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ASSESSMENT OF FOREST RESOURCES FOR FOREST MANAGEMENT

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SELOSTE:

METSÄVAROJEN ARVIOINTI METSÄTALOUDEN SUUNNITTELUA VARTEN

The general requirements for forest information required in forest management include the availability of quantitative data concerning forest areas and timber volumes, data describing the structure and quality of the forest by classes, data dealing with the forest dynamics such as increment and mortality, standwise data tied to on-the-ground locations, and the timeliness of all this information.

A review of the present inventory systems reveals variations in the information used to manage forests. In many cases, there appears to be an inadequacy of information. There may be no inventory system, or sampling may concern only overall features of the forest. The general trend has been towards a more common use of delineation of stands and the estimation of stand characteristics. In European countries, survey techniques have been improved by, for instance, trying to avoid subjective features in standwise assessments and through the use of index subcompartments which are remeasured. In North America, a new approach was recently introduced to generate stand tables which seems to have significant inventory capabilities. In some cases, the advanced inventory systems may simultaneously employ three kinds of inventories, each complementing the othe1.

In designing an inventory and management information system experiences gained elsewhere should be utilized with sudies of sampling methods, remote sensing techniques, new instrumentation and computer services. Yield tables and other aids are also important. While the decision making can thus be improved, it also becomes possible to introduce cheaper methods of periodic inventories. The information system should be only as elaborate as is required to do the job. The contents and accuracy of quantitative and qualitative information should be considered and differentiated according to the real needs. The costs of acquisition of inventory information correlates with a degree of sophistication of the system, but rarely exceeds one percent of the stumpage of the timber cut. Moreover, it is a common experience that the increase in wood production more than compensates the costs of planning on the basis of inventories.

INTRODUCTION

Sustained management of the forest requires a large amount of information from various fields. Information is necessary in order to comprehend the current state of an enterprise so that an evaluation of problems and prognoses of future developments are possible. Information is also needed in order to develop alternative means which can lead the enterprise from the present stage to the goals aimed at, and to control the implementation of the plans. Ways and means of acquiring and utilizing all this information are of major importance.

The information requirements of forest management were grouped by Davis (1966, p. 263–266) into three general categories: (1) Information originating externally to the forest: i.e. information on markets and timber supply, labour supply, administrative and financial organization, weather and climate, etc. (2) Information directly concerning the growing forest and associated ecosystems. In the main, these are questions of forest inventories of various kinds. (3) Information arising from the administrative operations of a forest enterprise, i.e. information concerning the forest other than that obtained from forest inventories. A wide range of operations information (cutting reports, records on silvicultural work, personnel time and activity cost reporting, records on equipment etc.) is necessary for legal and taxation purposes, higher management and for administrative control.

Other divisions of the information requirements are also possible. According to Speidel (1972, p. 29–30), there exists four sources of information for the planning process. The results of systematic observations and measurements present original information, while results gained through learning and anticipation belong to derived information. Experiences, research results and results of model analyses are forms of derived information. In general, they are greatly needed in the comprehensive and complex tasks of management planning.

Information provided by forest inventories must be combined with other data. A characteristic of good planning is a careful consideration and synthesis of all the available information. Nevertheless, the principal task of this paper is to concentrate on the forest inventory, to discuss the continuous assessment of the forest resource base in relation to forest management. First, attention will be paid to the general requirements of management planning inventories. Secondly, the main types of those inventories presently in use in several countries following a market economy will be described. Thirdly, on the basis of the foregoing some developments, special features and needs will be discussed, and a few conclusions will be drawn.

REQUIREMENTS

The principal instrument in the present connection is the forest management plan, the statement in which the owner lays down the long-term objectives he intends to pursue and lists the means he intends to employ in order to attain these objectives. The allowable cut and its composition with regard to the kind, quality and size of timber are of special interest. The ultimate task of the forest manager is to indicate where, when and how the cutting operations and the silvicultural measures should take place. Let us analyze the requirements for inventory information necessary to complete these tasks.

In order to solve the first problem, how much to cut, the minimum requirement is to be aware of the *timber volume* and inherent *forest area* data. Early attempts at estimating the allowable cut on this basis were made in Central Europe by means of formulas based on normal forests and utilizing total volume data. Quite recently, the mean relationship between the drain and growing stock has developed as a useful guide, e.g. in Finland and Norway.

An indication of the gross volume of the cut is, however, adequate in exceptional cases only. There exists the common need to specify the cut and, accordingly, the growing stock with regard to the tree species, kinds of timber, quality and size. Furthermore, the *structure of the forest* must be known in terms of the area distribution with regard to site, forest type, age, condition and treatment classes. The mensurational characteristics (heights, basal areas, diameters etc.) are commonly required by area classifications.

Next, we consider *forest dynamics* or »change» data, such as increment and mortality. In sustained yield management, this information is utilized for both the determination of the cut, prognoses and control. In single stands the increment is one indicator of maturity and treatment needs.

The question »how much to cut» may be answered on the basis of extensive, forest-wide data. Answering the question »where to cut» requires more detailed information; information which accounts for individual stand production and production potential. This need for *standwise information* strongly affects the inventory methods. Stands must be delineated on maps or on aerial photographs, and the inventory system must furnish data of sufficient content by stands. The aim »is to (1) select those stands which should be harvested in order to further the objectives of the land owner, and (2) to furnish a positive geographic location so that operational harvesting and reforestation may proceed in a planned, orderly manner» (Campbell 1974). Also the important problem of accessibility is closely related with the geographic location.

An additional requirement for inventory information is the *timeliness of the data.* According to Speidel (1972, p. 19–20), plans in forestry may be differentiated with regard to time, as follows: (1) long-term plans, (2) medium-term plans, and (3) short-term (annual) plans. Long-term plans are generally made in order to prepare for long term goals, such as investments or construction of a road-net. Overall calculations for wood production, which may be made for a given rotation length, i.e. up to 80 or 100 years, also belong to this category. Objects of the medium-term plans include the determination of the volume to be cut or the mechanization tasks. Short-term plans regulate the solution of immediate problems of production and acquisition. Very often the goals and contents of these medium- and short-term plans are parts of the long-term plan. These plans must therefore be considered mutually dependent.

The minimum duration of the long-term plans is in general 10, often 20 years. Medium-term plans normally cover 5 years e.g. in state and industrial forestry in Finland. Short-term plans are normally for one year, although some preparation may be started 3 years in advance. Finally, to accomplish the tasks in practice, monthly and weekly planning is required.

It can be concluded that planning is a continuous task. On the other hand, because of the dynamic nature of the forest, where growth continues and operations occur, inventory information becomes obsolete over much of the area within a certain number of years. For these reasons, a procedure for annual updating of the inventory data base is very necessary. »The up-to-date source of inventory information is the vital key in the management decision making process» (Bamping 1974; cf. also Campbell 1974).

PRESENT INVENTORIES

Different approaches

Several types of management planning inventories presently in use will now be briefly described. The division of the methods accords with the basic approach in the preparation and control of the management plans. The approach will therefore be more from the managers' point of view than from that of the mensurationist, and the emphasis will be on more recent developments.

The two extremes of the inventories in question may be represented by the case in which there is no inventory system at all and, on the other hand, the »check method» of Central-European origin, known at least by name almost everywhere (Knuchel 1953). In the former case, inventory data may be limited to acquisition cruises. For instance in the United States of America, mostly large private landowners and old saw mill companies are involved; harvesting areas are selected by employers and owners from personal knowledge of the land (Breeman 1974). In the countries of Northern Europe gaps in inventory information exist rather commonly in the farm forests and other small-size woodlots. At present, less than onefifth of the farm forests have plans based on forest surveys, whereas the coverage of relevant management plans is almost 100 per cent in other forests in Finland. This does not mean that silvicultural measures of the majority of these forests, which play a very important role in wood production, are carried out randomly, because here the forest owners' and their employees' personal knowledge enters into the picture.

The check method, mentioned above as the other extreme, is a system of 100 per cent enumeration of trees above a given DBH (breast height diameter) made at regular, 6 to 10 year intervals, compartment by compartment. Local volume tables called »tariffs» based principally on DBH of trees, are utilized to vompute the tree volumes. Trees removed are recorded in detail. The formula for the increment calculation reads

$$I = V_2 + N - V_1 - P$$

where the various symbols refer to the tree volumes of the following items: V_1 = initial inventory, V_2 = final inventory, N = exploited in the interval and P = recruitment.

One group of common systems for management-planning inventories proper consists of the use of sampling methods to describe the forest as a whole. This is done without in situ information, i.e. without describing the individual sub-compartments or stands.

In North America, double sampling has been rather common due to historical and other reasons, such as availability of aerial photographs at the time of the development of inventories, while in the countries of Northern Europe line-plot surveys and other forms of systematic sampling have been applied. In the past, the interval between successive inventories has been 10 years or even more. At present, from 5 to 10 years is more general.

Since the 1950s, Continuous Forest Inventory (CFI) with remeasured sample plots has been used in the U.S. and Canada, especially. In a number of cases it has been applied in the form of Sampling with Partial Replacement of sample plots (SPR) in which a certain proportion on the initial inventory plots are replaced by new ones. This method is also employed in some industrial forests elsewhere (cf. Cunia 1964; Nyyssönen 1967).

Inventory by Stands

The prevailing practice in management-planning inventories includes the delineation of stands on maps or aerial photographs, and the inventory of essential stand characteristics, such as site class, stand age and structure including the species distribution, volume and other growing stock attributes, and indications of desirable silvicultural treatment. This practice has long traditions in Northern Europe, for instance, where ocular estimation has been in broad use in the forests of different ownership groups: state, industry, and private. To avoid inherent subjective features, the constant use of relascope and other measurement devices has been emphasized in recent years. The usual inventory cycle is 10 years.

In Central Europe, stand delineation is mainly based upon existing forest maps. According to Speidel (1972; cf. Nyyssönen 1976), inventory of the growing stock volume is dependent upon the requirements of accuracy and the stand age, and is effected by estimation, measurement, or the use of earlier measurements and growth data. In young stands, and homogeneous stands of average age, volume estimations are made by means of Bitterlich points, form-height-tariffs, and yield tables. A 100 per cent tally is made of tree diameters in stands that are to be harvested in the coming management period, in older heterogeneous stands, and in stands used for control purposes. Sample plots are used in relatively homogeneous stands, older stands, and also in large stands. The results of an earlier tally plus growth and drain figures are used in those cases in which the necessary data are available.

The collection of standwise information, based upon sampling and measurements in forest areas of intensive management, has also been employed by the British Forestry Commission. In this case, the additional features are the intensive use of forest management tables, and the control of the development through index subcompartments that are measured repeatedly (Johnston and Bradley 1964).

A different approach for standwise inventories was recently described by Depta (1974). This large in situ inventory has recently been applied to some 2.5 million hectares of timberland of the Weyerhaueser Company in the U.S. The key component of the system is a stand table modelling technique, the »Stand Table Generator». Its most important feature is that it computes stand tables directly from the input coded stand descriptions. It is not a normal stand table fitting procedure in that it does not start with a stand table. Rather, it estimates complete stand tables in accordance with the specific description of an individual timber stand.

The basic stand description data input consists of the following items: basal area per acre, trees per acre, minimum tree DBH, average tree DBH and height, maximum tree DBH and height, and specification of even or uneven aged stand form. Output then consists of a stand table by DBH classes including stems, basal area and volume per acre. Since stands are individually and independently described, the descriptions can be refined as the stands are visited and measured in the normal process of forest management. However, field samples are not pre-requisite to generating stand tables, as the required system input can be estimated in a variety of ways, including aerial photo interpretation and measurement.

With regard to resultant inventory capabilities, the ability to partition, describe, and generate stand tables for stand »components» provides the inventory capability for individual stand volume, species mix, and tree size mix. Further, the stand tables provide the foundation of a flexible reporting system, especially when coupled with a tree volume equation which contains log merchandising capabilities. Other notable inventory capabilities concern log stock tables, log stocks by grade, and also growth.

Instead of the individual estimation of each stand, an approach mentioned by Nersten (1971) delineates the stands but their volume is estimated on the basis of the average for the stratum to which each stand belongs. Stage and Alley (1972) discuss considerations guiding the design of a forest inventory for providing in situ data for planning and programming timber management. A design is described for an inventory intended to be transitory between previous inventories that only provided estimates of forest totals and later inventories that could use a complete forest record of in situ data. The inventory procedure suggested employs a field examination of stands in sample subcompartments augmented by aerial photo interpretation of conditions in compartments and subcompartments not examined on the ground.

Combined Procedures

In addition to a basic system for the acquisition of inventory data, other approaches may complete the need for inventory information in management decision making. Thus, although delineation and estimation by stands are both commonly utilized in the construction of management plans in Finland, the permanent sample plots are being additionally installed to monitor the development of many large owners' forests, including the state's. Moreover, before the trees are cut a complete tally is usually carried out; the results are utilized to prepare a detailed logging-plan, but also to calculate the stumpage and payment for work done.

Let us now take as examples a couple of industrial companies which employ three kinds of inventories simultaneously, each one complementing the other, but each one useful for performing specific and different functions. As described by McDavid Hughes (1974), the Olinkraft Forest in Southern U.S.A. has (1) Continuous Forest Inventory, a light sample which is usually measured on a five-year basis and utilizes permanent points or plots. Its most important function is to afford control of the forest at the highest executive level in the forest operation. (2) Periodic Management Inventory is also a light sample of the administrative unit or block which is usually conducted on a ten-year basis and utilizes temporary points or plots. This inventory provides information on the primary breakdown of the forest. (3) Operational Reconnaissance Inventory is a heavy sample of each record unit in the working circle or block. This provides information necessary for daily operations. The main function is to lay the basis of control for the area under immediate operation by obtaining in situ data, record unit by record unit, or stand by stand. Maps are usually made. Cutting and silvicultural measures for each individual tract are recommended.

A large Swedish company, Svenska Cellulosa Aktiebolaget (SCA), is, according to a letter from Mr. J. Saraste, carrying out (1) enterprise inventories with 5 to 8 year intervals. This is a systematic, small-intensity sampling with temporary plots to control the forest situation and to provide the basis for overall planning, i.e. cutting budget, silvicultural measures and required fertilization. (2) Standwise inventory, »forest analysis», is largely based on aerial photographs and was, between 1968 and 1971, made by helicopter. It forms the basis for detailed planning of both logging and silviculture. The standwise information is updated partly manually for such changes as thinning and regeneration cuts, and partly by computer for increment on the basis of age, volume, diameter, etc. (3) Plot sampling or total tally give accurate tree volume data standwise before cutting operations, and these data are completed by the data concerning logging and accessibility.

DISCUSSION

The description of the inventory systems has revealed variations in the information relevant to the management of the forests. In the light of the objectives and requirements presented previously, there exists a lack of information in most cases. Breeman (1974) lists among the most common reasons for not having an adequate inventory system: lack of management objectives, the priority of raw material procurement problems, problems of convincing top management of the justification of inventory costs, lack of experienced people to design and maintain the inventory system, lack of personnel to do the field work, and lack of access to a computer. The items on the list may be quite different for another environment.

On the other hand, the inventory and management information system should be only as elaborate as is required to fulfill its task. The overall circumstances, requirements and stages of development are not similar everywhere. Davis (1966, p. 262) refers to the fact that in the initial stages of timber management, »inventories are of the stock type, placing primary emphasis on how much merchantable timber and other currently available resources there are. As practice develops emphasis changes from merely cutting a stock of existing timber to organization of forest areas for continued production. Inventory information required accordingly shifts from a stock to a production or flow-type inventory, necessary for guiding continuing and increasingly intensive management, area by area».

Speidel (1972, p. 76) reminds us that most of the instructions for forest management in Central Europe include an extensive catalogue of data to be collected. The relevance of these data for every enterprise should be questioned. It is possible to differentiate the need for quantitative and qualitative information. Consequently, before starting the data collection it is appropriate to state the real minimum information requirements for each particular case. This provides the advantage that irrelevant data will not be collected, whilst information really needed will not be forgotten.

The necessity for inventory data is closely combined with the availability of *yield tables* and other aids. In the United Kingdom, for instance, information requirements have been listed systematically and the management tables of a binding nature have been published (Forest . . . 1971). This has made it possible to introduce a cheaper method of periodic inventory checking (Johnston and Bradley 1964). Since this type of aid can be utilized in establishing priorities in the selection of the stands to be regenerated, as well as in growth projections, their importance and the need for their valid compilation techniques have been recently emphasized (cf. Ad hoc . . . 1966).

In recent years, several systems for modern forest management planning, based on the methods of operations research have been introduced (e.g. Navon 1971; Jöbstl 1973; Kilkki and Pökälä 1975). The results from their application are only as good as their information base. It is mandatory that the inventory will provide the data presumed, by treatment classes or other units. For instance, if high and low volume stands are combined in an overall stand condition summary, over projections may result (Campbell 1974).

The *accuracy* of the inventory results is a rather complex problem. It is a well-known fact that the appropriate sampling intensity, in principle, depends on two factors: variation within each of the crop types for which an estimate is required and the desired level of precision of the estimate. The inventory should be planned to meet the latter requirement. However, the forest manager may have difficulty in formulating this requirement even if he has the necessary information available on the management objectives (cf. Johnston et al. 1967, p. 470). Decision theory, the theory of evaluating the outcome of decisions made in a state of uncertainty or with incomplete information might here be utilized (Dress and Hall 1964).

A pragmatic, and simultaneously, a rather simple criteria for determining the necessary accuracy is to fix the minimum accuracy to the materialization of the monetary and production goals. If the minimum accuracy of the individual goal elements has been fixed, the minimum requirements for the input variables can be estimated (Speidel 1972, p. 77). Also, the effects on the calculated cut of alterations in some of the assumptions, which were studied by Nersten (1965), are of interest in this connection.

Costs of the acquisition of inventory information are closely correlated with the accuracy and the degree of sophistication of the whole system. The cost of mapping and inventory by stands made at 10 year intervals in Finland, for instance, seems to be some US$ 3 to 5 per hectare at the present time. (This does not include the cost of total enumerations usually done before cuttings. The cost of the latter measurements is saved in the form of more efficient harvest operations). Calculated for a stumpage value of timber cut during the planning period, the cost rarely exceeds one percent. The costs reported from the U.S. by Campbell (1974) were not essentially higher. In addition, through the use of the better information and scheduling system the annual harvest was immediately increased. This feature also seems to be a common experience elsewhere (cf. Morriss 1962).

Timeliness was emphasized previously as one of the main requirements of the inventory information. Instead of the repetition of the whole exercise of inventory, the remeasurement of the sample or a part of it may give results more efficiently than the use of temporary plots, at least with regard to the changes occurring in the growing stock. In forest management, however, additional techniques are required, since updating of information by stands is often assumed. The procedures and precision of this updating (»Fortschreibung») have been an object of much interest and study in Central Europe, where the necessary procedures have been built into computer programmes (e.g. Schöpfer and Nagel

1971; KURTH and DORER 1973). According to PRODAN (1967), »Fortschreibung» is the most elegant form of estimation if there exist results of previous inventories. In new procedures based on stand tables in North America, the increment data needed in updating are derived either from yield tables or from Continuous Forest Inventory (DEPTA 1974; McDAVID HUGHES 1974).

The ability to update the data should be combined with an easy data retrieval system based on the use of computers. Alternative ways of action in the management practice can thus be selected as required, for instance, by the changes in market situation of any particular time.

In addition to the aspects mentioned above, there are a number of questions concerning the practical organization of securing the inventory data base for forest management. These can not be discussed here in any detail. Such questions include the utilization of the national or regional inventories in management planning (cf. e.g. MORRISS 1962), and the need for cooperation between small woodlot owners and correspondingly the refinement of the techniques to meet their respective requirements.

CONCLUSION

The development of a system to meet all the requirements for forest information and which is to be maintained for use in today's management planning systems, is a demanding task. Essential requirements usually include up-to-date information for easy retrieval through computers and in situ data by stands. In extreme cases even a map of the location of individual trees may be needed for a logging plan, as in a mixed tropical forest. The review of present-day methods often indicates a lack of adequate information but also the existence of advanced systems which often means the application of various kinds of inventories simultaneously. Knowledge of these systems, investigations of sampling methods, remote sensing techniques and new instrumentation, and construction of yield tables and other aids will promote the development of methods which will more likely meet the requirements of a respective enterprise. Conditions can thus be created for making sound decisions in multiple use management, in which wood production forms a core but which does not overlook environmental effects, and which is the best guarantee of Forests for People.

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SELOSTE:

METSÄVAROJEN ARVIOINTI METSÄTALOUDEN SUUNNITTELUA VARTEN

Metsätalouden suunnittelussa tarpeelliseen metsää koskevaan informaatioon kuuluvat (1) tiedot metsäalasta ja puuston kuutiomäärästä, (2) luokittaiset metsän rakennetta ja laatua kuvaavat tiedot, (3) metsikkökuvioittain paikallistetut tiedot, (4) metsässä tapahtuvia muutoksia eli kasvua ja poistumaa koskevat tiedot sekä (5) kaikkien näiden tietojen ajanmukaisuus.

Nykyisiin inventointisysteemeihin kohdistunut katsaus on paljastanut suurta vaihtelua siinä informaatiossa, johon metsien käsittelyä koskeva päätöksenteko nojaa. Monissa tapauksissa informaatio on havaittu riittämättömäksi. Inventoinnit puuttuvat toisinaan kokonaan tai arviointi kohdistuu vain metsän yleispiirteisiin. Yleisenä suuntana on ollut siirtyminen kuviokohtaisiin arviointeihin. Euroopassa on arviointitekniikkaa pyritty parantamaan mm. tekemällä kuvioittaiset arvioinnit entistä objektiivisemmiksi ja ottamalla käyttöön toistuvasti mitattavia metsiköitä. Pohjois-Amerikassa taas on äskettäin kehitetty mielenkiintoinen menetelmä metsikön järeysrakenteen nopeaksi selvittämiseksi. Joissakin tapauksissa saattaa olla tarpeen käyttää samanaikaisesti kolmeakin erityyppistä, toisiaan täydentävää inventointia.

Suunnittelutietojen hankintaa ja inventointeja suunniteltaessa tulisi käyttää niitä kokemuksia, joita muualla on saatu, sekä selvittää otantamenetelmien, kaukokartoitustekniikan, uuden välineistön sekä atk-palvelujen soveltamista. Myös kasvu- ja tuotostaulukot sekä muut apuvälineet ovat tärkeitä. Samalla kun päätöksentekoa voidaan näin parantaa käy mahdolliseksi suorittaa toistuvat inventoinnit halvemmalla. Informaatiosysteemin tulisi kuitenkin olla vain niin yksityiskohtainen kuin tehtävä vaatii. Määrällisen ja laadullisen informaation sisältöä ja tarkkuutta olisi harkittava ja erilaistettava vastaamaan todellisia tarpeita. Informaation hankinnan kustannukset korreloivat inventointisysteemin kehittyneisyysasteen kanssa, mutta harvoin ylittävät yhtä prosenttia hakattavan puun kantohinnasta. Sen lisäksi on yleisesti todettu, että puuntuotannon lisäys kompensoi runsain mitoin ne kustannukset, jotka aiheutuvat inventointeihin perustuvasta suunnittelusta.