Survey of Forest Resources For Industries

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The paper deals with the question of surveys of forest resources for industries. There is a growing awareness that the forestry sector could play a more effective and decisive role in contributing to a nation's economy and welfare. The developed European countries have reaped the advantages of the Industrial Revolution, whereas in the developing countries the rich forest resources await stepped-up development.

For a proper knowledge of the forest resources of a country, region or an industrial catchment, it is necessary to assess reasonably accurately the volume of the existing growing stock and other connected indices such as increment, drain, accessibility, etc. All these are obtained through forest resources surveys. This paper describes the survey methodology and techniques which have been developed in several countries. The role of aerial photography and photo-interpretation in modern surveys has been highlighted.

There is much to commend in the inclusion of a provision in the Canadian Forest Act for carrying out provincial inventories and the allocation of Federal assistance for this purpose. The Swedish and Finnish National Forest Surveys could serve as useful models, and the concept of a "continuous inventory" on a national scale, which has developed in them, could constitute the ideal to aim at. Nevertheless, keeping the financial considerations and technological stage of development of a country in mind, it would be necessary to tailor the surveys to provide the required data and answers.

The use that is made in Sweden and more especially in Finland of forest inventory data for formulating silvicultural, management and industrial plans, shows that an important role such resource surveys can play. The MERA development plan for Finland could serve as a good illustration.

The idea of financing a resource survey in Mexico by a Bank is worthy of emulation by developing countries. This would generate a healthy developmental trend and provide the much-needed capital for formulating regional development plans based on resource surveys.

Wood-based industries, especially those of pulp and paper, are capital intensive items and it would be appropriate for any country to decide to invest say at least one percent of the projected outlay on resource surveys of the areas from where raw material are to be obtained.

INTRODUCTION

The state of forestry in the different regions of the world presents a wide range of a spectrum and it is interesting to find that in the different countries it is directly linked with the standard of industrial development. In Europe, which has reaped the fruits of the Industrial Revolution, the status of forestry is well recognized and intensive efforts have been made during the last 100 years to harness the forest resources intensively for industrial development. In the tropics on the other hand, even though conditions of growth are far better, it is found that actual out-turn is disproportionately low.

The Indian Scene : India today stands classified on the world map of forest resources as belonging to a 'deficit zone', and the rapid growth of population is making the situation more critical. The gap between the demand situation and production of wood is widening.

The projections of industrial wood requirement in India which have been made by the Planning Commission reveal that there will be a tremendous jump from 14 million cubic meters in 1970 to nearly 50 million cubic metres in 1985. The requirement of pulpwood alone will be in the neighbourhood of 10 million cubic meters in 1985.[1] The shortage of forest raw material for the wood-based industries would pose a serious problem in the near future and if not tackled quickly and effectively, it would jeopardise future development plans. Fortunately, there is a growing awareness in the country

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that forestry can provide a ready basis for industrial and economic development. There are glimmerings that forest development, integrated with agricultural and industrial progress, will come to be used deliberately as an essential part of measures to promote a self-sustaining economic growth and often as a useful form of public works capable of absorbing unemployed and underemployed rural manpower.

The Need for Forest Surveys

In the absence of a carefully thought out forest policy a nation's forest resources will not be used to the best advantage and will, actually be dissipated by unwise utilization and neglect. A rational forest policy, however, which aims at developing the forests as a national asset able to offer a conti iued supply of wood cannot be formulated unless the following information is available.

a) Extent aud location of the forests;
b) Forest ownership;
c) Composition of the growing stock of species, diameter, classes and quality;
d) Growth, natural losses and allowable cut;
e) Management status, removals and cutting practices;
f) Productive capacity; and
g) Importance for productive purposes.

This information is provided by forest inventories. It follows that a forest inventory is vital for planning balanced economic development. Such a forest inventory differs from an inventory in commerce or industry where the aim is merely to have a record of the volume of goods on hand at a given time. A forest is not merely a stock of wood but an association of living plants which should be treated as a renewable crop.

For a systematic and scientific expansion of wood-based industries, it is necessary as a first step to have adequate and continuing inventories of the renewable natural resources to determine their condition, productivity and potential use in relation to human needs and to support these as a guide to the proper utilization and treatment of these resources. It cannot be emphacized too much, that, in a rapidly developing country, an organization must be in a condition of growth; it must recognisc the necessity for constant reappraisal of its status, carry out continuous planning for future development and be aware of the possibility of acquiring or disposing of resources.

The type of survey is generally determined by the specific conditions of the forest and the country for which it is made. Financial and administrative considerations could constitute obstacles to the carrying out of forest resources surveys, but it needs to be recognized that the possibilities for future economic development which may be discovered through a systematic examination of the forest resources will be so great that they justify all practicable efforts to acquire the necessary information. It would, however, be worth-while to keep in mind the principle that justifiable survey cost should be determined in proportion to the benefits which they are expected to provide and the time when such benefits can be expected to start accruing.

Types of Forest Resources Surveys

Where no information is available for a certain forest area, a reconnaissance survey should be first undertaken to locate those areas which deserve priority in planning and development. If some general background information on areas ripe for development is available, a detailed pre-investment survey should be done to determine precisely how much capital would be required for development purposes, or how available capital can be spent most effectively. However as early as possible each country should aim at a national forest inventory which will provide a record of the whole country's forest wealth and reveal how effective the forest policy has been.

The main types of forest resources surveys are briefly described below :

a) **Reconnaissance Surveys** : These are designed to furnish preliminary information regardiag the location and extent of large areas of forest at low cost. Recognition of broad classes within the forest must be undertaken and non-forested land must be classified. It could also be possible to estimate roughly timber volumes over the survey areas. Such surveys were undertaken in the Central and Southern Zones of the Preinvestment Survey Project in India with the help of a fixed-wing plane and a helicopter. A good deal of success was obtained in carrying out a rough stratification of forest types by vegetation, density and volume classes. Such surveys take very little time and yield a good deal of useful information. It was estimated that the cost of an aerial reconnaissance could be not more than 1 paisa per hectare and it could be possible to co-

ver an area of at least 5,000 sq. kilometers per day.[2,3]

b) **Large Area Surveys** including National Forest Inventories aim at providing more detailed classification of the forested areas and estimates of volume of standing timber in large areas. Provision is generally made for studies of growth and drain and for the preparation of forest maps. Good results can be obtained at relatively small cost per unit area. The percentage of cruise may range from 0.10% or less to appreciably less than 2%. Such surveys are of importance in deciding forest policy and general planning of forest industries development. National forest inventories not only help in yield regulation, but they can be an essential factor in national land use planning.

c) **Working Plan Surveys :** These are carried out in areas which are under management or which have been revealed by surveys of the type of (a) or (b) as being fit for early management. They must provide all the detailed information necessary for the preparation of working plans for relatively intensive management of limited areas. The percentage of cruise depends largely on the volume of the stands and may range roughly between 1-15%.

The range of forest resources surveys could lie between types (a) to (c). It may also be necessary to choose between a national forest inventory and a local inventory. The former is naturally always desirable, especially when connected with a general plan of land use, but in many developing countries it is often more to the point to start with a local inventory and progress to the national scale only after forestry reaches a certain stage of development.

The Role of Aerial Photographs in Forest Surveys

In earlier times surveys were carried out entirely on the ground and a full stock-taking of every tree over a eartain diameter was the usual practice. Strip sampling with a 5% cruise was developed by Brandis in Burma about 100 years ago. This happened at a time when mathematical statistics as a tool was in its infancy and a theoretical basis for sampling design was still lacking. There have been tremendous developments during the last three decades and mathematical statistics are offering increasing assistance to forest science and forest inventory. But. there is one limiting factor, i. e. that ground surveys are time consuming and costly operations.

During recent decades the development of aerial survey techniques has revolutionized forest survey methods. Since World war II, in particular, aerial photographs have been employed on an increasing scale and in many contexts are already established as a method. There are areas, especially in Northern European countries, such as Sweden, Finland and Norway, where the primary value of aerial photographs is still only in the form of maps facilitating the work. On the other hand, there are countries like U.S.A. and Canada where a considerable saving has been achieved by the use of aerial photographs, in particular as a result of reduced ground work which involves high expenses. It is particularly important to reduce the ground work required in tropical forests because field work is very often difficult and laborious on account of the character of the forests, climate and the lack of communications.

The extent and location of forests are the first items of informtion to be obtained from aerial photographs. If the quality and scale of the photographs are adequate, certain forest strata can be differentiated on the photographs, such as forest types, density classes and stand height classes. Under certain conditions it is possible to recognise certain species and to assess the volume of growing stock. Careful ground checks are, however. required to ralate the aerial photo.interpretation properly to the stands.

Effect of Stratification on Plot Sizes and Numbers : In 1963 Aarne Nyyssonen[4] carried out investigations in Finland on the number and the most efficient size of sample plots and the effect of stratification on forest inventories under Finnish conditions. It was found that in surveying the cubic volume of a single stratum, fewer sample plots are required than in cruising a forest area in which several strata are represented. Moreover, the number of sample plots required for the different strata decreases more markedly with the increasing size of plots. By the application of stratification, the larger sample plots prove relatively more efficient. From this it becomes obvious that the application of stratification is worthy of serious consideration within forest areas which comprise parts with distinct deviations from each other. Two different approaches could be tried for the distribution of sample plots among the strata i. e. optimum allocation and proportional allocation. The former distributes the sample plots in proportion to the products

of the areas and standard deviations of the different strata, whereas in the latter the sample plots are distributed proportional to area.

The characteristics of modern forest resources survey methods could be summed up as rational work planning, use of photogrammetry and aerial photo-interpretation, application of mathematical statistics in devising sampling design and modern data processing on electronic computers. Thanks to these, forest inventories have been brought within the economic reach of most countries.

Considerations of Accuracy : There is a common statistical rule that the number of sample plots (or other kind of sampling units) may be decreased K^2 times, if the required accuracy is allowed to decrease K times.[5] In other words, if the merchantable volume of certain forest is known within an accuracy of ± 5 percent, then, according to the relevant statistical calculation, 1000 samples are necessary. If only an accuracy of $\pm$ 10 percent, ($K=2$) is needed, $\frac{1000}{4}=250$ samples are sufficient. And if an accuracy of ± 20 percent is adequate, the number of samples becomes $\frac{1000}{16}=63$.

Bearing in mind the statistical difficulties to be found in the tropical forests and the high cost of carrying out inventories in these forests, these considerations must be given careful study. The lowest possible accuracy or, in othor words, the widest possible range of error limits with regard to the actual purposes of the inventories should be explored in order that the inventory method will be as economical as possible. For general inventory purposes it is adequate to prescribe an error of the mean not exceeding $\pm$ 10 percent with a probability of 95 per cent.

Forest Resources Surveys in the Developed Countries

Actually, it will not be practicable to deal in this paper, at some length, with the methodology and techniques of forest surveys which are followed in the developed countries. Attention would, therefore, be confined only to the more importent aspects of such surveys, from which it could be possible to draw some ideas and lessons. Another important point that will be examined is the part that such surveys play in guiding management, silvicultural and industrial practices and policies. For the sake of examples forest resources surveys in (1) Sweden, (2) Finland, (3) Canada, (4) U.S.S.R. and (5) England will be considered. These countries have been chosen with a definite purpose. The first two are actively engaged in maximizing the production of wood and linking it to the ambitious programmes of expanded production of processed goods, especially pulp and paper. As for Canada and U.S.S.R. they have vast forest resources, and it is of interest to study how they are surveying these. The example of United Kingdom has been chosen because it affords a good illustration of the role that man-made forests play in it and the methods of forecasting production from them.

1. Sweden[6]:—The National Forest Survey Organization in Sweden is nearly 45 years old. It plays an important role in determining forestry practices and the formulation of industrial plans. The first national forest survey was carried out in 1923-29. It was a pure strip survey within strips 10 meters wide and located at fixed distances apart.

The second National Survey was carried out in 1938-52 as a line plot survey along the same lines as the first survey but, in addition, various forms and sizes of sample plots were tested and it was found that the most suitable type is a circular plot with an area of about 140 square meters (radius 6. 64 meters).

The earlier surveys were performed as provincial inventories, but in the third inventory which was started in 1953 and completed in 1962, the entire country was covered by a low percentage inventory which was repeated each year. Thus in 10 years the entire country was covered by the same percentage as employed in the second National Survey.

In the Fourth National Survey which is going on at present, a new phase involving cutting statistics in the form of stump enumeration has been added. With this method the growing stock and the changes it undergoes, may be followed throughout the whole country. The targets achieved annually by the National Forest Survey are in the range of 1400 survey tracts, 14,000 sample plots for stock-taking on forest land and 40,000 sample plots for stump enumeration. The annual cost of the survey is estimated to be nearly Rs. 30,00,000 of which 55% is allotted to field work and 45% to office work.

The National Forest Survey has determined the forest area to be 24 million hectares and the total growing stock to be in the range of 2,400 million cubic meters. The total growing stock throughout the country has increased by 11.8%.

One of the main aims of the Swedish

National Forest Survey is to have a thorough knowledge of the condition of Swedish forests and the changes occuring in them in order to enable a correct judgement to be formed concerning forestry questions of current interest. The information includes data concerning the size and composition of the growing stock, the rate of growth and also the present drain. In addition, the survey gives a land classification including a detailed description of the forest area.

The importance of National Forest Survey for a country like Sweden, where timber production and wood-based industries play a vital role in the national economy can be realized from the mass of useful information it supplies to foresters and industrialists. Thanks to the National Forest Survey, it has been found that the annual cut in Sweden could be raised by nearly 11 million cubic metres. Translated in terms of industrial expansion it means millions of more Kronors to the state exchequer and better export opportunities.

2. Finland[7,8]:—The country lives decisively on its forest wealth. In its capacity as the back-bone of Finnish Exports, the forest industry has held a focal position in the economic growth for many decades.

The area covered by forests in Finland is 20 million hectares. The total growing stock is estimated to be 1400 million cubic meters, giving an average of 70 cubic meters per hectare. The annual growth is estimated to be in the range of 43 million cubic meters.

Forest inventories have been carried out in Finland from the year 1921-22, on a fifteen year cycle. The third inventory was carried out in the year 1951-53. This revealed that the growing stock was increasing rapidly and that the annual cut could be stepped up appreciably. This proved to be the signal for a rapid expansion of the pu'p and paper industry. Since 1960 continuous inventory work is done in Finland, but unlike Sweden, a certain part of the country (about 1/10th) is covered each year. For the last Forty years plans for the development of Finland's forest resources have been prepared parallel with, and on the basis of, the national forest inventories. As long as the cut was smaller than the growth these plans were matters of principle used as a guide for logging. As Industrialization progressed in the post-World war II period, the removal from the forests began to exceed the increment. It then became necessary to consider ways and means of intensifying silviculture and accordingly, of increasing of allowable cut.

On the basis of wood utilization development studies and the results of the Third National Forest Inventory (1951-53) a development plan for the forestry sector was drawn up in 1961 which foresaw an annual cut of 47 million cubic meters as against a corresponding annual growth estimate of 46 million cubic meters.

The prognoses of wood utilization made by the Planning Comittee in 1961 were rendered out of date with the phenomenal expansion of the pulp and paper industry. Thus, in the year 1964 the so-called MERA programme was drawn up by the Forestry Financing Corporation for the development of forest resources. This is resulting in activity which, in a couple of decades, will produce several million hectares of new stands and the drainage of the majority of the country's swamps. The age of planned development of forest resources has dawned in Finland, and full preparations have been made for fulfilling the projected estimates of wood requirement of 66 million cubic meters in the year 2000. The development plans, which are based on the national inventories, have come to be regarded as a basic condition for acceptable and progressive forestry and are vitally important for maintaining the standard of living of a Finland competitive in the world of the future.

3. **Canada**[9] : Forest inventories in Canada are carried out under Federal Provincial Forestry Agreements entered into under the provisions of the Canada Forestry Act, and they are dealt with by individual provinces. The inventory programmes called for by the agreements cover a gross area of 2, 650,000 square kms. As a rule Canadian forest inventories are accompanied by forest type maps. Special characteristics include the great reliance which is placed on air photography and the extent to which sample plots are established individually in well-distributed locations in forest classes determined from the air photographs.

On the basis of these agreements the Federal Government makes financial contributions to the provinces to facilitate forest inventories. Seven of Canada's provinces have come

under the agreement.

The standards employed have been set forth in Schedule A of the Fedral-Provincial Agreement and include the following :

"Part 3: General specifications for forest inventory surveys.

1. If the proporotion of the total area of a province occupied by forests is small, reconnaissance surveys based on aerial photography on a scale of 1 : 40,000 should be undertaken. Forest areas should be outlined on planimetric maps on a scale of 1 : 63,360 and forested areas should be photographed at 1 : 15,940 and mapped at a scale not smaller than 1 : 63,360 or larger than 1 : 15,840.

2. If the proportion of forest area is large, the original photography should be at a scale 1 : 15,840 and mapping at a scale not smaller than 1 :63,360 or larger than 1 : 15,840,

3. Federal assistance may be extended to share in the cost of photolithographed forest maps at a scale not larger than 1 : 63,360 provided such maps follow an approved system of forest classification, legend, etc.

4. Ground sampling should be used upon the distribution of different forest classes as determined from aerial photographs.

5. Stratified random sampling procedures should be followed where conditions of accessibility permit. Sampling procedures should be designed to give gross volume estimates of probable error of plus or minus 10 per cent."

The methods employed in Canadian Forest inventories vary considerably from region to region depending upon the intensity of the information required. The value and accessibility of the timber, together with the circumstances of land tenure and cutting right, are factors of basic importance.

4. **U.S S.R.**[10] : A basic feature of forest inventories in the U.S.S.R. is the distinction drawn between :

a) the total area of the forest reserve lands;

b) the forest area; and

c) the forested (or forest-covered) area.

The forest area (835,692,000 ha.) is divided according to the form of management into—

	(Hectares)
a) Centrally managed forests	... 5,797,000
b) Granted forests	...790,669,000
c) Collective farm forests	... 39,226,000

The forests growing over these areas are inventoried according to the sizes of the areas, their timber reserves and the prevalence of coniferous or broad-leaved types.

The division of the centrally managed forests into three groups according to their national economic significance is of major importance in the inventory of the forest resources of the U.S.S.R. Group I includes green zones, forests protecting fields and soils, forests in resort areas, restricted shelter belts along rivers, railways, higways, etc. Group II includes forests of economic and general water conservation importance growing in forest scarce regions. Group III includes all other forests. It is in the forests of this third group that the main activity of the logging industry takes place.

For each group special procedures for forest utilization have been established. Should the national economic significance of any particular forest range change, it is transferred from one group to another. In fact, a number of transfers have taken place recently. These changes, which show the process of intensification of the country's forest economy, are fully reflected in the revised inventories which are prepared from time to time.

Recently, in the forest inventory, a distinction has been drawn in the forests of centralized management between forests in use (exploited forests) and unexploited forests.

The total growing stock over the forested area is estimated to be nearly 80,000 million cubic metres, and the annual growth to be nearly 860 million cubic metres. The average standing volume per hectare is 93 cubic metres.

It has been stressed that particular attention should be given to problems of and indices reflecting the intensity of the forest economy. For this purpose consideration should be given to the possibility of introducing the following indices :

1. The area of artificially created forests.
2. The area of tree plantations which have not yet reached exploitable age.
3. The area and output of forest nurseries.
4. The number of man-days spent during the inventory year on all types of forest work.
5. Length of forest roads: total length and per hectare of forest area.

There is another group of indicators, forest economic indices, which would be well worth including in forest statistics such as:

1. Average marketable stumpage value for the main species of industrial timber.
2. Total income from the utilization of forests.
3. Expenditures on the forest economy.

5. **United Kingdom:** [11] The Forestry Commission in U. K. has built up a forest estate totalling 646,000 hectares actually under tree crops between 1919, the year of its formation and 1966. This area has been achieved almost entirely by planting fast-growing conifers. In terms of productivity this means that there is a rapidly expanding quantity of home-grown timber to be utilized. The figures for actual production from the Commission's forests and forecasts for the year 1970 and 1975 are as shown below:

	Production in million cubic meters		
Year	**Thinning**	**Felling**	**Total**
1960	0.537	0.186	0.723
1965	0.745	0.286	1.031
1970	1.140	0.318	1.458
1975 (anticipated)	1.591	0.491	2.082

It can be seen that thinnings will continue to provide the bulk of production for some time to come. The material to be utilized will, therefore, continue to be mainly of small diameter.

In order to utilize the increasing volume efficiently it is necessary to develop existing markets and also to establish new ones. The bulk of the small-dimension wood obtabined from thinning can only be utilised by the pulp and man-made board manufacturers. These industries are capital-intensive and it is essential that they should have a guarantee of future supplies, which in turn requires the ability to forecast accurately.

Where age-class distribution within the forests is normal and where forestry is a traditional industry, it is possible to forecast on the basis of past performance. But in the case of the Eorestry Commission's estate there is an abnormal distribution of age-classes. The use of past records of production is impossible. As such, a new forecasting procedure has been developed, which is based on field information interpreted through production Forecast Tables. The information required for forecasting is collected along with information needed for planning and management by centrally controlled survey teams. There are about ten teams and the country is divided into five regions. Where suitable aerial photographs are available these are used to reduce the amount of ground survey required.

In forecasting future production from thinnings the system of classifying growth potential through "yield class tables" is followed. Yield class curves have been prepared for all major species, relating to top height and age and are used for the determination of yield class for individual even-aged stands.

The forecast for each area is calculated centrally from ths detailed field data, and provides an objective index of potential production, made on the basis of standard management assumptions which are common to all parts of the country. Forecasting is carried out every five years and the forecast is made for the years 0, 5, 10 and 20 ahead.

Forest Resources Surveys in the Developing Countries

Considerable interest is being taken by internationl agencies in the question of developing the forest resources of the tropical and Latin American countries, as it is being increasingly realized that with efficient management, they could play a decisive role in meeting the rapidly growing demand for wood in the world. F.A.O. is providing useful assistance to several countries in carrying out inventories and preinvestment surveys of forest resources, and within the last decade, more than thirty countries have received UN assistance in carrying out such surveys. There is considerable available literature on the subject, and from its study, it could be possible to get an effective idea of the evolution of a survey methodology for the developing countries. Only five examples of forest resources surveys carried out recently in the tropical or Latin American countries have been chosen. If anything, these examples should serve to highlight the need for adjusting methods developed in Europe and America to suit the peculiar needs of developing countries.

A. **Thailand:**[12] In 1955 inventory work was carried out by Professor F. Loetsch in the northern teak bearing provinces of Thailand, with

a view to devise and develop the most economical and statistically sound inventory techniques with the greatest possible use of the available aerial photographs (on scale 1 : 15,000 and 1 : 40,000) for different types of forests.

In has been amply demonstrated that combination of photo-stratification and sampling techniques leads to statistically sound and economical inventory methods for the Thai tropical forests. Stratification of aerial photographs works particularly well in the case of the tropical evergreen forests of Thailand because *Dipterocarpus alatus* the most valuable species can be recognised clearly in the photographs. In measuring the avilable volume of marketable stock in the most important groups of species, the sampling technique of using small circle sample plots along lines has proved successful. In view of the special conditions of the country, the arrangement of ground samples according to the "tract unit system" and the "camp unit system" proved to be a practicable method in the teak-bearing areas. Ground measurements themselves were calculated on the basal area at diameter breast height and were taken with the so-called "Bitterlich-Tarifmesswinkel." The mass valuation of the stock was obtained by ocular estimation of the Wannerweights per 5 meter log. This combination of measuring and ocular estimate proved very successful, especially under Thai conditions. The experience gained during field work, as well as in calculating the results by means of the punch card system was to form the basis for the future organization of the proposed National Forest Inventory of Thailand. The parameters obtained of the individual types of forest make it possible to calculate the number of ground samples required.

Growing Stock: The stocking of the Thai tropical forest per unit is relatively low. Thus, it is necessary to have a larger number of sample plots than for European forests which have a larger growing stock and not more than 3 to 8 species per area unit in order to obtain the required accuracy. The character of the Thai forests with regard to estimated growing stcok is:—

Type	No. of trees per ha. over 30 cm. dbh	Basal area m^2 per ha.	Merchantable volume m^3
Evergreen all species	30–50	15–23	130–210
Mixed Deciduous	30–50	5–10	20–70
Yang-bearing evergreen, *Dipterocarpus alatus only*	5-15	6–13	50–130
Teak-bearing mixed deciduous, teak only	5–35	1–8	5–60

Aerial Photogrphhs For Stratification : Photographs on a scale of 1 : 15,000 from Uthai Thani province were examined and it was found that the following strata could be recognised:

1. Evergreen forest
2. Mixed deciduous
3. Dry dipterocarp
4. Scrub and bamboo, and
5. Non-forested area,

Fortunately the most valuable species in the Thailand evergreen forest *Yang* (*Dipterocarpus alatus*) is at the same time the only species which may be clearly recognised from the photographs owing to its large crowns and brightly shining leaves. This facilitates enormously the inventory of these forests.

B. **Sudan**: In 1964 the Government of Sudan sought the help of F.A.O. in carrying out an inventory in some forest areas. The inventory work, among other things, included the item of carrying out aerial reconnaissance flights for the selection of a suitable site for a sawmill. For this purpose aerial photographs were to be interpreted and mapped and a terrestrial inventory was to be carried out with a helicopter in the forest areas, which were to be preselected by aerial reconnaissance.

Terrestrial Inventory: The next step following on the compilation of the map based on photointerpretation and forest type delineation was the terrestrial inventory, which must be made in order to check the interpretation and to collect information concerning quantity and quality of avilable standing timber and of species distribution,

Usually, a limited number of samples was obtained from each stratum and the variability of the volume per unit area was calculated from them. With the help of the standard deviation obtained from these plots, the number of plots which were required for a predetermined accuracy could then be calculated.

In the ground inventory it was recommended to have about 15 trees

per sample unit. In order to facilitate quick measurements, circular plots were recommended of which the centre would be the only fixed point to be located.

A plot area of 100 m^2 which is easily surveyable in dense forest, requires a radius of 5.64 metres. For the forests of Sudan it was estimated that 10 circles of 100 m^2 each were needed.

In more open forests, layer plots with, for example, a radius of 12.6 metres could be used. The plot size belonging to this radius is 500 m^2, which was still surveyable in this open type.

For a certain forest area an equal number of plots per cluster should always be taken. The single plot constituted the measuring unit and the combined plots per cluster were to be used as the calculation unit.

C. **Mexico:**[13] It has been estimated that Mexico possesses some 10 million hectares of coniferous forests, out of which one fifth of the resources are untouched. Despite these resources and its general industrial efforts, Mexico still imports annually the whole of its newsprint consumption requirements and more than half of its paper and pulp requirements, to a value of Rupees fifteen crores. These quantities correspond to barely 500,000 cubic metres of local softwoods (*Pinus and Abies spp*). Since one hectare of conifers in Mexico yields about 3 cubic metres per year, the systematic management of 200,000 hectares would suffice for producing newsprint and pulp which now entail a considerable expenditure of foreign exchange to import.

Some years ago, the Mexican Government decided on expansion of the domestic pulp and paper industries and for one project an area of approximately 500,000 hectares, half of which is stocked with conifers, was selected in Michoaken State on which to base not only a pulp and newsprint mill, but also an integrated series of forest industries.

The study, implementation and administration of the project were entrusted to *Nacional Financiera S.A.* which is the official bank of Mexico for promoting and financing the industrial development of the country.

The general requirements of the Project were laid down as a sulphate pulp mill with a minimum capacity of 30,000 tonnes per year and a newsprint mill with a minimum capacity of 32,000 tonnes per year of mechanical pulp which, mixed with about 8,000 tonnes of semi-bleached pulp from the other mill, could produce about 40,000 tonnes of newsprint annually. At the same time, it was proposed to establish a sawmill which would absorb the balance of the timber supplies left over from the requirements of the two pulp mills. Ultimately, a veneer mill was envisaged to use high grade logs and an activated charcoal plant to use the saw mill waste and the hardwoods for the area which are generally of too poor quality for conversion to lumber. All these mills were to be fully integrated with one another so as to ensure the most economic use of all the wood removed from the forest.

A forest inventory was carried out over nearly 100,000 hectares of good exploitable forests with a view to find out if the area could actually supply the minimum requirements of the projected industries and to reveal the measures that would be required to be taken to develop the infrastructure to exploit the forest potential.

D. **Surinam:**[14] A Forest inventory was undertaken in Surinam in 1964 by F.A.O. It was felt by the Forest Service that in view of the existing and proposed development schemes in West Surinam in the Agricultural and mining field, a complete evaluation of the forest potential of the area should be taken in hand at an early date, to enable forestry to contribute its part to a comprehensive development planning. The area selected for inventory work was located in the western section of the exploitable forest belt between Coranti jn and Coppename rivers and the objective was to assess the forest potential of the area for the purpose of planning forestry development in this part of the country. The area to be surveyed was 181,000 hectares, which was judged to be merchantable and accessible from a study of aerial photographs.

A previous inventory of parts of Eastern Surinam which was carried out in 1949-50 was based on systematic, 10 metres wide inventory lines and detailed measuring and punch card indexing of every qualifying tree on the lines. The design proposed in the new inventory was to be a random one, with two units per block and, nearly 6 to 12 blocks per inventory unit depending on the variability within the unit. A new 1 : 20,000 air photo project was proposed to be undertaken to help with definition of units and effective

stratification of the forest type in them.

Apart from the use of a Speigel-relascope in inventory work, the other innovations proposed were:

i) the use of field forms convenient for manual or machine conversion to computer input, and

ii) electronic computer analysis and tabulation of the inventory data and of data for volume table construction and stand structure investigations.

E. **Brazil**[15]: A forest inventory was carried out in Brazil from 1953 to 1965 under the expanded programme of Technical Assistance. About 13 percent of the World's forests and nearly 60 percent of the forests of South America are found in Brazil. With this important forest resource, proper management is essential so that the forests are not indiscriminately destroyed and a valuable heritage lost to to-day's and future generations.

Based on the extensive work carried out in Surinam and Brazil it became clear that the execution of forest inventory work, especially in less accessible regions, without the help of aerial photographs, i. e., solely from field observations, had become definitely obsolete.

The scale of photopraphy used in Brazil was generally 1 : 25,000. The main use of aerial photographs in connection with the forest inventories was for mapping purposes. It has been pointed out that a forest inventory without a map is an absurdity.

For the survey of forest resources a simple random sampling design was tried out. Contrary to expectations this simple random sampling in tropical rain forest proved to be extremely easy. At first, main transects were made through the middle of the forest to be surveyed. These were cleaned trails along which the surveyors and their crews could move easily (average speed 4 km. per hour), while every 20 metres were marked with a numbered stick, so the place on the map and in the field was known exactly.

The best sample plot size is 0.1 to 0.2 hectare and it should be rectangular or square.

The best procedure is to make a simple random sample with a varying number of plots. During the survey the results are to be continuously checked until an accuracy of 10 percent with 0.95 probability has been achieved.

The G.O.I./U.N.S.F. Preinvestment Survey of Forest Resources Project

A step in the right direction was taken by Government to start in 1965 the above project, thanks to the generous aid given by United Nations, with a view to carry out a survey by modern methods of nearly five million hectares of potential forest areas in the country. The project which ended in October, 1968, prepared an inventory of the growing stock of the survey area with the help of interpretation of aerial photographs supported by low intensity ground sampling and carried out comprehensive cost and market studies and integrated them with elaborate industrial feasibility studies for wood-based industries, and more especially of pulp and paper.

One of the most important contributions made by the Project is that it has put the forestry personnel abreast of modern forest survey techniques based on aerial photointerpretation and ground sampling which are adopted by industrially developed countries. Such extensive survey operatoins could be integrated as an essential prerequisite to the planning of wood-based industries which are a capital-intensive item. During the Fourth and Fifth Plan periods there will be a considerable expansion in the production of pulp and paper for which it would be necessary to assess the available potential from the existing forests. The experience gained in the project would be of cosiderable use in expanding such surveys in the country for drawing up sound plans of industrial development.

Conclusions

The development and utilization of forest resources can contribute substantially to the economic growth and welfare of a country. In fact, the export of forest products from developing countries promises to be a most expansive trade sector, and prospects for a continuing growth in the future appear very encouraging, more than for many other commodities exported by them. As a first step forest resource evaluation and trade and industrial development assume roles of parmount importance. One basic pre-requisite for industrial development in forestry is the assured availability of the required raw material in appropriate quantities, qualities, and at a cost permitting the derived products to be competitive on the market. This kind of information is provided by forest inventories. Successful forest

industry development is also dependent on adequate and efficient wood-processing facilities in the producing countries and knowledge of markets for the products.

Forest resources surveys involve a number of elements whose relative emphasis would vary depending on the needs of the country in which they are carried out. They could vary in emphasis according to the nature of local problems and the stage of forestry development of the country. Some emphasize resource appraisal, while others concentrate more on industrial problems of production improvement and increased trade.

Wood-based industries, especially those of pulp and paper are capital-intensive items, and it would be appropriate for any country to decide to invest, say at least one per cent of the projected outlay, on carrying out forest resources surveys of the areas from where raw meterials are to be obtained, in order to get correct answers about the availability of raw meterial, its quality and composition, the most suitable locations of the processing plants and the economics of series of steps starting with exploitation of the raw material and ending with the marketing of the finished products.

The ideal to aim at should be a national inventory which is kept up-to-date by means of continuous inventories or periodic reinventories as in the case of Sweden, Finland, Canada, U. S. A. and U. S. S. R. As an immediate goal, however, it may not be within the means of most of developing countries, especially where the area involved is large. The other alternative would, therefore, be to delineate through reconnaissance surveys, forest areas of interest from the point of industrial development and to have reliable inventories carried out in them. This would amount to the direct linking of surveys to industrial plans, or in other words, to tailoring forest surveys to meet the most urgent national needs.

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