», in which annual samples are confined to one section of the area. In preparing a cost analysis, it would be somewhat difficult to make comparisons by taking the costs of the Norwegian and Swedish inventories as a starting point, since there are differences between

those countries with respect to forestry circumstances, sizes of crew, rates of pay, etc. For this reason, the costs in the most recent Swedish inventory will serve as a basis for the analysis of transport costs in particular. Following this, the question will be raised: How much less would the transport and total costs be, if other conditions remained the same, and a survey made province by province (as in Norway) instead of the annual measurement of one-tenth of the total sample throughout the country. Of course, at this stage the Norwegian and other data can be applied.

The assumption that the other conditions would remain the same despite the changeover from one method to the other might, of course, mean some extent of over-simplification of the problem. If the present method in Norway were replaced by the current Swedish one, some other stages of the work, such as estimation of removal, would probably be done differently. Nevertheless, broadly speaking it might be possible to compare the relative costs of the two methods on this basis.

The land area of Sweden is about 410 000 square kilometres. In the national forest inventory, about 1000 survey tracts are as a rule measured annually. In 1961, which is the year of the cost data, 1 100 tracts were measured, each of them thus representing an average area of 370 sq.km.

The total cost of the inventory in 1961 was 1.070 million Swedish crowns (krone), i.e. U.S. $207 000. The cost of field work was $0.^{573}$ mill. crowns, or 54 per cent. The average cost for a tract was thus 520 crowns in field work and 970 crowns in total. Wages, daily allowances and similar items, also including some transport, were 433, direct car costs 43, and instruments, map material etc. 44 crowns per tract.

The direct car cost, 43 crowns, is about 8 per cent of the field work cost. The average length of the daily drive was approximately 115 kilometres, and the time required for actual travelling $2.^{2}$ hours out of $8.^{5}$ hours, the average length of a day without breaks for meals. Thus, 26 per cent of the day was spent in the car; in the opinion of the head of the survey, the corresponding cost should be deducted from the total wage bill, 433 crowns per tract, to arrive at the transport costs. This gives 112 crowns; after addition of the direct car cost of 43 crowns, we get 155 crowns, representing about 30 per cent of the field work cost, and 16 per cent of the total cost of the inventory.

It may now be asked, how much less would the cost be, if instead of sampling the whole country each year (Method 1), the samples were taken from one section of the country (Method 2). The average area represented by each tract in this section is 10 per cent of 370 sq.km, i.e. 37 sq.km. Since the conditions are otherwise supposed to remain the same, the problem is concerned with the effect of lower car costs.

To estimate the length of drive necessary if sampling is carried out in a new way, the experience gained in the national forest inventory of Norway, and in

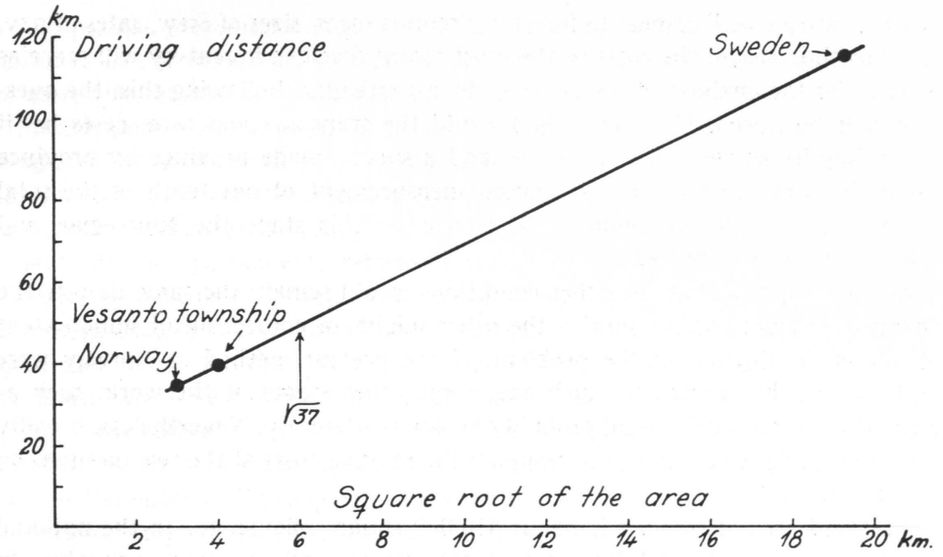

Fig. 4. The regression of driving distance on the square root of the average area represented by the annual tracts.

the inventory of one township, Vesanto, in Finland, can be used, although of course the circumstances in these two cases cannot be exactly the same as in Sweden.

As was mentioned earlier, each survey tract in Norway represents an area of 9 sq.km., which requires a drive of 35 kilometres, and a period of 1 hour. In the 1962 Vesanto inventory, a tract was measured for each 4-kilometre square, viz. an area of 16 sq.km. If approximately one day's work is assumed for each tract, the length of drive per tract can be estimated at 40 kilometres, requiring 1.15 hours.

We may now assume that the drive per tract is proportional to the square root of the area represented by the tract. Fig. 4 is based on this assumption, and gives about 50 kilometres as the length of drive required for a tract representing an area of 37 sq.km.

Naturally, the direct car cost does not decrease in a way which is directly proportional to the reduction in driving distance, but more slowly. Since the relationship between the lengths of drive in two cases is $\frac{50}{115} = 0.44$, we may assume that the costs in the shorter drive are about two thirds of those in the longer drive. This would give 0.67 times 43 crowns = 29 crowns as a direct car cost in sampling one section of the country. The difference is 43—29 crowns = 14 crowns.

Not even the time used for driving will decrease in direct proportion to the driving distance, because on shorter runs a relatively large part will be on poorer roads. In Sweden 115 kilometres requires 2.2 hours, representing 52 kilometres an hour. In Norway, and in the Vesanto township in Finland, the speed was 35 km/h. It can be assumed that 50 kilometres in Swedish conditions would be driven at 45 km/h, which means the driving period of 1.1 hours, i.e. half of the time required in Method 1. This is 13 per cent of the average working day, 8.5 hours, and can mean a saving of 0.13 times 433 crowns = 56 crowns in wages. Thus the total saving in Method 2 is 14 + 56 crowns = 70 crowns per tract, and all the driving costs in Method 2 amount to 29 + 56 crowns = 85 crowns, instead of the 155 crowns for Method 1.

On this basis, we arrive at the following cost comparison per tract:

	Method 1	Method 2
Field work	520	450 crowns
Total	970	900 »

Thus the difference in total costs between the two methods is 7 to 8 per cent. It may be added that the car cost in Method 2 is 19 per cent of the cost of field work and 8 per cent of the total cost of inventory. The corresponding percentages for Method 1 are 30 and 16 per cent, as mentioned earlier.

Discussion

The above-described features of forest inventory methods in Scandinavia, together with the subsequent cost analysis, constitute the necessary bases for comparison of the alternatives in procedures for continuous national inventories. In Method 1, annually measured samples are taken throughout the country, but in Method 2, samples are confined to one section (or sections) of the country each year.

Costs. Comparison of the inventory costs had to be carried out in a rather simplified form. At any rate, on the assumption of the same degree of accuracy it appeared that the total costs of Method 2 are about 7 to 8 per cent lower than those of Method 1, by reason of the difference in transport.

Currency of the results. When it is asked how up-to-date the survey results are in both methods for any year in which estimates might be needed, the whole country and the sections should be treated separately. As far as the whole country is concerned, in the application of Method 1 there exist continuous possibilities of acquiring fresh, relatively reliable results, although both the accuracy and the detail of the results are improved when the data for a number of years are combined. On an average, the results obtained from Method 2 are at least as many years old as one half of the length of a survey cycle.

For a certain section, say a province of the country, Method 1 gives some preliminary results as early as one year or two after the survey has been begun, but assuming immediate computation of the data more accurate estimates are n/2 years old (survey cycle, n years). By using Method 2, accurate results are available every *nth* year, but the results obtained by this system may often be rather old when it is necessary to make some important decision connected with the forest resource situation. The difficulty with this type of method was experienced earlier as regards the whole country in Finland, where an effort was made at a concentrated nation-wide inventory after a certain period. It may of course be possible to improve the situation in this and other cases after surveys have been in progress for a number of years by the use of regression methods, in order to get more reliable current estimates. For example, it may be assumed that the growth is a function of the initially measured volume, remeasured volume, timber cut, mortality and elapsed time. But there is no guarantee that these methods will prove advantageous.

Frequent mention has been made that Method 2 is to be recommended if the emphasis is laid upon regional information and planning. The points raised above indicate the need to bear in mind some of the drawbacks of the method in this respect.

Survey of removal. To follow development of the forest resource situation, timber removals (annual or periodic cuts) should also be known. In Finland, for example, three extensive studies have been carried out with respect to wood utilization and timber removals, immediately after each national forest inventory, but as separate studies (cf. ILVESSALO 1954). These investigations were based upon official and other statistics, enquiries, direct measurements, and to some extent on pure estimates. In Norway, the Central Bureau of Statistics has compiled the corresponding information. In Sweden, the annual timber cut has been estimated since 1953 from stump enumeration made in the national forest inventory; the only stumps subjected to measurement were those from the most recent cutting year.

It should be mentioned that stump measurements have also been made on a large scale in Finland, over a period of years, to provide experience of the method, and that some experimental measurements have been made in the Norwegian national inventory, too.

It seems that one thing it will be necessary to know in future is the amount of timber used for different purposes, and this cannot be decided from stumps; but as a check on the total amounts of cut, its distribution among tree species and diameter classes, etc., stump measurements are very helpful. In addition, when the balance between the allowable cut and timber removal approaches the critical point, and there exists a danger of over-cutting, the annual statistics are needed. These can be derived from stumps. The stumps most accurately recognized are those of the latest cutting-year, although a period of up to 10

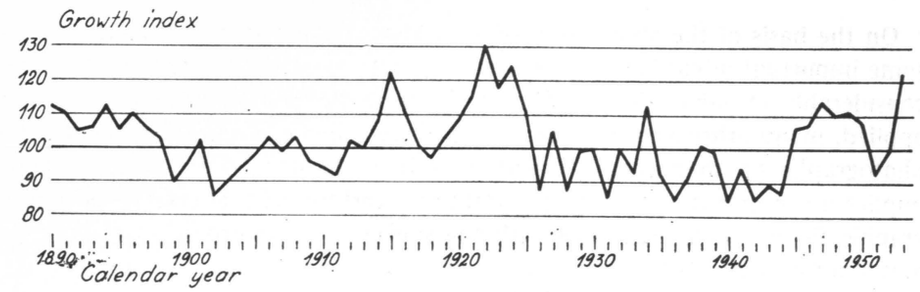

Fig. 5. Annual growth indices of Scotch pine in southern half of Finland in 1890—1953.

years can be used (NYYSSÖNEN 1955). All this means that there is often a need of annual stump sampling throughout the whole country. From the standpoint of the present discussion of alternative methods, again, this means that Method 1 is preferable to Method 2.

A continuous forest inventory with its permanent check on timber resources, their growth, and so on, may of course diminish the necessity for stump measurements.

Other annual information. In conjunction with the national forest inventory, some other information required every year may also be compiled. All this speaks in favour of the use of Method 1. For example, there is the estimation of coming seed crops from the cones, which may prove of great value in silviculture for the arrangement of seed collections, seed-bed preparation, etc. Another interesting problem is the occurrence of pests and damage caused by insects; the national inventory may be taken advantage of in this respect.

The annual variation in growth attributable to climatic reasons is a very important phenomenon. In recent decades, a great deal of attention has been devoted to growth variations and their influence in growth studies. By way of example, Fig. 5 shows the annual growth indices (average = 100) of Scotch pine in southern half of Finland (ILVESSALO 1956). When the growth is calculated from increment borings of the last 5 or 10-year period, and this information is used in determination of the allowable cut in which growth projection is needed, the result may be a very biased one if the annual indices are unknown. For instance, the growth of the period 1921—25 would result in an over-estimation and that of the period 1940—44 an under-estimation of the future increment and cutting possibilities. Since the growth indices make it possible to improve the increment forecast, they can be of great help in management planning in practical forestry. The collection of data for the purpose from different parts of the country might be properly arranged in the national forest inventory, if Method 1 is used. However, other possibilities exist for collection of the required data.

On the basis of the above discussion, it can be concluded that Method 1 has some important advantages, although the points mentioned here naturally vary considerably in value. For the final decision of the method of inventory to be applied, many other aspects must be considered. For example, the use of aerial photographs is perhaps more efficient in Method 2 than Method 1, since Method 2 implies a concentration of survey efforts in a certain area, and repeated photographic flights might be linked with the survey work in order to provide fresh material for photo stratification and similar items. For the time being, however, it is not easy to see how the practical difficulties could be overcome to ensure greater benefit from the concentrated photography in northern Europe.

It must be noted that the comparison of different alternatives has in this instance been restricted to two methods. Of course, it would be possible to sample the whole country, or a section of it in some other way each year. Administrative management units might be employed as a basis, by sampling definite number of forests under different ownership, and combining them to provide a picture of the forest resources in a given geographical area. This method has been partly applied in some regions of the United States (e.g. the Lake States); some special studies on the method will be published in Finland in the near future. In a way, accordingly, there is a question of combining of national and management planning inventories. This method seems to be worth further attention in such countries as Finland, Norway and Sweden, where small-scale private farm forestry is very important, and where management planning of these holdings could benefit greatly from the national forest inventory if administrative areas were used as sampling units.

Summary

A comparison has been made between two alternative methods of continuous national forest inventory. According to Method 1, samples measured annually are taken throughout the country, but in Method 2 samples are confined to one section of the country each year. The figures are derived from rather intensive national forest inventories carried out in the North-European countries Finland, Norway and Sweden. Systematic sampling on the ground has been employed, without remeasured sample plots. Field work has been concentrated on survey tracts, square in form and corresponding approximately to one day's work by a survey crew. Nevertheless some conclusions as to application may be drawn, for instance in the procedures which make use of aerial photography and permanent plots.

For the whole country, Method 1 gives results, which are continuosly up-to-date, although detailed information requires observation over a period of several years. On an average, the results obtained from Method 2 are at least n/2 years old (survey cycle, n years). For a specific section of the country, Method 1 gives preliminary results even after surveying for one or two years, but more accurate estimates are at least n/2 years old. If Method 2 is employed, accurate results are available every n*th* year, although the findings according to this system may often be comparatively old when some important decision has to be made in connection with the forest resource situation. Thus, Method 2 is not always to be recommended, even if the emphasis is laid on regional information and planning.

To gain knowledge of annual timber removals, often necessary in assessing the forest resource situation, stump measurements can be used, either exclusively or by way of control. The corresponding sampling must be effected throughout the whole country, and this can be done only when Method 1 is used. Other information required annually, such as estimates of the coming seed crops, or the occurrence of pests, along with the annual variation of growth due to the climate, favour Method 1.

It can thus be said that Method 1 has some important advantages, although these must be bought at higher cost. A comparison of inventory costs shows, assuming the same degree of accuracy, that the total expenditure for Method 2 is about 7 to 8 per cent lower than that for Method 1, owing to the difference in transport requirements. To arrive at a final decision as regards the method of

inventory, many other aspects need consideration. For example, the use of aerial photographs may be arranged more efficiently in Method 2 than in Method 1. It should also be borne in mind that it is possible to take a yearly sample of the whole country, or a section of it in some other way, such as by using administrative areas as sampling units.

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