THE INVENTORY OF FOREST RESOURCES

by

Y. Ilvessalo, D. Ph.

Professor at the Forest Research Institute of Suomi.

A knowledge of the forest resources of an individual country, and even of the whole world, may be considered important for many reasons. Only with reliable statistics gathered as far as possible simultaneously can a forest producing country summarize its forest balances. Only if such data are available, can the forest working industries of a country make their calculations of the existing supplies of raw materials, which is essential in planning operations that extend far into the future, and in organizing new industrial establishments or enlarging the existing ones. In addition to knowledge of the forest resources of a country and its separate districts generally, from the point of view of a country's forest grower it is also important to know in what direction the forest production of the country is developing, and what advantages seem permanently to exist for carrying on forestry and for making it more efficient. From the economic point of view of an entire country, apart from a knowledge of its own forest resources, a familiarity with the forest resources of other forest producing countries is also essential. As the countries importing forest products partly meet their lumber demands from their own forests, it is important, both for the economics of such countries themselves as well as from the point of view of the countries exporting wood products to them, to be acquainted with their forest resources as well. It would, therefore, seem desirable from the economic point of view of each individual country, as well as from that of the whole world, that reliable, homogeneous, and as nearly as possible simultaneous forest statistics should be compiled of the whole world, or at least of those forest resources included in its economic sphere, together with data of wood consumption and of the forest balance.

Several countries, realizing the importance of their forest resources have already compiled such statistics, or are now preparing them. But many countries have no such statistics whatsoever, or they are

based on the results of rather uncertain calculations and estimates made at different periods. In most countries, and in the greater part of the world's forests, in order to establish reliable, homogeneous and simultaneous statistics of forest resources and of the present condition of the forests, a general survey of forests equivalent to an inventory of the forest resources should be instituted.

The present time may be considered suitable for general inventories of forest resources on a large scale. The forest resources of the world have diminished to a great extent because of the increased consumption, and the value and uses of forests have thereby greatly increased. New uses for wood have constantly appeared, accelerating even its present rapid rate of consumption. In many countries, too, that export forest products, the annual consumption of the forests has already exceeded or will soon exceed the annual growth, so that the forest balances should quickly be ascertained, before cutting is increased and a return to an equilibrium becomes difficult. The fact is not without significance also, that the necessary labour for this kind of inventory work can at present be had easily, since men of the forestry profession in very many countries are suffering from lack of employment.

There are several methods for making inventories of the forest resources of a country, and different methods may be applicable in different countries. In countries where forestry is intensive and where the forest owners generally have working plans drafted for their forests, it may be possible, on the basis of these, to gather reliable and sufficiently homogeneous and simultaneous statistics on the condition of the country's forests and on the forest resources in full. But on the other hand, this method is not applicable in countries where forestry is less intensive, and the summarizing of forest resources becomes possible only through a general, simultaneous survey. In the latter case, which is the case with the largest part of the world's forests, a separate survey of all the forests of the country naturally is neither possible, nor even necessary, but recourse in this instance should be taken to some tried, representative method. This case only is referred to in the following, which describes the general outlines of a plan for a system that can be used in surveying a country's forest resources.

The representative method of forest surveying generally presupposes the taking of so-called sample plots. There are, of course, many different ways of taking these sample plots. One of these methods,

line forest surveying, which has been used in forest inventory for a long time in the northern countries, among others in Suomi for about half a century, has been demonstrated to be very suitable for the purpose in question by many previous investigations and at present on the largest scale by the recently completed simultaneous survey of the entire forests of Suomi, both in regard to the reliability of its results as well as its quickness and comparatively low costs.

Line surveying, in a way, comprises a large number of sample plots (lines) that are scattered evenly over all parts of the forest under survey. This, therefore, is a representative method in which, in order to obtain the most approximately correct results and the actual variation, the mutually parallel sample lines are always placed equidistantly from each other, and as perpendicularly as possible to the general longitudinal direction of the land figures (map figures). When lines are thus laid sufficiently close together, it is probable that they will correctly interpret the entire forest, if the district under survey consists of a collective whole.

It is obvious, that in line forest surveying the closer the lines are drawn to each other, the greater the accuracy which is obtained, for thus the greater percentage of the entire forest area is surveyed. By diminishing more and more the distance between the lines any accuracy desirable is reached, but this, of course, only by increasing the costs in a corresponding measure. Such a distance between the lines, or survey percentage, must therefore be chosen as gives the required accuracy at reasonable cost. Tests that have been made have shown that in order to obtain a satisfactory accuracy the survey percentage may be relatively so much smaller, *i. e.* the lines so much wider apart, as the area under survey is larger and more homogeneous. The accuracy of line surveying primarily depends on the distance between the lines, and not nearly to the same extent on the width of the lines themselves. By placing narrower lines closer together the variations are better accounted for, and generally in statistical work the accuracy of data increases as the square root of the number of observations.

Line surveying is an advantageous method also in this way, viz.: — that the accuracy of the results can fairly easily be tested with the aid of methods based on mathematic-statistical calculation which are already developed on a firm foundation and which in Suomi, too, especially during very recent times, have been under most thorough investigation.

In commencing the surveying of an entire country's forests, a programme comprising the smallest details is necessary, for only in this way can the work of several survey parties be made similar throughout, so that all the results can be combined in due course without trouble into one group of statistics. For the same reason it is also important that the foremen in charge of the labourers engaged in the work, should be fully competent men, who have been thoroughly trained in line surveying on trial lines before the commencement of the work, and that the work of the surveying parties is continuously watched and directed.

When a homogeneous and a simultaneous statistical report of the forests of an *entire country* is the main object of the survey, in addition to the above, it is also desirable that the time of the survey shall not be spread over too long a period, but over as few successive years as possible in order that age-class, volume, growth, and other data can be adapted to some chosen epoch, without more or less inaccurate extraneous calculations. Thus, it would seem expedient for the linear distance to be chosen of such an extent, that while very accurate results (say within an accuracy of 1 %) are rapidly obtained for the most important questions with regard to the whole country, in some degree less exact results (say within 5 %) may be accepted for its smaller districts.

The survey lines are planned on the most accurate map of the country obtainable, and each surveying party receives a line map of its own territory for checking and other purposes.

The composition of the surveying party depends on the kind of work to be done on the line. When the line survey comprises in addition to regular surveying, also the counting and measuring of trees occurring within a chosen width along the line, the most suitably composed party should contain 8 persons: (1) a foreman (this position is filled best by a forester who has graduated from the highest course in forestry at college and who is especially skilled in forest mensuration), who supervises the work and does the estimating etc., filling in the survey form for every figure touched by the line; (2) a book-keeper (this position is filled best by a practical forest ranger who is a graduate of a lower course in forestry), who, among his other duties, records the gauger's announcements of the diameter measurements in the usual way; (3) a compass-man, who, travelling ahead of the rest of the party, determines the direction of the line with a dioptric-compass; (4, 5) two measurers, who measure the distances

travelled for the determination of the length of each land figure occurring on the line; (6, 7) 2 gaugers, who measure the diameters of the trees occurring on the respective sides of the line; (8) a porter, who assists in carrying instruments, tools, etc., and who measures with a staff the width of the line from its centre, whenever necessary to indicate to the gaugers which trees are included in the line. If growth investigations are constantly made in connection with the survey, then more assistants are needed.

In such territories where forestry is rather intensive and sufficient funds are available, the composition of the line surveying party, as outlined, is probably the most suitable. But where forestry is less intensive and costs have to be considered, the expenses can well be reduced without great detriment, especially by not counting the trees continuously nor taking growth data along the entire line, in which case these data are limited to sample plots that are measured at regular intervals along the line. (For sample plots in the survey of Finnish forests, for instance, the last 50×10 m^2 of every second kilometre of the survey line were chosen, and for the scarcer, but more important merchantable timbers [trees of at least 20 cm at breast-height] a gauging area of 100×10 m^2 taken also, at the end of every other kilometre). In addition to smaller expenses, this is advantageous, too, for the reason that on long survey lines there cannot be full assurance, even with constant supervision, of careful definition in counting or leaving out the many trees that occur just on the border of the line, which is likely to cause considerable errors, because each tree represents several hundred or even several thousand trees, depending on the size of the surveying percentage. The daily working results are about 2 km more, and the working expenses are reduced to about one-half of those described in the first instance, if the individual measuring is limited to the sample plots only.

In limiting the counting of trees to sample plots, the volume and the growth of the stands cannot be calculated separately for each land figure touching the line. But as it is necessary for statistical purposes to know the volume and growth of each stand touching the line, these are estimated ocularly, while travelling along the line through the woods with the help of growth and yield tables so far as they exist, and other subsidiary means. The estimating is done by the foreman of the party, who must be versed in this kind of work. But ocular estimates, by themselves, cannot, of course, be accepted as satisfactory, because with them might be combined, besides occasional

errors in a positive and negative direction which generally counterbalance each other on a large scale, also systematic errors, which make the estimator's results regularly too large or too small, etc. This systematic faultiness must be absolutely eliminated from the estimated results before they are used. For this reason the ocular results of the estimator are checked and corrected, after completion of the work, with the aid of the sample plots that he has taken, upon which his ocular estimate is known and upon which the calculated, or actual volume and growth is later obtained by calculations in the office. In Suomi, where ocular estimation is used to a considerable extent, this checking is generally accomplished with correlation calculations and with the aid of regression lines, based on them. The estimates of each estimator are checked in several sections, so that possible variations at different times will also become apparent. It is also often advantageous to check separately the estimates of large and small volumes, as well as that of growths. By drawing on the same co-ordinates (where the abscissa is the calculated and the ordinate the ocularly estimated volume or growth), a normal line and a smoothed line indicating the estimator's manner of ocular estimating, which is obtained from the regression equation in checking his estimates, the estimator's ability will be seen clearly, and whether or not it contains systematic faultiness and of what kind the latter is.

The correlation between the ocularly estimated and the calculated values of volume or growth is especially distinct; thus, in the survey of Finnish forests the correlation coefficient, on the average, was for volume 0.902 ± 0.016, and for growth 0.800 ± 0.024, so that ocularly estimated values for volume and growth can be corrected with great certainty to coincide with reality with the aid of such smoothing calculations.

The facts to which attention should mainly be devoted in line surveying and which therefore should be contained in the surveying forms upon which they are marked at every figure touching the line in order to give sufficiently illuminative statistical data on the different aspects of the forests and the forest lands, may be mainly limited to the following:

Land owners, differentiating between the most important groups, such as the State, private owners, Joint Stock Companies, communities, etc.

Superficial deposit, as for example, moraine, sand, clay, etc.

Kind of land, as for example, forest land, field, etc.

Quality class of the locality (site), *i. e.*, forest or moor type.

For the investigation of forest lands it can also be stated, whether the figure is for grazing purposes or not, whether it is considered fit for cultivation or not, and for the investigation of moors, the depth of the moor, the possibilities of drainage and of cultivation, etc.

In estimating stands, undergrowth and so-called hold-overs are distinguished from the dominant forest, whenever the stand is of such uneven age and of such uneven height that such successions are easily perceptible.

The species of trees are recorded by estimating what percentage of the volume of the stand belongs to each species of tree.

Age-class is determined in odd 10-year periods by boring (10 = age-class 1—20 years, 30 = age-class 21—40 years, etc.), and in uneven-aged stands both the mean age and the age limits are noted.

Density of the stand is estimated according to how many tenth parts of the area of the figure are covered by forest.

Quality class of the stand is best recorded by the aid of growth and yield tables by estimating how many tenth parts the volume of the stand forms of the volume of a corresponding normal stand.

The height is estimated for dominant height (Oberhöhe).

The growing stock is estimated with bark included, for instance, to full 10-cubic metre amounts per hectare.

The volume growth (current annual) is estimated unbarked by the aid of experience, growth-boring, and with the growth percentages of growth and yield tables, for instance, to one-half cubic metres.

When the line runs along the border of two estates, types, or stands, the length of the line is divided between them.

In order to show the present silvicultural condition it is important that for each figure and stand on the line, records pertaining to this phase are also taken, *i. e.*, is the forest unthinned or thinned, or cut; what thinning or reproduction cutting method has been used; has the stand been spoiled or destroyed by cutting; artificial reproductions, etc.

A comprehensive statistical record of the forests can be arranged from the data on the above facts alone, which may be considered sufficient for taking an inventory of the forests of a country and for outlining plans for the forestry in the future. Since the survey, as it has been described here in some of its most important features, is comparatively inexpensive (the outdoor work of the Finnish survey cost — the linear distance being 26 kilometres — one dollar for each

kilometre of line, or 0.00043 dollars for each hectare of the country's land area), there do not seem to be any insurmountable obstacles in the way of surveying the forest resources of a country.

Suomenkielinen selostus.

Maan metsävarojen arvioiminen.

Monista sekä metsätaloudellisista että yleisistä kansantaloudellisista syistä pidetään nykyisin hyvin toivottavana yhtenäisen ja luotettavan tilaston aikaan saamista jokaisen maan ja koko maailmankin metsävaroista sekä puunkulutuksesta ja metsätaseesta kokonaisuudessaan. Useat maat ovatkin jo ryhtyneet toimenpiteisiin tällaisen tilaston laatimiseksi. Enimmissä maissa ovat tiedot maan metsävaroista niin epäluotettavat ja puutteelliset, että tilaston aikaan saamiseksi on varta vasten suoritettava maan metsien yleinen arvioiminen.

Menettelytapoja maan metsävarojen selvittämiseksi on useitakin valittavissa ja eri maissa lieneekin erilaisia menetelmiä sovellettava. Muutamissa maissa, missä metsille yleisesti on laadittu taloussuunnitelmat, saatettaneen niiden perusteella riittävä tilasto koko maan metsistä kerätä. Mutta enimmissä maissa tällaista keinoa ei ole käytettävissä, vaan metsävarojen selvittely on mahdollinen vain yleisen ja yhtäaikaisen arvioimisen perusteella. Silloin ei luonnollisesti maan kaikkien metsien yksityiskohtainen arvioiminen ole mahdollinen eikä se ole tarpeellinenkaan, vaan riittävän tarkkaan tulokseen päästään jonkin koetellun edustavan menettelytavan avulla.

Pohjoismaissa on sekä käytännön että tutkimusten perusteella parhaaksi menetelmäksi suuria metsäaloja arvioitaessa osoittautunut n. s. linja-arvioiminen. Tämä menetelmä on, paitsi yleensä tarkkoihin tuloksiin johtava ja suhteellisesti halpa, myöskin siinä suhteessa edullinen arvioimistapa, että sen tulosten luotettavuus voidaan verraten helposti tarkistaa jo varmalle pohjalle kehitettyjen matemaattistilastollisten laskelmien avulla.

Ryhdyttäessä kokonaisen maan metsävarojen arvioimiseen on yksityiskohtaisesti pieniäkin seikkoja selvittelevän suunnitelman laatiminen ja arvioimistyössä toimivien henkilöiden harjottaminen koelinjoilla välttämätöntä. Vain siten on takeita lukuisien arvioimisjoukkojen työn yhdenmukaisuudesta.

Milloin yhtenäisen ja yhtäaikaisen tilaston aikaan saaminen koko maan metsistä on arvioimisen päätarkotuksena, on edullista, että arvioimistyö ei jakaannu kovin pitkälle ajanjaksolle, vaan mahdollisimman harvoihin peräkkäisiin vuosiin, niin että tilastot voidaan ilman epävarmoja lisälaskelmia keskittää johonkin määrättyyn ajankohtaan. Tällöin tuntuisi tarkoituksenmukaiselta määrätä arvioimislinjojen välinen etäisyys niin suureksi, että koko maahan nähden saadaan tarkat tulokset mahdollisimman nopeasti, kun taas maan pienempiin osiin nähden tyydytään jonkun verran vähemmän tarkkoihin tuloksiin.

Laajoja alueita käsittävässä linja-arvioimisessa ei suurien kustannusten takia useinkaan kannata suorittaa puiden lukua ja mittausta, kasvututkimuksia j. n. e. yhtämittaisesti pitkin matkaa koko linjalla, vaan ne rajoitetaan linjoilla määrättyjen säännöllisten välimatkojen päässä toisistaan otetuille koealoille. Paitsi kustannusten supistamiseksi tämä on edullista siitäkin syystä, että pitkillä arvioimislinjoilla ei voi olla alituisesta silmälläpidosta huolimatta riittäviä takeita juuri linjakaistaleen rajoille sattuvien sangen lukuisien puiden joko mukaan lukemisen tahi pois jättämisen huolellisesta tarkastamisesta, mistä taas voi aiheutua huomattavia virheellisyyksiä, kun arvioimisprosentti pakostakin on hyvin pieni.

Rajoitettaessa metsikköön kohdistuvat suoranaiset mittaukset koealoihin, toimitetaan arvioiminen koealojen välisillä linjanosilla jokaisella metsäkuviolla silmämääräisesti. Arvioimisen toimittaa arvioimisjoukon johtaja, jonka siis tulee olla tällaiseen työhön hyvin harjaantunut. Silmämääräisen arvioimisen tuloksiin sellaisinaan ei kuitenkaan tyydytä, vaan ne ovat tarkistettavat ja oikaistavat sitä varten kehitettyjä, yleensä korrelatiolaskelmiin ja niiden avulla saataviin regressioviivoihin perustuvia menettelyjä käyttäen. On osoittautunut, että arvioimiseen perehtyneillä henkilöillä on silmämääräisesti arvioitujen kuutiomäärä- tahi kasvuarvojen ja laskettujen eli todellisten kuutiomäärä- tahi kasvuarvojen välillä erittäin selvä riippuvaisuus. Niinpä tätä riippuvaisuutta osottava korrelatiokerroin oli Suomen metsien yleisessä arvioimisessa toimineilla arvostelijoilla keskimäärin kuutiomäärään nähden 0.902 ± 0.016 ja kasvuun nähden 0.800 ± 0.024, joten silmämääräiset arviot voitiin sangen suurella varmuudella oikaista täysin todellisuutta vastaaviksi.

Ne seikat, joihin arvioimisessa ensi sijassa on huomiota kiinnitettävä ovat: maanomistaja, maalaji, tiluslaji ja metsätyyppi, metsikön puulaji-, ikäluokka-, tiheys- ja hyvyyssuhteet, metsikön kuutiomäärä ja vuotuinen kuutiokasvu ha kohden, n. s. arvopuiden lukumäärä sekä metsikön nykyinen metsänhoidollinen tila. Jo näitä seikkoja käsittävien muistiinpanojen perusteella saadaan metsistä riittävä tilasto maan metsävarojen selvittämiseksi.

Kun arvioimistyö sellaisena kuin se tässä muutamiin tärkeimpiin piirteisiinsä nähden on kuvattu vaatii suhteellisesti vähän kustannuksia — esim. Suomessa 26 km linjavälein suoritettuna keskimäärin 1.7 penniä valtakunnan maa-alan jokaista hehtaaria kohden ja 2.4 penniä metsähehtaaria kohden — ei liene voittamattomia esteitä olemassa yhä useampien maiden metsävarojen arvioimiselle lähiaikoina.