FWM 401 LECTURE NOTES

FOREST INVENTORY AND MANAGEMENT PLAN

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SUMMARY

A 100% enumeration of any forest resource is not always feasible due to the constraints of time, money, labour, in-precision and the bulky nature of the data that might result. This might cause some incorrect calculations of the results of the exercise.

Hence a very important techniques in forest resource inventory is sampling of a part of the forest, the result of which is blown up to get a reliable estimate of the needed parameter in the whole forest.

This Lecture note has therefore been able to discuss the importance of sampling techniques in forest resource inventory. Also efforts has been made to elucidate on the various sampling designs available together with the statistical tools necessary for the computation of the results depending of course on the information being sort for.

Finally, the various applications of sampling results were also briefly discussed to further press home the importance of sampling techniques as an indispensable tool in forest management.

THE IMPORTANCE OF EFFECTIVE SAMPLING TECHNIQUES IN FOREST MANAGEMENT

INTRODUCTION

The forest is ecologically defined as a plant community predominantly made up of trees or other woody vegetation and usually with a close canopy.

It is exhaustible but renewable natural resource operating within biological limits. Therefore it has to be scientifically as well as economically well managed in order to continue to produce the necessary goods and services on a sustained yield basis.

These goods and services produced by the forest are in the form of timber production, protection against wind and water erosion, protection of water catchment's areas, habitat for wildlife and recreational facilities which the forest offer. Therefore forest management is the practical application of the scientific, technical and economic principles of forestry to the operation of forest properties or the practical application of all branches of forestry to the efficient working and organization of all the forest.

Forest resource inventory is one of such management principles of forestry adopted to achieve the objects of producing goods and services from the forests.

Since the forest produces goods and services, it can be termed to be an industry though operating within biological limits. Hence some business methods such as resource inventory or stock taking has to be incorporated into the management of forest enterprise as it applied in other business ventures. Though some other peculiarities of the forest distinguistics it from others industries, sources of raw material, and even other users of land. These peculiarities naturally effect its management and they includes the long gestation period, the market which may change during the period of growth and thereby invalidate the original decision and the long period involved before return on investment. This therefore means that different tools of management has to be evolved in order to derive the maximum benefits from the forest. Forest inventory is one of such tools. It is a stock taking exercise and has been defined by Hush et al, (1972) as the procedure for obtaining information on the quantity and quality of the forest resources and many of the characteristics of the area on which the trees are growing.

In order to carry out forest resource inventory or stock taking, the best is to carry out a 100% enumeration but this is not always feasible because of some constraints such as time, cost involved, personnel's, the large and complex nature of the forest e.t.c. Hence the only option left is to carry out the enumeration in a part of the population the result of which are blown-up to give an estimate of the whole population. This process is referred to as sampling.

The focus of this paper therefore is to discuss the importance of effective sampling techniques in forests resource management.

MEANING AND SCOPE OF FOREST INVENTORY

Forest inventory has been defined by Husch et al, (1972) as the procedure for obtaining information on the quantity and quality of the forest resource and many of the characteristics of the land area on which the trees are growing.

A complete forest inventory for timber or wood resources evaluation provides the following basic information: a description of the forested area including ownership and accessibility, estimates of timber quality and quantities and estimates of growth and drain. Non-timber information may also be included on wildlife, areas of recreational and touristic interest, soil and land use capabilities on water shed values.

Emphasis on or elimination of any of these elements will depend upon the objectives the inventory. Table (1) below adapted from Husch et al, (1972) indicates relative emphasis for the kinds of inventories though the priority classes assigned are not hard and fast but subjective in nature.

SAMPLING IN FOREST INVENTORY AND ITS IMPORANCE

As earlier pointed out sampling is a necessary technique used in most forest resource stock taking for economic reasons (FAO, 1973). This is because of the fact that the populations to be assessed for the purpose of say assessment of trees for volume table or of defect or for estimation of menstruation parameters in plantation are usually too large for 100% enumeration to be carried out. Akindele (1990) has also advanced some reasons for which 100% count in forestry may not be successfully carried out. They are as follows:

Firstly, where it seems possible to carry out a complete enumeration, the cost in terms of men and materials is usually prohibitive considering the economic status of most nations now.

Secondly, accessibility problem is another constraint to complete enumeration. That is, the forest to be assessed may not be very assessable due to some site factors such as flowing, topography swamps, e.t.c.

Thirdly, the time involved before the information from the inventory is supplied is another hindrance to successful 100% enumeration. That is, it is time consuming.

Fourthly, due to the extent of the work it is done haphazardly. Thorough supervision is scarcely done. Thus in-precise estimates are produced.

Fifthly, some information requires either partial or total destruction of the units before they can be obtained. This is often the case for information on weed properties. In such cases, it is unreasonable to embark on complete enumeration.

Therefore only a part of the entire population called sample is studied with a view to obtaining information on the entire population. This means that measurements are usually restricted to a sample and the values obtained are blown up to give estimates for the whole population.

Summarily, sampling saves time and money, and requires less labour since the number of population to be measured is comparatively small, it becomes possible to make the measurements with more ease and accuracy.

THE SAMPLING DESIGN

In speaking about sampling design in forest inventory generally refers to the disposition of the field samples. Several sampling designs are applicable in forestry but for the purpose of this paper a few basic will be discussed in general with the hope that the final details of the sampling procedure must be decided upon for each inventory exercise.

Sampling design may be broadly classified into two groups: namely, probability and non-probability sampling. In a probability sampling design the probability of selecting sampling unit is either known or assumed. It may or may not be equal for all the sampling units. For these design randomization is employed in selecting a sample and thus it is possible to apply statistical sampling theory and obtain unbiased estimates of the sampling errors. Examples of probability sampling designs are:

1) Simple random sampling
2) Stratified or restricted random sampling
3) Multistage sampling
4) Multi-phase sampling
5) Cluster sampling
6) Point sampling
7) 3-p Sampling
8) Sequential sampling.

THE SIMPLE RANDOM SAMPLING

This is also known as unrestricted random sampling. It is applicable to small forest areas or stands which can be considered as a single unrestricted (i.e. homogenous) population. A fundamental idea in the use of this sampling design is that in choosing a sample of 'n' units every possible combination of 'n' units should have an equal chance of being selected. By this method the total population is divided into 'N' sampling units. Using a table of random numbers (or any other random devices) 'n' units are selected for enumeration.

THE STRATIFIED RANDOM SAMPLING

This is also known as the restricted random sampling. It is applicable to small or medium sized forest area in which strata can be recognized due to heterogeneity. The stratification could be based on species composition, age distribution, vegetation cover, e.t.c. It is however normally desirable that the stratification criterion be correlated with the parameter to be estimated. This type of random sampling design provides separate estimates of the measured variance for each stratum. Hence for a given sampling intensity, it gives more precise estimates.

In using this design the entire population is first of all divided into strata. Where natural stratification exists, the boundary of each stratum is delineated on the map. Each stratum is then divided into sampling units (plots or strips). Sample plots are then randomly selected then the sampling units within each stratum.

MULTISTAGE SAMPLING DESIGN

This sampling design is applicable in situations when locating and getting to a sampling units is expensive while measurements of the units is relatively cheap. For instance, in a large natural high forest with several compartments, it may be very expensive to get to a compartment whereas measuring the trees within any particular compartment is relatively cheap. In this instance, the various compartments may be recognized as primary units. Few of these primary units will be randomly selected.

This is the first stage of sampling. Each of the primary units is then divided into secondary units from which some samples would be randomly selected. This is the second stage of sampling. Further division of each of the selected secondary units could be made for a random selection of tertiary units.

In forest inventory exercise, two-stage sampling is the most common type of multi-stage sampling design used. Generally, multi-stage sampling design gives estimate of a given precision at a cost lower than that of simple random sampling. Usually, the precision and cost both increase as the number of selected primary units is increased and the number of selected secondary units per primary unit is decreased.

When the primary units are unequal in sizes, we can have stratified two-stage sampling. In this case, the primary units are grouped into strata according to sizes and second stage sampling is then carried out with each stratum.

Alternatively, the primary units can be selected with probability proportional to size. The secondary units are then selected with equal probabilities within each primary unit.

MULTI-PHASE SAMPLING DESIGN

Multi-phase sampling design consists of selecting a large first-phase sample of auxiliary variable (X) which will provide a precise estimate of the primary variable (Y). A sub-sample of the first-phase units is then selected and accurate measurements of the primary variable taken. Further phases may be added if required. However, the most common type of multi-phase sampling is two-phase sampling. This is also referred to as double sampling. Double sampling relies on the relationship between one variable (Y) and another (X) which can both be measured or estimated in a forest population.

It thus permits the use of regression method. In an inventory to determine the timber volume (Y) of a forest population, a random sample of trees may be selected and their basal areas (X) obtained as the auxiliary estimator of the timber volumes (Y). The auxiliary variable (X) is measured on large number of samples while the principal variable (Y) is measured on a sub-sampled randomly chosen from the large samples. The functional relationship between the X and Y observations for the sub-sample is then determined. It may be linear, exponential, e.t.c. The commonest type of relationship is the linear relationship, expressed by the equation:-

$$Y = a + bx$$

Where Y = the dependent (principal) variable

X = the independent (auxiliary) variable

a and b are regression parameters.

Once the relationship is determined, the equation is then used to estimate the value of Y for the whole population. Double sampling could also be used to update forest inventory records.

Multi-phase sampling design has the advantage of ensuring a reduction of the number of measurements of the costly or difficult variable without sacrificing precision of the estimate.

Structurally, multi-phase sampling differs from multi-stage sampling in that, in the former the same sampling units are used throughout, whereas in the latter, a hierarchy of sampling units is used.

CLUSTER SAMPLING

In this sampling design, a group of individuals becomes the unit of observation, and the unit value is the proportion of the individuals in the group having the specified attribute. It is applicable in studies involving estimation of survival percentage of a plantation in regeneration survey:

- estimation of defects; and
- estimation of generation percentage.

In survival or defect studies, a row of trees may be regarded as a cluster, while in germination studies, a batch of seeds grown in a dish or germination box is the cluster. Each cluster is the unit of observation and the unit value is the survival or the germination percentage. If clusters are small in size (i.e. with less than 100 units per cluster) or if values greater than 80% or less than 20% are present for some clusters, arcsin transformation is to be adopted before any computation is carried out.

Stratified random sampling may be combined with clusters as in the case of examining germination percentage of a seed lot made up of seeds from several sources. Here, the sources are the strata.

SELECTIVE SAMPLING

This involves the arbitrary selection of trees without any statistical basis. The method is subjective since it is based on information and experience rather than the statistical theory of randomization. This is probably the method used by timber contractors in selecting trees for exploitation during logging exercise. This is a non-probability sampling design;

hence, the reliability of estimates obtained from it cannot be ascertained.

SYSTEMATIC SAMPLING DESIGNS

In these designs, the forest population is divided into 'N' sampling units. To select the sample, a unit is taken from the first 'K' unit, and every 'kth' unit thereafter. Thus, once the first unit is selected, the location of other units to be selected is automatically deduced from that first selection. All random designs have one or more corresponding systematic ones.

The sampling units may be plots or strips. In systematic designs, once the first unit is selected, the other units which do not belong to future samples have zero probability of being selected, while the 'K'S' have the probability of 1. In some instances, the selection of the first sample may be done randomly.

Notwithstanding, this does not yet make the sampling design a probability one. Since only the first unit is randomly selected, the variance cannot be estimated. The major setback of systematic sampling design is the impossibility of obtaining the sampling error. Thus, it is not possible to give the reliability of estimates obtained from the sampling design. Despite this shortcoming, the design is still well-favoured among practicing foresters due to the following reasons:-

- It is relatively easy to use
- It ensures a wide coverage of the population being sampled
- It allows for easy verification and supervision.

STATISTICAL TOOLS IN THE PROCESSING OF DATA COLLECTED IN A SAMPLING EXERCISE

No matter how a sampling exercise is perfectly carried out, the data has to be well processed before any meaningful inference can be drawn from it.

Therefore the data has to be subjected to some computational or statistical procedures so as to make it result oriented. Because of the fact that various data or variables require different statistical or computational procedures, a distinction has to be made between continuous and discrete variable. For instance discrete variables are those that assume specific counting values e.g. 1, 2, 3, 4, 5. While continuous variables are those that assume any value between certain limits e.g. number of students per room.

In the light of the above some statistical tools are made use of in processing the data so obtained from a sampling exercise.

They are briefly discussed as follows:-

(a) **VARIANCE**

The variance of individuals in a population is a measure of the dispersion of individual units about their mean. A large variance indicates wide dispersion; while a small variance indicates a little dispersion. Very rarely will we know the population variance it must be estimated from the sample data.

$$S^2 = \sum_{i=1}^{n} \frac{(yi - y)^2}{n-1}$$

Where S^2 = sample estimate of the population variance

yi = the value of the ith unit in the sample

'y = the arithmetic mean of the sample

i.e.

$$\text{Mean of X or Y} = \frac{\sum_{i=1}^{n} yi ---- yn}{n} \quad X = \frac{\sum_{i=1}^{n} Xi ---- Xn}{n}.$$

n = no of observations. Computation of the sample variance is simplified by the formula

$$S^2 = \frac{\sum_{i=1}^{n} y^2_1 - \frac{(\sum_{i=1}^{n} y1)^2}{n}}{n-1}$$

(b) **STANDARD DEVIATION**

This is also a measure of variation among the individuals in a population. It is usually denoted by S and is the square root of the variance i.e. $S = S^2$

(c) **STANDARD ERRORS AND CONFIDENCE LIMITS**

Because of the variations that would often arise from sample estimates, it is always desirable to set confidence limits in any sampling exercise i.e. one need to indicate how much variation might be expected among sample estimates. For instance an estimate of mean dbh that would vary between 10 and 11cm would inspire more confidence that the one that might range from 6 – 18cm. The standard error of the mean and a table of ‘t’ values are used for setting up confidence limits.

Standard error of mean $S\bar{x} = \frac{S}{N}$

Therefore the confidence limit (CL) can be calculated from the formula

$$C.L. = X - t\,(0.05)s\bar{x} - \bar{x} + t\,(0.05)\,S\bar{x}.$$

It is very important that the forest manager should note that confidence limits and accompanying statements of probability accounts, for sampling variation only. It is assumed that sampling procedures are unbiased field measurements are with errors and no computational mistakes are included. If these assumptions are incorrect, confidence statements may be misleading.

(d) **COEFFICIENT OF VARIATION (CV)**

The CV is the variation of the standard deviation (S) to the mean ($\bar{X}$). It is always expressed as % age. CV parts the expression of variability on relative basis.

$$CV = \frac{S}{\bar{X}} \times 100$$

(e) **COVARIANCE** (SXY) - This is a measure of how to variables vary in relationship to each other (covariability).

For random samples, the formula for the estimated covariance (S X Y) of x and y is

$$S_{XY} = \frac{\sum_{i=1}^{n} xy - \frac{(\sum_{i=1}^{n} xi)(\sum_{i=1}^{n} yi)}{n}}{n-1}$$

(f) **CORRELATION COEFFICIENT (r)**

This is a measure of the degree of linear association between two variables that is unaffected by the size of the unit values is the simple correlation coefficient denoted by r.

$$r = \frac{\text{Covariance of X and Y}}{\sqrt{\text{(Variance of X) variance Y)}}}$$

$$r = \frac{S_{XY}}{\sqrt{(Sx^2)(Sy^2)}}$$

The r varies between -1 and +1. As in covariance, a positive value indicates that the larger values of Y tend to be associated with the larger values of X. A $-v^e$ value indicates an association of the larger values of Y with the small values of X. A value close to +1 or -1 indicates strong linear association between the two variables. Correlations close to zero suggest there is little or no linear association.

(g) **REGRESSION**

This could be defined as the amount of change in the dependent variable resulting from one unit of change in the independent variable. Also when the production of one variable from other variable is the classified as one of regression.

If a relationship follows a straight line, it is described by regression formula. $Y = a + Bx$ where b is the regression. Coefficient, a is the point where the line crosses the Y axis i.e. a is the Y intercept while X and Y are observations.

THE APPLICATION OF EFFECTIVE SAMPLING TECHNIQUES IN FOREST MANAGEMENT IN NIGERIA

The need for sampling techniques to be effective and result oriented in meeting the objectives of carrying out the exercise cannot be over stressed.

The effects of a sampling technique are the outcome of the use of the results of the exercise i.e. how the results have met the management objectives.

In Nigeria forest resource management, sampling has been effective in the following areas:-

Firstly, this technique has been found useful as far back as 1913 in Olokemeji and Manu Forest Resources to determine the stocking of the economic species in the reserves. This was supposed to be the formal surveys of Nigerian Forest (Ojo, 1990).

Secondly, sampling is an important tool in the enumeration of merchantable sized trees of recognizable economic trees in a forest estate. This is a very necessary exercise as far as timber concession holders are concern. For instance between 1930 and 1935 a series of 1% sampling intensity of merchantable trees were carried out by timber concession holders for exportation to European Markets.

Thirdly, forest sampling is an important tool in assessing a forest plantation if it will be able to meet the raw material needs of proposed industries. For example effective sampling exercise will have to be carried out if the present plantations of Gmelina aborea in Ogun and Ondo States would be able to support the proposed Iwopin Paper Mill.

Fourthly, result oriented forest sampling is also very imperative in carrying our regeneration counts in a forest in order to arrive at management prescription for such a forest. Without such an effective sampling and well computed results, the how and why in the management of a productive or unproductive forest resource might be difficult.

This type of sampling has been carried out in the former Western region which now comprises of Oyo, Ogun, Ondo, Delta, Edo, Osun States. Inventory layouts were of strips 20m wide regularly spaced to give sampling intensity of between 1% and 5%. In most cases only trees of 2 feet (1.3mdbh) girth or larger were enumerated.

Data were also collected on selected economic species for regretting count of economic seedlings and samplings from 1m high up to pole stage.

Fifthly, stratified random sampling has also been applied in sampling survey of Akure, Ofosu, Ifon and Gilli-Gilli reserves with the recruitment of professional expertise familiar with statistically robust sampling design for field surveys. Table 2 adapted from Ojo (1990) gives a summary of the application of sampling to the management of the Nigerian high forest systems.

Sixthly, sophisticated survey approach has been carried out in Nigeria since 1967 using aerial photographs to stratify the forest into types. This was followed by the SLAR (Side Looking Airborn Radar) survey of the entire country which revealed the area and location of different vegetation types which were mapped.

The findings led to the development of a frame work for a subsequent phase of detailed forest inventory and assessment of land potential for plantation establishment.

The indicative high forest inventory which commenced with a Pilot study in 1973 followed by the SLAR Survey and remains the most extensive and sophisticated inventory exercise of its kind applied in Nigeria.

The inventory exercise had the following objectives:-

(a) To determine the amount and quality of utilized species of sale-able size and those of other species with potential future markets.

(b) To assess the degree of exploitation and the quality and type of regrowth to be expected in future. The inventory was carried out using systematic sampling techniques.

Seventhly, sampling has been found useful in providing secondary information on the occurrence and density of food yielding trees. For instance Okafor (1992) found out the range of average density of trees such as (Kigelia africana) 0.007 to 3.39 (Cola gigantea). Trvingia gabonensis and Tetrapleura tetraptera occurred in all the reserves extracted from Redhead's Forest Enumeration data of 1965. The mean frequency of edible tree species in the analyzed forest reserves was 12% while the mean density was 0.53% per hectare.

TABLE 2: EARLY ENUMERATIONS OF THE NIGERIAN HIGH FOREST RESERVES

FOREST RESERVE	YEAR	SAMPLING INTENSITY	SAMPLING TECHNIQUE	REMARKS (ha)	PRESENT POLITICAL BOUNDARY
Afi Rivers	1934	1%	Systematic	214 in Southern block	
Cross River North	1935	1%, 2%, 5%	Systematic	30cm wide	
Cross River South		2½%	Systematic	strips	Akwa-Ibom
				196 ha	

Eme River		100%		all trees 19cm	
Oban	1955- 1956 1956-7 ?	2½% 2½% 2½% 100%	Systematic Systematic -	dbh 41espected dbh 105 ha 2 ½% of 256km^2	and Cross River States
Okwango	1955-6	2½%	-	30m wide strips	
Ukpon River	1935 & 1951	1%	Systematic	all spp. 49cm dbh	
Amahor	1956	25%	Systematic		
Ebue	1931	1%	Systematic		
Ekiadolor	1939	1%	Systematic		
Gilli-gilli	1961	0.23%	Random		
Iguobazua	1938	1%	Systematic		
Obaretin	1939	1%	Systematic		Bendel
Ohosu	1940	1%	Systematic		
Okhuesan	1954	5%	Systematic	Nigerian	State
Okomu	1936	1%	Systematic	Hardwood	
Ologho	1939	1%	Systematic	Proposed but	
Ologhlo-Emu- Urho	1962	100%		not executed	
Owan	1963				
Ozalla	1953	1%	Systematic		
Sapoba	1933 1934 1935	1%	Systematic		
FOREST RESERVE	**YEAR**	**SAMPLING INTENSITY**	**SAMPLING TECHNIQUE**	**REMARKS (ha)**	**PRESENT POLITICAL BOUNDARY**
Ukpe-Sobo	1963	-	-	-	
Unea-Ima	1962	25%	Systematic	All spp. 49cm dbh	
Usonigbe	1936	1%	Systematic		
Aworo	1952	1%	Systematic	103.6km2	
Egua	1935 1946	1% 5%	Systematic Systematic	only econ. spp	
Ilaro	1933 1945	1% 5%	Systematic Systematic	Include seedling counts -	Ogun State
Ohunbe	1949	5%	Systematic	-	
Olokemeji	1913	-			

	1933 1953 – 1954	1% 5%	Systematic	Stocking and Magt. Plan	
Omo	1931	1%	Systematic		
Akure		1%	Systematic		
Akure Ofosu	1962	0.5	Random		
Ala	1936	1%	Systematic		
Idanre	1935	1%	Systematic		
Ifon	1961	0.8%	Random		
Ikare	1953	1%	Systematic	Summary of 32	Ondo State
Little Osse	1952	1%	Systematic		
Ogbese	1952	1%	Systematic		
Ondo	1936	1%	Systematic		
Oni River	1956	5%	Systematic		
Onishere	1961	1%	Systematic		
Owo	1936	1%	Systematic		
Ago-Owu	1949			16.2 ha	
Gambari (Mamu Gambari	1933 1935	1% 20%	Systematic	Coupe 13 only	Oyo State
Ijaiye	1934	1%	Systematic		Oyo State
Ikeji-Ipetu	1954	1%	Systematic		
Illa	1957	1%	Systematic		
Osho	1958	1%	Systematic		
Shasha	1935 1964	1% 1%	Systematic Systematic		

The density of some food yielding trees was also estimated from the inventory data of Sutter (179). From this data it was found out that the average density ranged from 0.004 (Damiellia oliverii) trees/ha to 11.38 (Cola gigantia). The mean density per species was 2.3 trees/ha. e.t.c. Both Redhead (1965) and Sutter's (1974) were carried out in the Southern Nigeria.

RECIPES FOR EFFECTIVE SAMPLING TECHNIQUES FOR FOREST MANAGEMENT

From the foregoing, the need for an effective and result oriented sampling cannot be over emphasized in forest resource management. Hence the following suggestions are offered:

Firstly, the collection of field data and all the labour carried out would be of no use if the data are not processed and adequate reports compiled and properly stored for future use. Hence it is recommended that accurate statistical and computational tools should be used in analyzing the data so collected.

Secondly, well trained personnel's should always be made use of during the exercise both in data collection and processing.

Thirdly, fund and other logistics such as vehicles, camping equipments, medical facilities e.t.c. should be adequately provided for the personnel's.

Fourthly, proper storage and retrieval systems should be ensured for the end report of the exercise. Preferably the information should be stored in a computer for easy retrieval.

CONCLUSION

In conclusion, a result oriented sampling is a pre-requisite for efficient management of any forest enterprise. It is therefore very imperative that it should be well planned for an objectives of the exercise clearly stated for ease of operation and application.

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